



Antietam National Battlefield Natural Resource Condition Assessment

National Capital Region

Natural Resource Report NPS/NCRN/NRR—2011/413



ON THE COVER

Burnside Bridge in Antietam National Battlefield.
NPS NCRN I&M.

Antietam National Battlefield Natural Resource Condition Assessment

National Capital Region

Natural Resource Report NPS/NCRN/NRR—2011/413

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Executive Summary

The lands within Antietam National Battlefield 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. Habitats ‘managed for natural resource values’ were the natural habitats (forests, wetlands and waterways, warm-season grasslands) and were assessed for ecological value, while habitats ‘managed for agricultural values’ (croplands and pastures) were assessed for being the most ecologically sustainable croplands and pastures possible.

Patches of forest within Antietam National Battlefield are well connected; however, forest interior area is small, providing moderate 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 or low oxygen; however, high salinity and nutrients indicate degraded habitat value which is reflected in the regionally low diversity of benthos and fishes. The karst geology of Antietam and the surrounding landscape has implications for water quality of the streams within the park, affecting acid neutralizing capacity, temperature, and salinity of the waterways.

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. Assessment of these habitats could be improved by inclusion of metrics indicative of groundwater condition, to better understand the effects of the karst geology of the area.

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. Warm-season grassland areas are currently not contiguous, limiting the 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.

The croplands and pastures within Antietam National Battlefield are susceptible to the high deer populations. It is recommended to implement deer population controls to ensure that these leased lands are viable. These land use areas are in high compliance with best management practice—it is recommended to organize and document compliance monitoring as well as to research new techniques of sustainable agriculture that would maintain historical land use while maintaining maximum resource condition in habitats managed for natural resource values within the park. Currently, assessment of implementation and effectiveness of Nutrient Management Plans and Soil & Water Conservation Plans have not been carried out. It is recom-

Habitats ‘managed for natural resource values’ were the natural habitats (forests, wetlands and waterways, warm-season grasslands) and were assessed for ecological value, while habitats ‘managed for agricultural values’ (croplands and pastures) were assessed for being the most ecologically sustainable croplands and pastures possible.

mended to monitor and enforce implementation as well as to investigate soil nutrients within these habitats to provide for better productivity and resource preservation. These additional data would improve future resource condition assessments for this habitat.

Pasture habitat within Antietam National Battlefield includes areas of cool-season grassland, which are currently managed as pasture with no immediate management goal to transition these areas to native warm-season grassland.

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 Antietam National Battlefield; 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 also provide a greater understanding of current features and potential threats to park resources. One of the key challenges to water quality is high nutrients—identification of sources would assist in assessing potential threats. 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 streambanks to reduce nutrient runoff from agricultural and pasture lands into waterways needs to be carried out in a way that maintains the cultural viewshed of the park. Studies to identify plant species that are small enough to maintain viewsheds but large enough to remove maximum nutrient content from surface and subsurface waters flowing from agricultural and pastoral lands would assist in improving compliance with best management practices for these habitats.

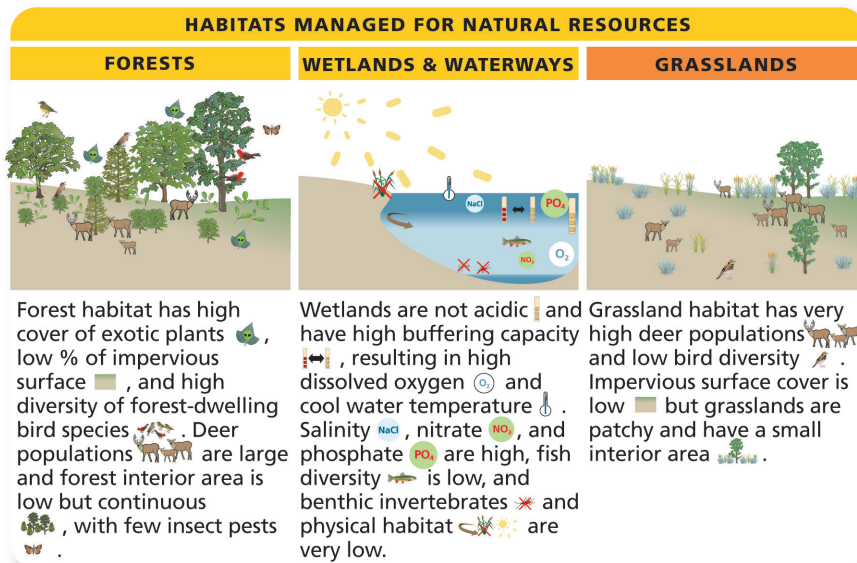


A relatively new approach to assessing and reporting on park resource conditions, Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national parks. Over the next several years, the National Park Service (NPS) plans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

Habitats in Antietam National Battlefield are in good condition overall. Habitats managed for natural resources are in fair condition. Forests were in fair condition, with high cover of exotic plants and large deer populations balanced by good bird diversity and continuous forest cover. Wetlands and waterways were also in fair condition, with good pH and buffering capacity but high nutrients and low stream biological diversity. Grasslands were in poor condition, due to large deer populations, low bird diversity, and patchy nature.

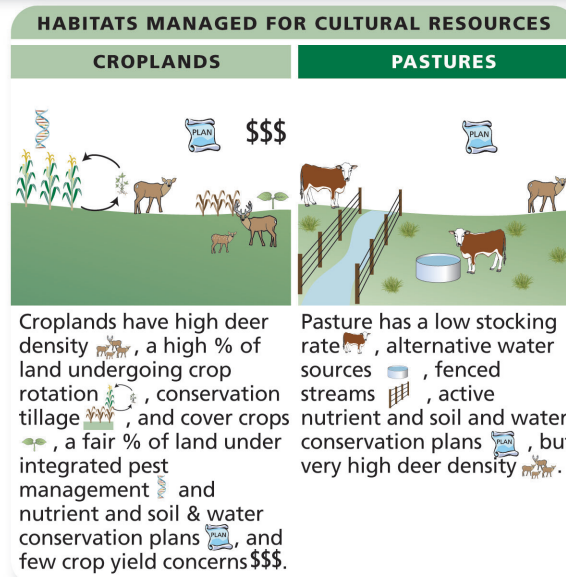
Habitats managed for agricultural values were in good condition overall. Croplands were in good condition, with good adoption of best management practices but also with large deer populations. Pastures were in very good condition with very good adoption of best management practices.

HABITAT-BASED NATURAL RESOURCE CONDITION ASSESSMENT OF ANTIETAM NATIONAL BATTLEFIELD



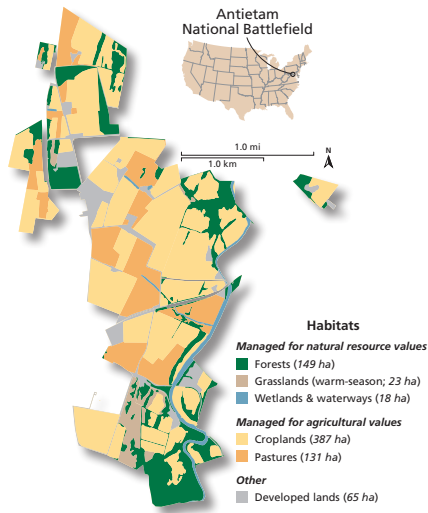
The habitat-based natural resource condition assessment is area-weighted. Areas of each habitat are given below:

- Forests: 149 ha
- Wetlands & waterways: 18 ha
- Warm-season grasslands: 23 ha
- Croplands: 387 ha
- Pastures: 131 ha

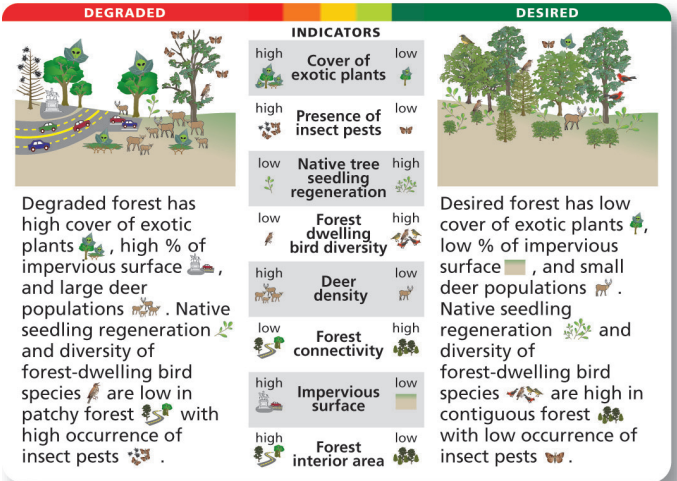


Habitat framework

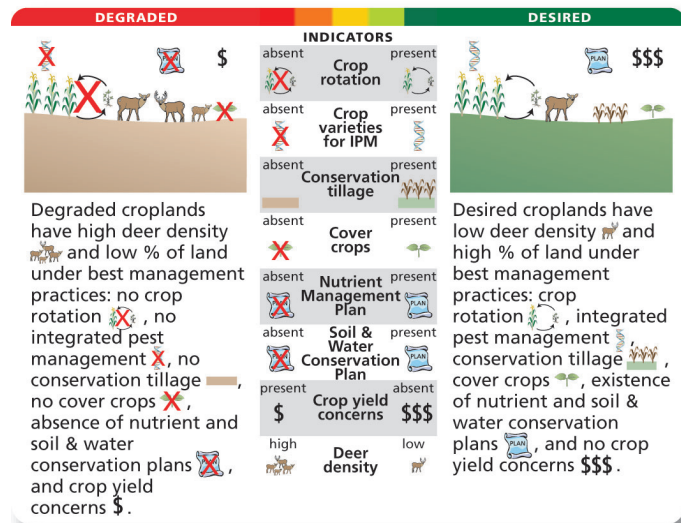
Habitats within the park were defined as being either managed for natural resource values or managed for agricultural values. A habitat map was created and desired/ degraded conditions were defined for each habitat. Metrics were then assigned to these habitat types, compared to established thresholds,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



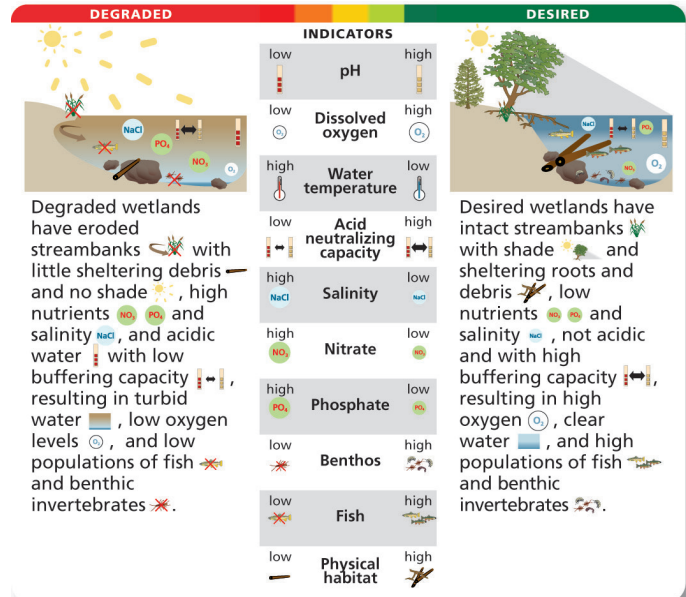
FORESTS



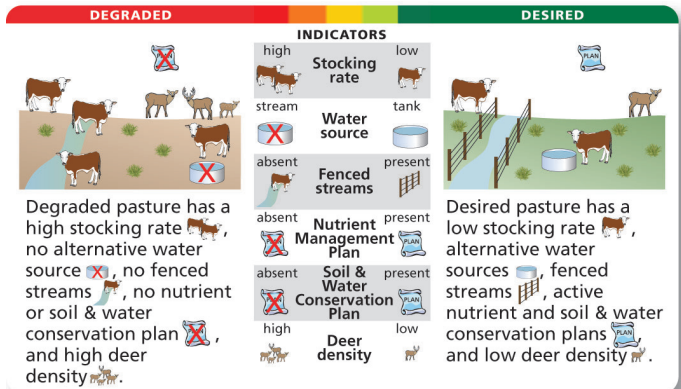
CROPLANDS



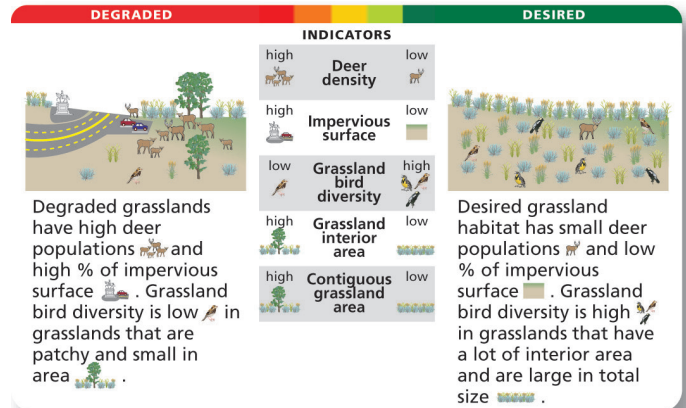
WETLANDS & WATERWAYS



PASTURES



WARM-SEASON GRASSLANDS



Developed in collaboration with:



For more information, please visit the Park's Visitor Center or call 301-432-5124.

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Chapter 1: NRCA background information

1.1 NRCA BACKGROUND INFORMATION

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter “parks”. For these condition analyses they also report on trends (as possible), critical data gaps, and general level of confidence for study findings. The resources and indicators emphasized in the project work depend on a park’s resource setting, status of resource stewardship planning and science in identifying high-priority indicators for that park, and availability of data and expertise to assess current conditions for the things identified on a list of potential study resources and indicators.

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

- are multi-disciplinary in scope;¹
- employ hierarchical indicator frameworks;²
- identify or develop logical reference conditions/values to compare current condition data against;^{3,4}
- emphasize spatial evaluation of conditions and GIS (map) products;⁵
- summarize key findings by park areas;⁶ and
- follow national NRCA guidelines and standards for study design and reporting products.

Although current condition reporting relative to logical forms of reference conditions and values is the primary objective,

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

Credibility for study findings derives from the data, methods, and reference values used in the project work—are they appropriate for the stated purpose and adequately documented? For each study indicator where current condition or trend is reported it is important to identify critical data gaps and describe level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject matter experts at critical points during the project timeline is also important: 1) to assist selection of study indicators; 2) to recommend study data sets, methods, and reference conditions and values to use; and 3) to help provide a multi-disciplinary review of draft study findings and products.

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

Antietam National Battlefield was established by Act of Congress on August 30, 1890 to commemorate the Battle of Antietam fought on September 17, 1862. The battle is considered by many historians to be one of the most crucial battles of the Civil War and the turning point against the Confederacy. The restriction of the Confederacy's northward movement by the Union forces at Antietam eventually enabled President Lincoln to issue the Emancipation Proclamation, injecting new moral values into the Union cause and subsequently altering the course of international politics. It was also at Antietam that more Americans died in battle than during any other single day in American military history (Snell and Brown 1982, NPS 1992).¹⁰

Congress originally placed the Antietam battlefield under the supervision of the Secretary of War. It was later transferred, along with 47 other historic areas, to the National Park Service on June 10, 1933.¹¹ Antietam and "Chickamauga and Chattanooga National Park or Military Park" were the first Civil War battlefields to be preserved by the War Department. However, both parks came to represent and illustrate two widely diverging methods of preserving battlefields. The Chickamauga method (used at Gettysburg, Shiloh, Kings Mountain, and other sites) involved acquiring much of the land of the battlefield for preservation, while the Antietam method (used at Appomattox, Fort Necessity, Kennesaw Mountain, and other sites) involved only as much land acquisition as was required for the building of roads and the erection of monuments and markers. The Antietam method was favored for its low cost and because it would not commit the United States to the perpetual care and maintenance of large areas (Snell and Brown 1982).

The legacy of the Antietam method of preserving battlefields is that of the 1,320 ha



Antietam National Battlefield is a cultural resource park.

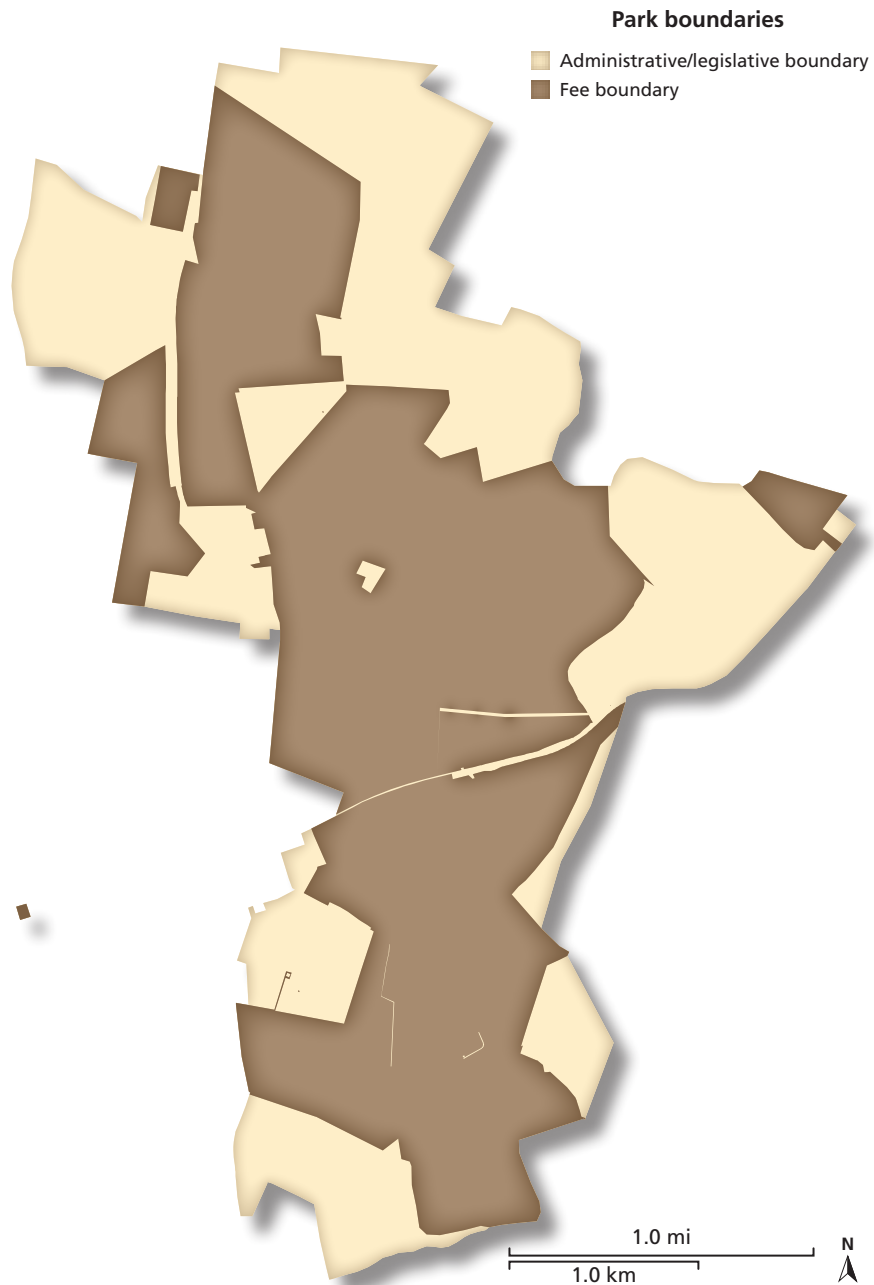
(3,263 acres) within the administrative/legislative boundary of the battlefield, 784 ha (1,937 acres) are owned in fee by the federal government (Figure 2.1) and managed by the National Park Service to maintain the historic setting and provide for visitor use, 205 ha (506 acres) are privately owned, and 332 ha (820 acres) are in private ownership with easements held by the federal government that restrict the levels and types of allowable development (ANTI 2009).

The battlefield is situated in a rural area of south Washington County, Maryland (Figure 2.2). A number of structures remain from the historic period, including the Miller, Mumma, Piper, Otto, and Sherrick farmhouses and the Pry house. Additionally, several structures and features added to the battlefield after the war are now considered historic in their own right, including Antietam National Cemetery where 4,776 Federal soldiers are buried, the road system established by the Army in the 1890s, the 103 monuments placed by states and individuals to commemorate those who fought at Antietam, and the observation tower overlooking Bloody Lane (Snell and Brown 1982).

10. Several historical details used in this report about Antietam National Battlefield have been excerpted from the excellent administrative history of Antietam written by Charles Snell and Sharon Brown in 1982.

11. President Franklin D. Roosevelt signed Executive Order 6166 which consolidated all National Parks and National Monuments, National Military Parks, the 11 National Cemeteries, National Memorials, and the National Capital Parks into a single National Park System.

Figure 2.1. GIS data layer¹² showing the administrative/legislative and fee boundaries of Antietam National Battlefield, which encompass 1,320 ha (3,263 acres) and 784 ha (1,937 acres), respectively.



Antietam National Cemetery sits on approximately 4.4 ha (11 acres) within the park. Established on March 23, 1865 by the state of Maryland, the cemetery’s board of trustees turned their charge over to the Department of War in 1877, which oversaw the cemetery until it was turned over to the care of the National Park Service in 1933.

The scene at Antietam today is essentially as it was in 1862—a collection of farms and farmlands in a rural setting (NPS 1992). The park is divided by the two-lane Route 34

(Boonsboro Pike) which passes southwest through the park into neighboring Sharpsburg, Maryland and on towards the Potomac River. Northbound Sharpsburg Pike (Route 65) runs along the park’s western edge, and through the park’s West Woods. The climate of Washington County is of the humid-temperate, continental type.

Antietam consists primarily of broad, rolling valleys. Limestone underlying most of the park’s forests and fields results in a karst topography of springs,

12. ANTI.

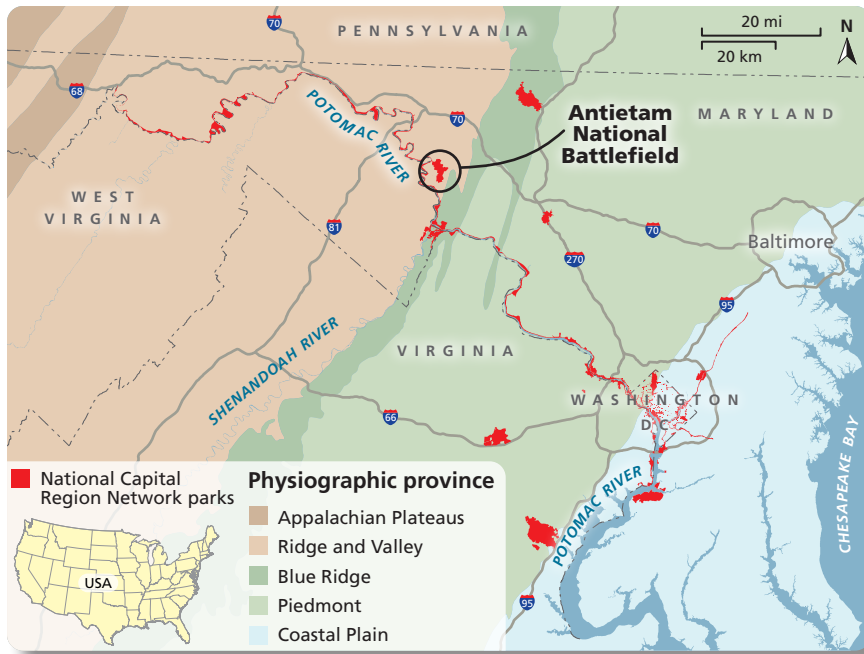
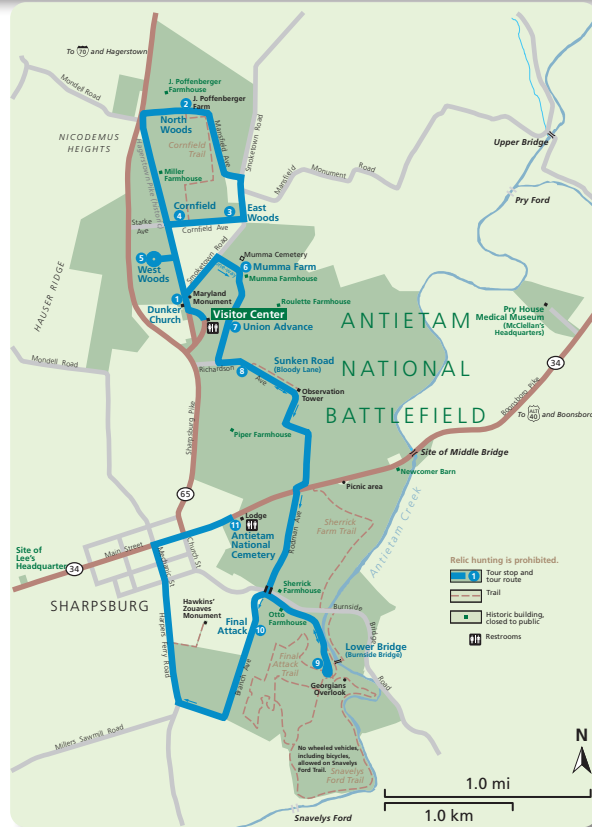


Figure 2.2. Location of Antietam National Battlefield in western Maryland.¹³



intermittent streams, and sinkholes. The soils of the battlefield are generally acidic, strongly leached, and highly or potentially highly erodible. Much of the battlefield has been used as farmland for well over a century.

At the time of the battle, corn was the primary crop, and orchards and family gardens were common. The park's farms are still actively cultivated, grazed, or planted in grass. A small number of grassland acres have been planted with native (warm-season)¹⁴ grasses to improve its quality as wildlife habitat.

13. NPS.

Antietam Creek, a tributary of the Potomac River, runs along the east side of the park and is adjoined by a small floodplain forest. About 140 ha (345 acres) of the park on and around the battle sites were originally wooded, with oak (*Quercus* spp.), maple (*Acer* spp.), and sycamore (*Platanus occidentalis*) the primary species, along with hickories (*Carya* spp.) and walnut (*Juglans* spp.; NPS 1992, 2002). Currently, the largest forest and natural area in the park is Snavely Woods, one of the best-developed native oak/hickory forests on limestone remaining in Washington County, Maryland. The historically significant North, East, and West Woods—once mature woodlots—underwent significant clearing and cultivation following 1862. In keeping with the park’s General Management Plan (NPS 1992), reforestation efforts for these woods began in 1995, to restore the visual integrity of the battlefield. The park’s grasslands, woodlands, and waters are home to a variety of wildlife—birds, woodchucks (*Marmota monax*), and white-tailed deer (*Odocoileus virginianus*) are among the most common and conspicuous.

In summary, Antietam National Battlefield is one of the first battlefield parks to be established in the nation and used a land acquisition model that left significant areas of land in private ownership. The park today retains much of its Civil War-era character and is heavily agricultural. Karst topography influences the character of the soils, water, and vegetation. Many of the woodlands and grasslands that were cleared or cultivated since the battle in 1862 are undergoing or are slated for restoration. Visitation to Antietam has been increasing over the past decade, with nearly 353,000 visitors recorded in 2008 (NPS Public Use Statistics Office).¹⁵

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

Antietam National Battlefield covers 1,320 ha (3,263 acres) and is located in southern Washington County in western Maryland (Figure 2.2). Approximately 5 km (3 mi) of the 66-km (41-mi) Antietam Creek—a tributary of the Potomac River and ultimately Chesapeake Bay—run through the park. The park is located at the bottom of the 241 km² (93 mi²) Antietam Creek watershed, which extends north into Pennsylvania (Figure 2.3).

Geology

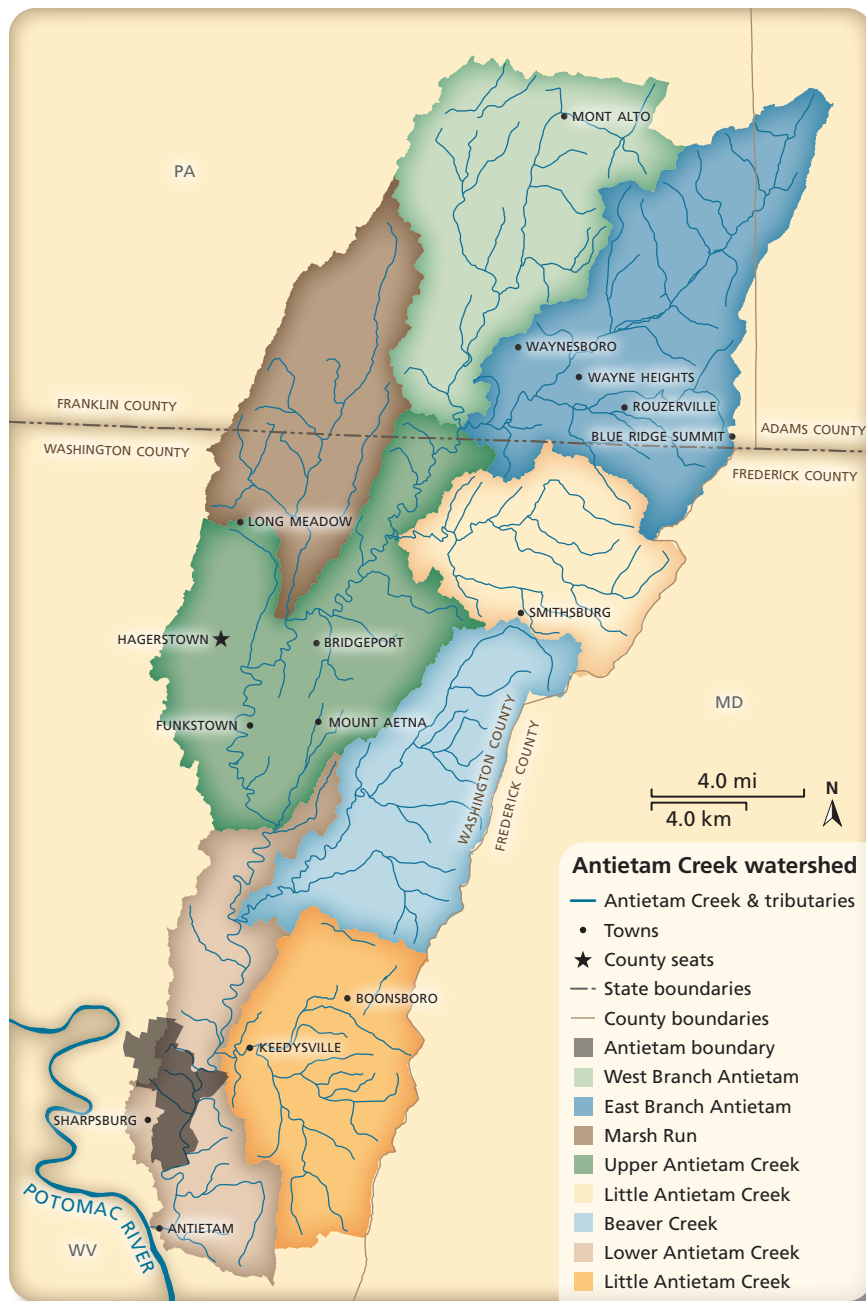
The park is located entirely within the Ridge and Valley physiographic province, with the exception of some small outholdings in the east which are in the Blue Ridge physiographic province. The Ridge and Valley province is characterized by long, parallel ridges separated by valleys (Thorneberry–Ehrlich 2005). These valleys formed where resistant sandstone ridges border carbonate formations. The carbonate is more easily eroded, leaving valleys. Areas dominated by the carbonate formations (such as Antietam National Battlefield) exhibit karst topography—a term used to describe the features produced by dissolution of carbonate rocks, including fissures, sinkholes, underground streams, and caverns. The park itself is dotted with sinkholes and springs (Figure 2.4), although a comprehensive inventory of the karst features of the park has not yet been performed.

Antietam National Battlefield ranges from 90–160 m (300–520 ft) above sea level (Figure 2.5). The geology of the park played a significant role in the battles, marking strategic battle lines and last stands, and remains an important resource preservation consideration (Thorneberry–Ehrlich 2005). The primary bedrock underlying the park is the carbonate limestone (primarily Conococheague and Elkbrook limestone) typical of the valley regions of the Ridge and Valley physiographic province (Figure

14. 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.

15. <http://www.nature.nps.gov/stats>

Figure 2.3. Antietam Creek and its watershed.¹⁶



2.6). This karst topography is susceptible to dissolution by both surface water and groundwater and this is accelerated by increasing air pollution in the eastern United States which increases the acidity of rainwater.

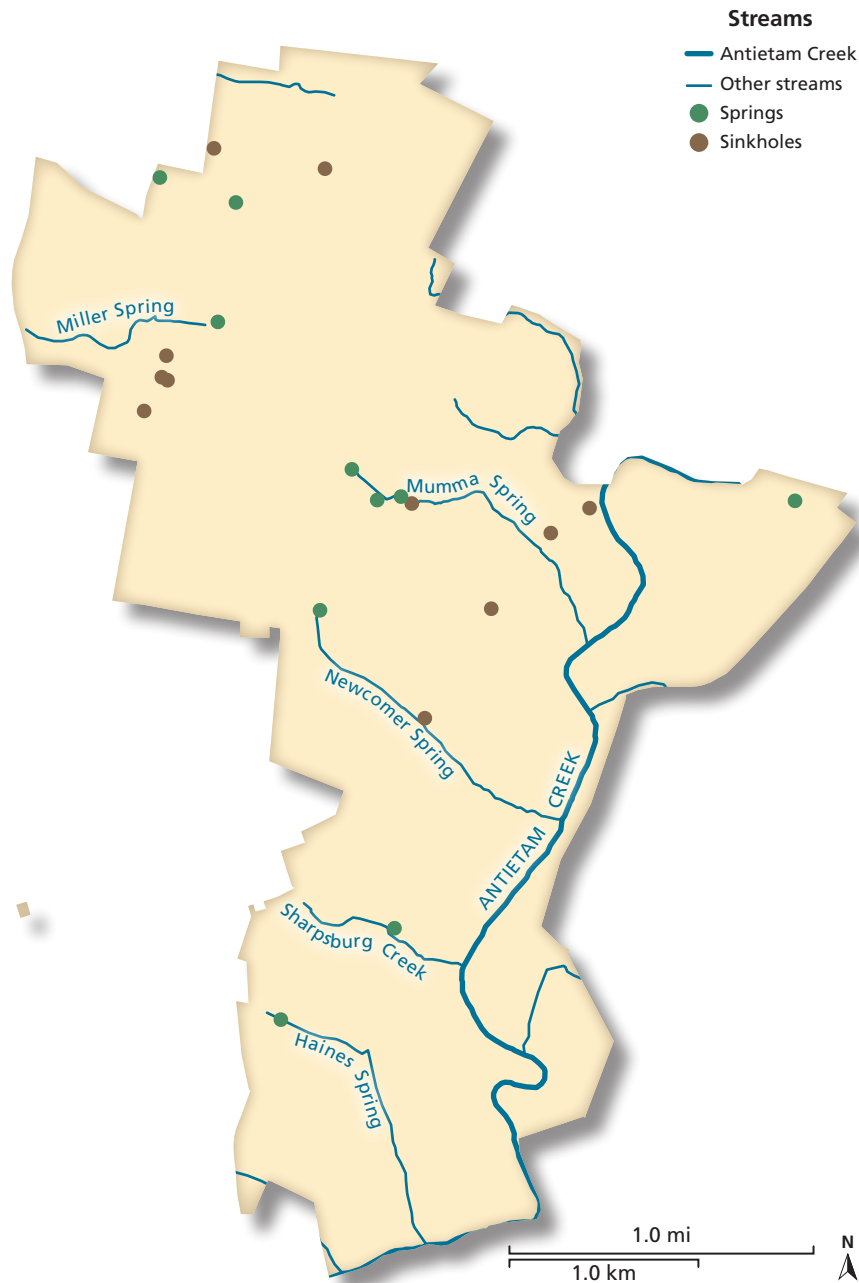
Due to the karst landscape, the groundwater discharge of the Antietam Creek basin is about 85% of the total discharge—higher than surrounding areas not underlain by folded and faulted carbonate rocks—resulting in large quantities of groundwater stored in the soil and substrate and very

productive aquifers in the area (Thorneberry–Ehrlich 2005). This has resulted in limited surface expression of water and therefore the low density of perennial streams in the basin.

The soils of Antietam National Battlefield are primarily derived from the weathering of the limestone bedrock that underlies the park, resulting in well-drained loam and clay soils with patches of exposed bedrock throughout (Figure 2.7). Many of the flatter areas in the park are classified as prime farmland, a designation identifying land

16. USGS EDNA watersheds, ESRI, ANTI.

Figure 2.4. GIS data layer¹⁷ depicting the stream network, springs, and sinkholes in Antietam National Battlefield.



that has a favorable combination of physical and chemical characteristics to promote greater production of crops, pasture, or hay.

Trails

There are several trails in the National Battlefield (Figure 2.8). The Antietam Remembered Trail is a short trail that loops to significant landmarks and monuments near the visitor center. The Bloody Lane Trail winds through the historic Mumma and Roulette Farms, following in the footsteps of Union soldiers as they advanced

toward the Sunken Road. The West Woods Trail weaves through the historic woodlot where the Union Army launched numerous attacks. The Final Attack Trail is located where the Union soldiers launched their final advance to drive the Confederate Army from Maryland, only to be turned back by A.P. Hill’s final Confederate counterattack. The Snavelly Ford Trail follows Antietam Creek for much of its length. The Union Advance Trail crosses Burnside Bridge and makes a loop on the east side of Antietam Creek and explores the area where

17. ANTI.

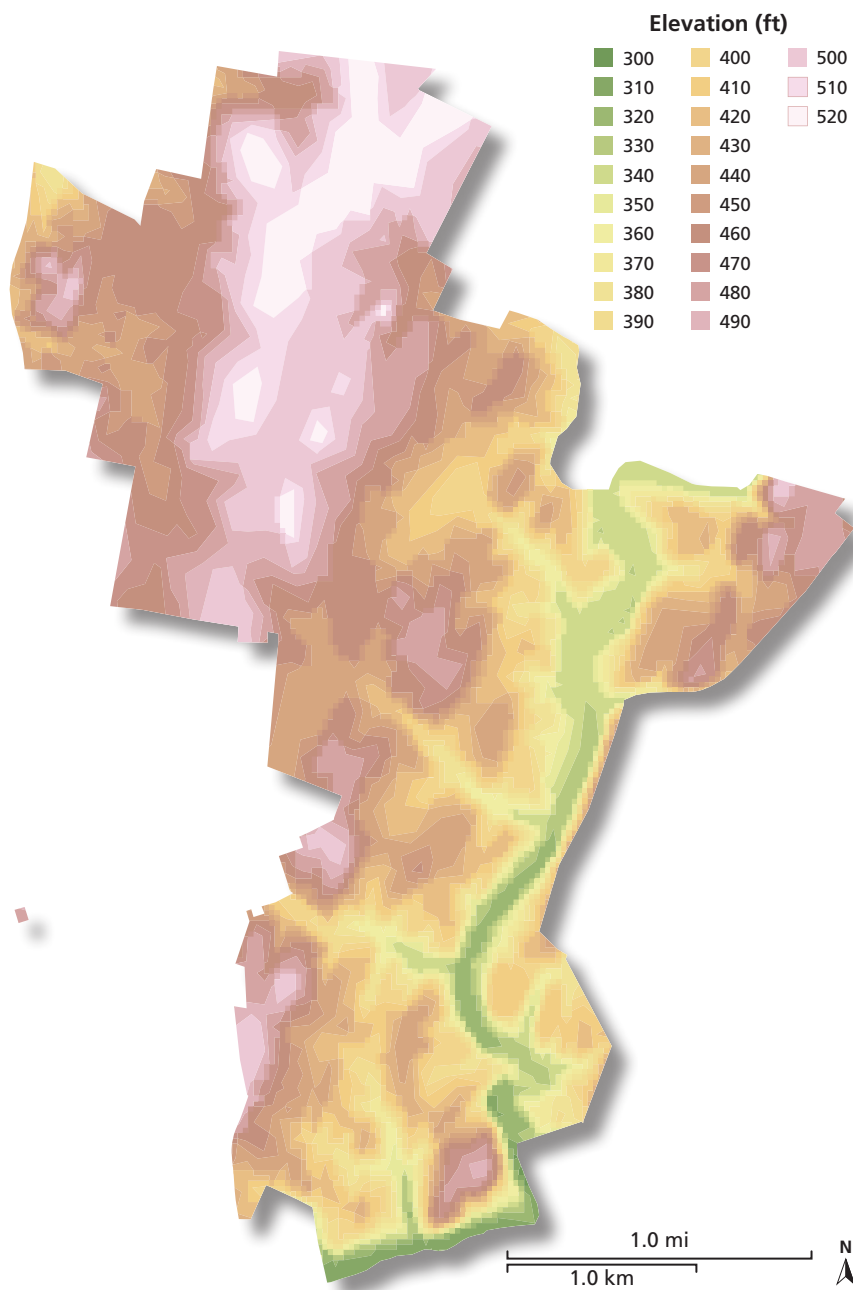


Figure 2.5. GIS data layer¹⁸ of topographic elevation for Antietam National Battlefield.

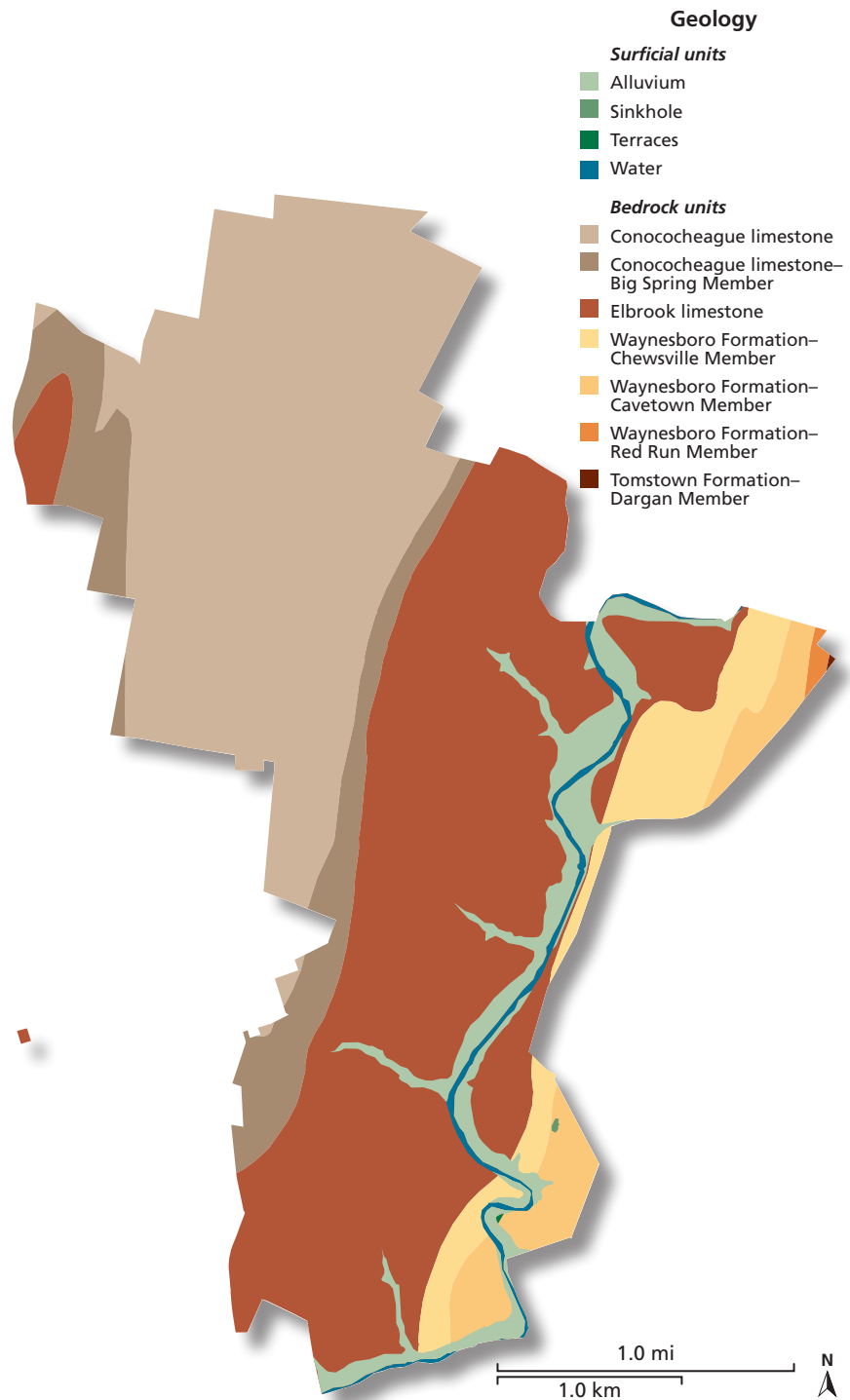
the Confederates defended the Burnside Bridge, then crosses over the creek to where the Union Ninth Corps made their advances to capture the bridge. The Cornfield Trail covers most of the area where the early morning action of battle took place. The Sherrick Farm Trail meanders through farm fields and woodlots typical of Antietam. The trail ends at the famous Burnside Bridge. The Three Farms Trail connects the north end trails to the south end trails by joining the Bloody Lane Trail in the north to the Sherrick Farm Trail in the south.

Forests

Forest and woodlands management at Antietam National Battlefield is guided by the General Management Plan (NPS 1992). This involves restoring and re-establishing the approximately 140 ha (345 acres) of woods that existed at the time of the battle in 1862, including re-establishing about 30 ha (75 acres) of the West Woods, 7.7 ha (19 acres) of the North Woods, 16 ha (39 acres) of the East Woods, and a number of smaller unnamed woods. Native mesic limestone forest species (primarily

18. National Elevation Database: Gesch et al 2002, Gesch 2007, ANTI.

Figure 2.6. GIS data layer¹⁹ of surficial and bedrock geology in Antietam National Battlefield.



oak, maple, sycamore, hickories, and walnut) are selected for restoration and reforestation. Maryland has lost the majority of its mesic limestone forests and restoration will potentially provide habitat for a variety of rare plant species. All springs and streams in the park include a riparian buffer, connecting forest patches within the park (Figure 2.9).

Wetlands and waterways

The U.S. Fish and Wildlife Service’s National Wetlands Inventory (NWI) database has identified several types of wetlands within Antietam National Battlefield (Figure 2.9). These areas are mostly comprised of ‘fresh-water forested/shrub wetland’ (i.e., floodplain and riparian areas along Antietam Creek and its tributaries) and the waterways them-

19. Thorneberry-Ehrlich 2005, ANTI.

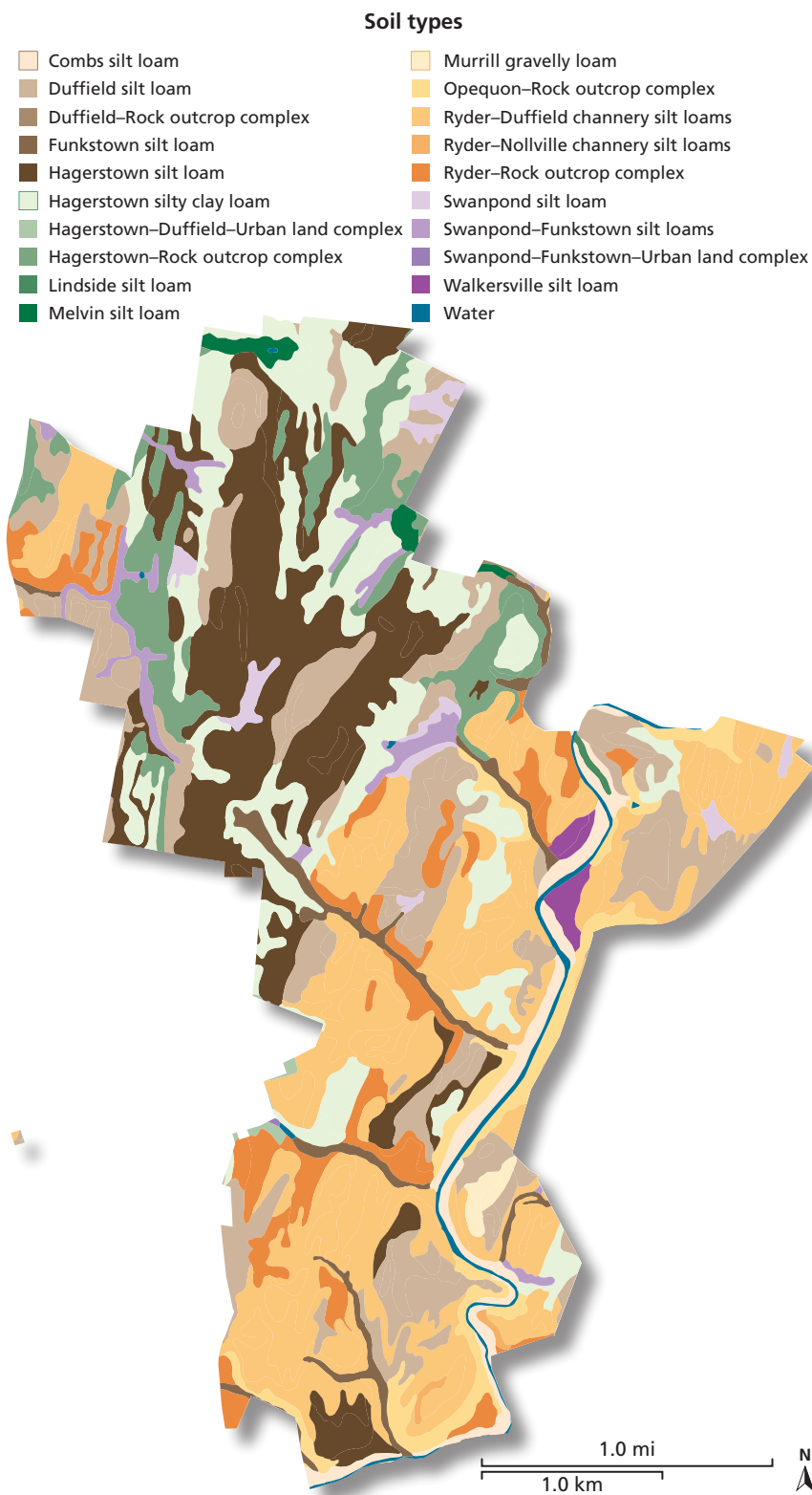


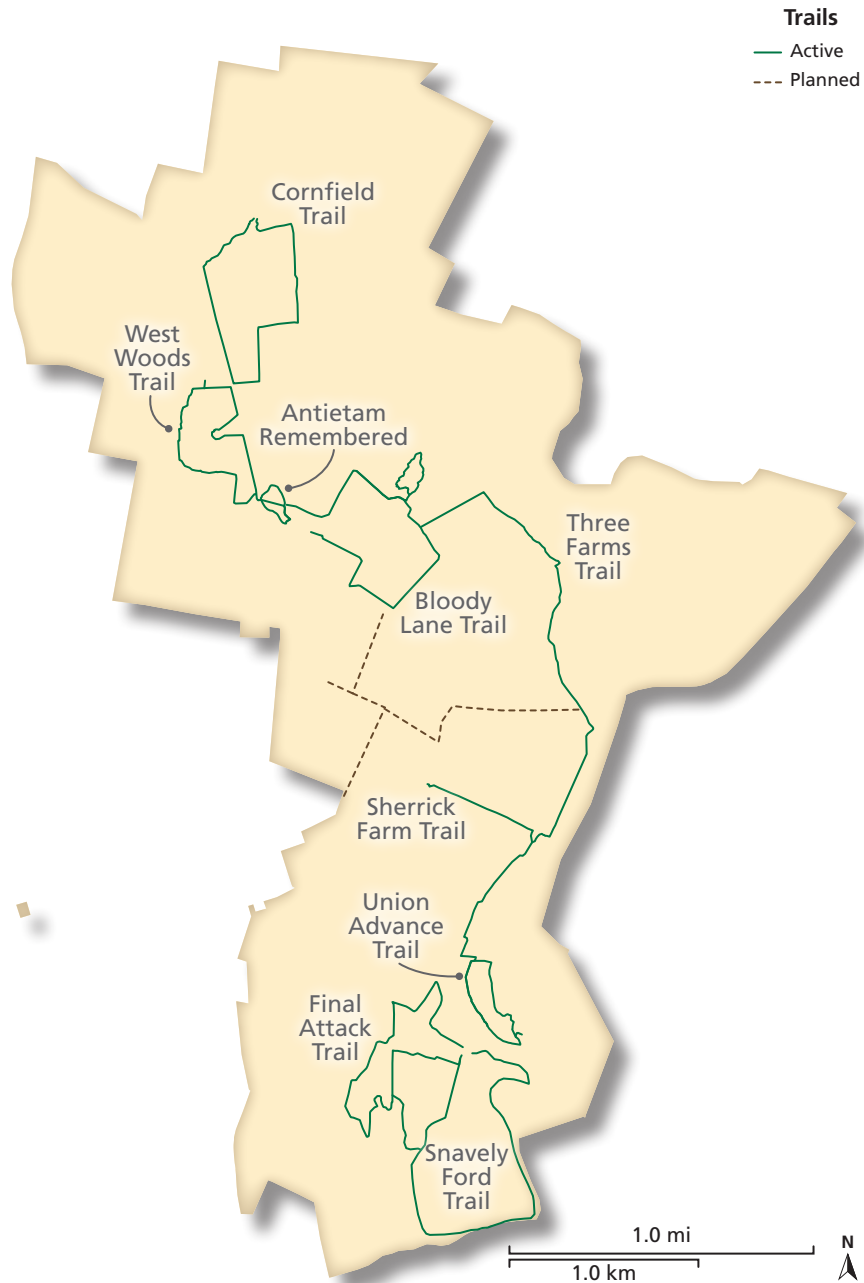
Figure 2.7. GIS data layer²⁰ of soil types found in Antietam National Battlefield.

selves—Antietam Creek, Mumma Spring, and Sharpsburg Creek—as well as small areas of freshwater emergent wetlands and freshwater ponds. All of the NWI-classified areas are considered ‘wetlands’ for legal and policy

purposes. However, the floodplain and riparian areas were considered as ‘forest’ for the ecological and habitat purposes of this assessment (see Figure 3.1 and Section 3.5.2—*Habitat framework* for detailed methodology).

20. SSURGO, ANTI.

Figure 2.8. GIS data layer²¹ showing the trail system of Antietam National Battlefield.



Grasslands

Managed to maintain historic scenes and land use patterns that existed at the time of the battle, Antietam National Battlefield contains approximately 23 ha (58 acres) of managed warm-season grasslands, as well as 131 ha (323 acres) of cool-season grasslands (Figure 2.9). Warm-season grassland species are those that initiate growth in late spring and reach their peak during the warm summer months (Peterjohn 2006). These warm-season species are generally native to the Mid-Atlantic region, including

such grasses as switchgrass (*Panicum virgatum*), big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), and Indian grass (*Sorghastrum nutans*). 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. Cool-season grassland species start growing in early spring and flower from late spring through early summer. Storage in rhizomes controls

21. ANTI.

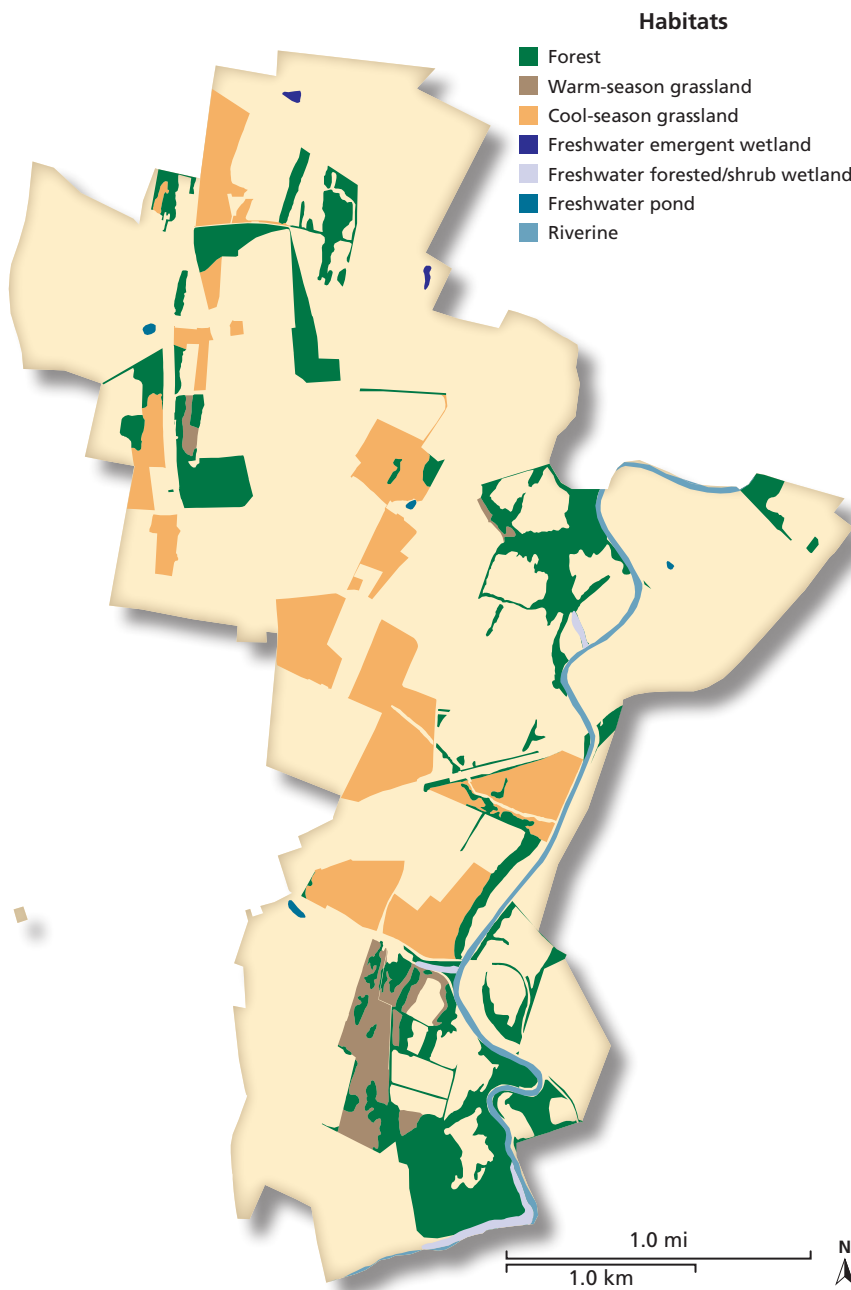


Figure 2.9. GIS data layer²² showing general location and types of habitats in Antietam National Battlefield.

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).

Agricultural lands

Agriculture is the most prominent land use within the park boundary and a variety of farming activities take place (NPS 1992). The farms range in size from 6.1 ha (15 acres) to nearly 80 ha (200 acres) and

are a mix of federally owned lands leased to private farmers, privately owned farmed lands, and privately owned farmed lands with easements held by the federal government. Crops grown include wheat, soybeans, corn, barley, and timothy. At the time of the battle, Antietam National Battlefield contained approximately 14 ha (35 acres) of apple orchards, which are in the process of being restored using historic apple varieties. Some federal and private lands within the battlefield are also grazed by cattle, sheep, and goats.

22. National Wetlands Inventory, ANTI.

Rare, threatened, and endangered species

Antietam National Battlefield provides habitat for several plant species of concern, including some state-listed species. These are balsam fir (*Abies balsamea*), fringed brome (*Bromus ciliates*), cuckooflower (*Cardamine pratensis*), Hitchcock's sedge (*Carex hitchcockiana*), troublesome sedge (*Carex molesta*), burr-reed sedge (*Carex sparganioides*), vasevine/leatherflower (*Clematis viorna*), bulb bladderfern/bulblet fern (*Cystopteris bulbifera*), dwarf larkspur (*Delphinium tricorne*), shooting-star (*Dodecatheon meadia*), downy milk pea (*Galactia volubilis*), shining bedstraw (*Galium concinnum*), Kentucky coffee-tree (*Gymnocladus dioicus*), cow parsnip (*Heracleum maximum*), green violet (*Hybanthus concolor*), goldenseal (*Hydrastis canadensis*), butternut (*Juglans cinerea*), large twayblade/brown widelip orchid (*Liparis liliifolia*), Loesel's twayblade/yellow widelip orchid (*Liparis loeselii*), white bergamot/basal bee-balm (*Monarda clinopodia*), American ginseng (*Panax quinquefolius*), mudbank crowngrass/Walter's paspalum (*Paspalum dissectum*), Virginia ground-cherry (*Physalis virginiana*), Eastern prickly gooseberry (*Ribes cynosbati*), heartwing dock/Engelmann's dock (*Rumex hastatulus*), sandbar willow (*Salix exigua*), hoary skullcap/downy skullcap (*Scutellaria incana*), veined skullcap (*Scutellaria nervosa*), American mountain ash (*Sorbus americana*), Short's aster (*Symphyotrichum shortii*), arborvitae (*Thuja occidentalis*), and golden zizia/golden Alexanders (*Zizia aurea*).

In addition to these plants, there are several state-listed species of fish (checkered sculpin [*Cottus* sp. cf. *cognatus*], shield darter [*Percina peltata*]), birds (common raven [*Corvus corax*]), mollusks (cherry-stone drop snail [*Hendersonia occulta*]) and insects (giant swallowtail [*Papilio cresphontes*]) present in the park.

2.1.2 Resource management issues overview

Antietam National Battlefield 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 has continued to increase, particularly around Hagerstown (north of Antietam) and Frederick (east of the park; Figure 2.11). Not surprisingly, housing density also increased between 2000 and 2010, with increases occurring in all directions (Figure 2.12). Road density is also highest in these areas (Figure 2.13). High road density (>1.5 km km⁻²) can impact turtle populations (Gibbs and Shriver 2002, Steen and Gibbs 2004). The area surrounding Antietam National Battlefield also has a low proportion of protected areas (Figure 2.14). Protection of 10–60% of suitable habitat is necessary to sustain long-term populations of area-sensitive and rare species (Andr n 1994, Environmental Law Institute 2003). Excessive numbers of white-tailed deer use the park as a refuge, resulting in overgrazing of native flora, particularly tree seedlings. Exotic and invasive plants out-compete 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

Due to the park's location at the bottom of the Antietam Creek watershed (Figure 2.3), it is susceptible to degradation of landscape and water quality that occurs outside the park and therefore beyond park management's control. The future quality of the creek and its tributaries are potentially impacted by agricultural inputs (manure and fertilizers, pesticides) from park and adjacent farmlands, upstream industrial and sewage discharge, and the increase of impervious surfaces and stormwater runoff in surrounding residential areas (Figure 2.15). Groundwater is also easily impacted because the park lies on a porous limestone bed (Thorneberry–Ehrlich 2005).

In 2002, a Total Maximum Daily Load (TMDL) was approved for Antietam

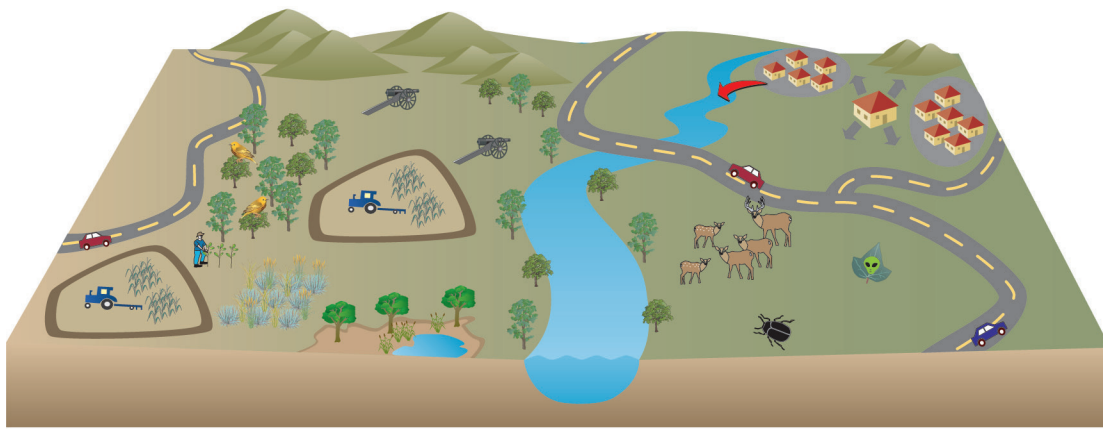














Figure 2.10. Conceptual diagram illustrating the major resource values and stressors in Antietam National Battlefield.

Resource values

-  Historic sites
-  Hickory/chestnut oak forests
-  Wetlands
-  Warm-season grasslands
-  Agriculture
-  Native species
-  Replanting

Resource stressors

-  Encroaching development reduces habitat for native flora and fauna
-  Overabundance of white-tailed deer results in overgrazing of native flora
-  Invasive/exotic species outcompete native species
-  Insect pests damage forest trees
-  High road density

Creek for carbonaceous and nitrogenous biochemical oxygen demand (CBOD and NBOD, respectively) and in 2008, a TMDL was established for sediment (MDE 2002, 2009). These were based on low dissolved oxygen levels and high levels of sediments as identified in Maryland Department of the Environment’s (MDE) 1996 and 1998 Section 303(d) lists of impaired waters. 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—in the case of Antietam Creek in the vicinity of the park,

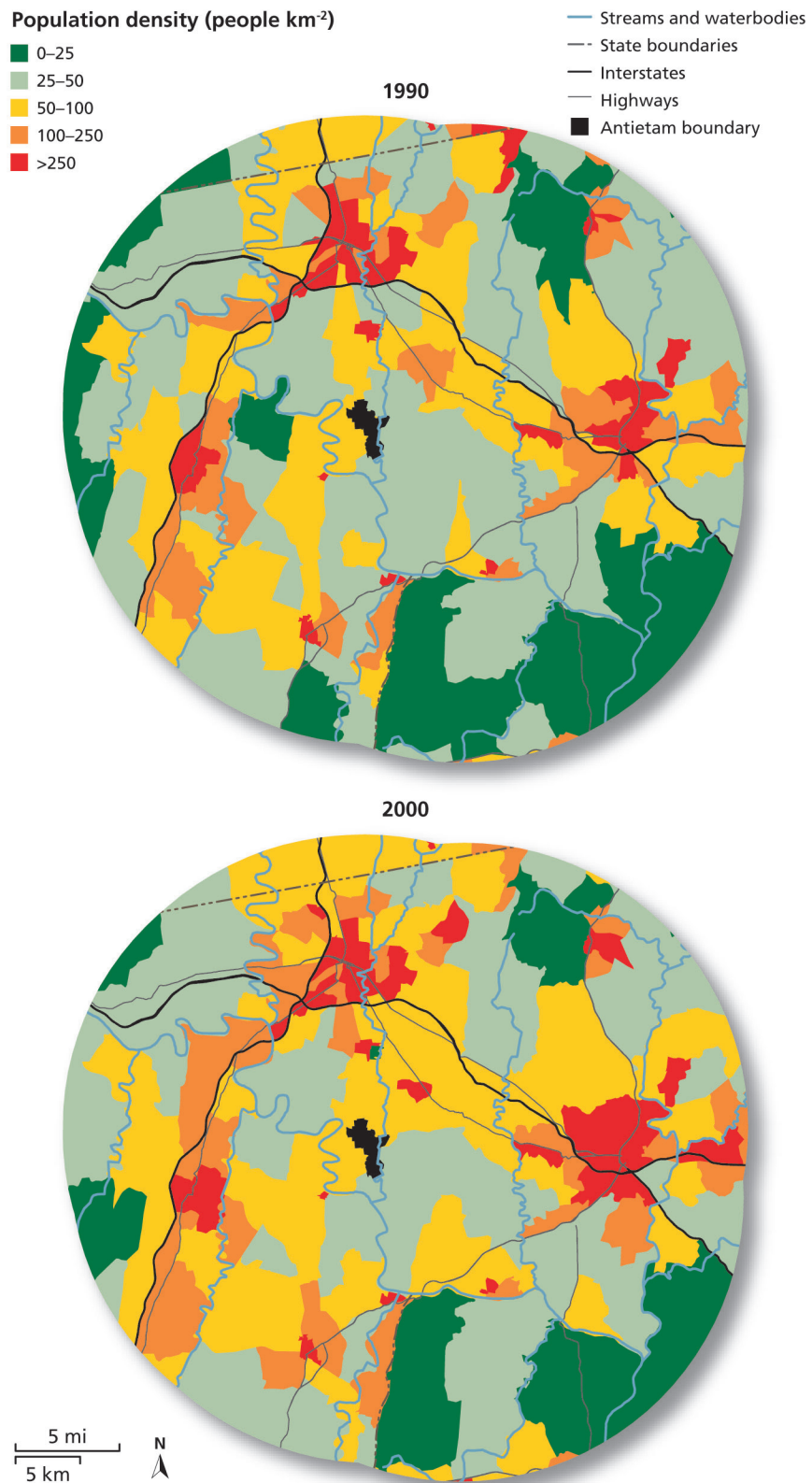
it is designated as a Use IV-P waterbody (Recreational Trout Waters and Public Water Supply; MDE 2010).

The waters of Antietam Creek have also been identified by MDE as impaired by bacteria, nutrients, and impacts to biological communities. A TMDL for bacteria was submitted to the U.S. EPA to address that impairment, and the listing for nutrients and biological community impacts will be addressed separately at a future date (MDE 2009).

Grasslands

With grasslands and pasture lands making up a significant portion of Antietam National Battlefield’s historic and current

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/im/monitor/npscape/index.cfm>

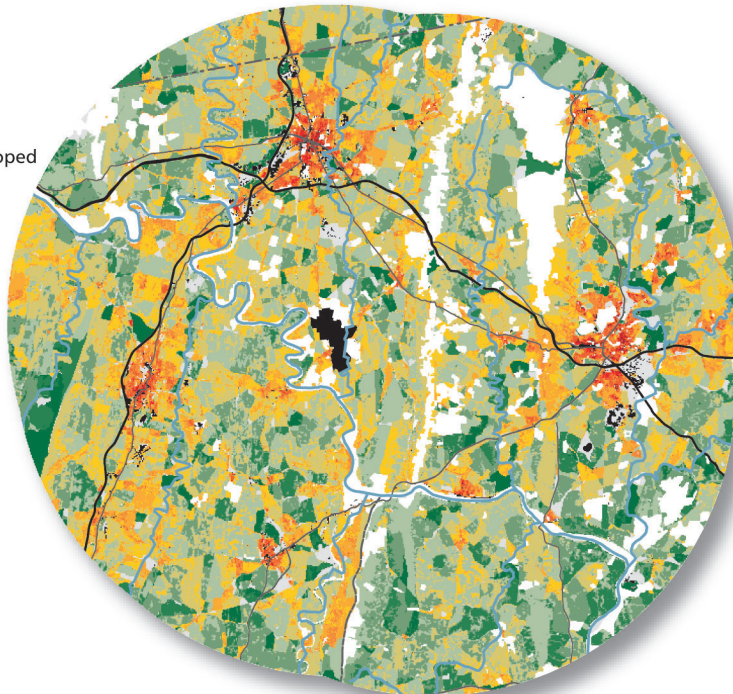
Housing density (units km⁻²)

- Commercial/industrial
- >2,470
- 1,235-2,470
- 495-1,234
- 146-494
- 50-145
- 25-49
- 13-24
- 7-12
- 4-6
- 1.5-3
- <1.5
- Private undeveloped

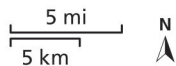
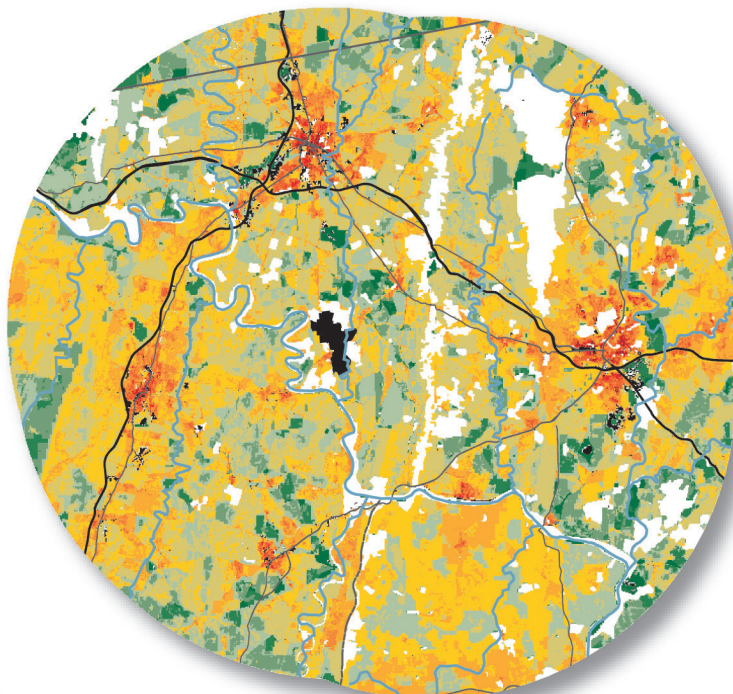
- Streams and waterbodies
- - State boundaries
- Interstates
- Highways
- Antietam boundary

Figure 2.12. GIS data layer²⁴ showing population density surrounding the park in 1990 and 2000.

2000

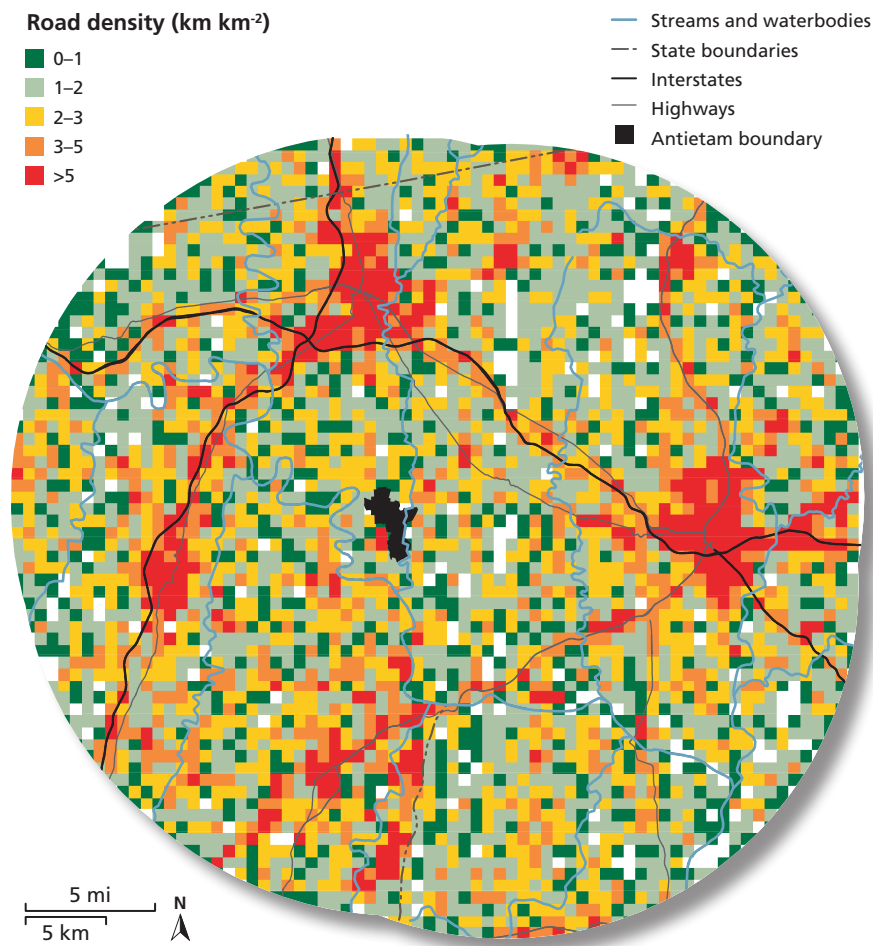


2010



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.



viewsheds, management of grasslands is high on the list of Antietam’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, grazing, and prescribed burns (Peterjohn 2006) and indeed, Antietam National Battlefield has prescribed fire plans in place for grasslands on the Otto Farm.

Forests

The mosaic of forest, grassland, and agricultural lands at Antietam National Battlefield is ideal habitat for white-tailed deer (*Odocoileus virginianus*). Deer populations in the Mid-Atlantic region exceed 40 deer km⁻² (104 deer mi⁻²) for rural and suburban national historical parks (Bates 2009). Research evidence suggests that overbrowsing by white-tailed deer can negatively affect forests by reducing growth and survival rates of native tree seedlings and saplings and preventing adult recruitment into tree populations (Russell et al. 2001). Excess herbivory may also cause irreversible shifts in successional stable-state forests by altering plant species compositions (Stromayer and Warren 1997, Augustine et al. 1998). Besides directly impacting vegetative communities, deer overbrowsing can contribute to declines in breeding bird abundances by decreasing the structural diversity and density in the forest understory (McShea and Rappole 1997).

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

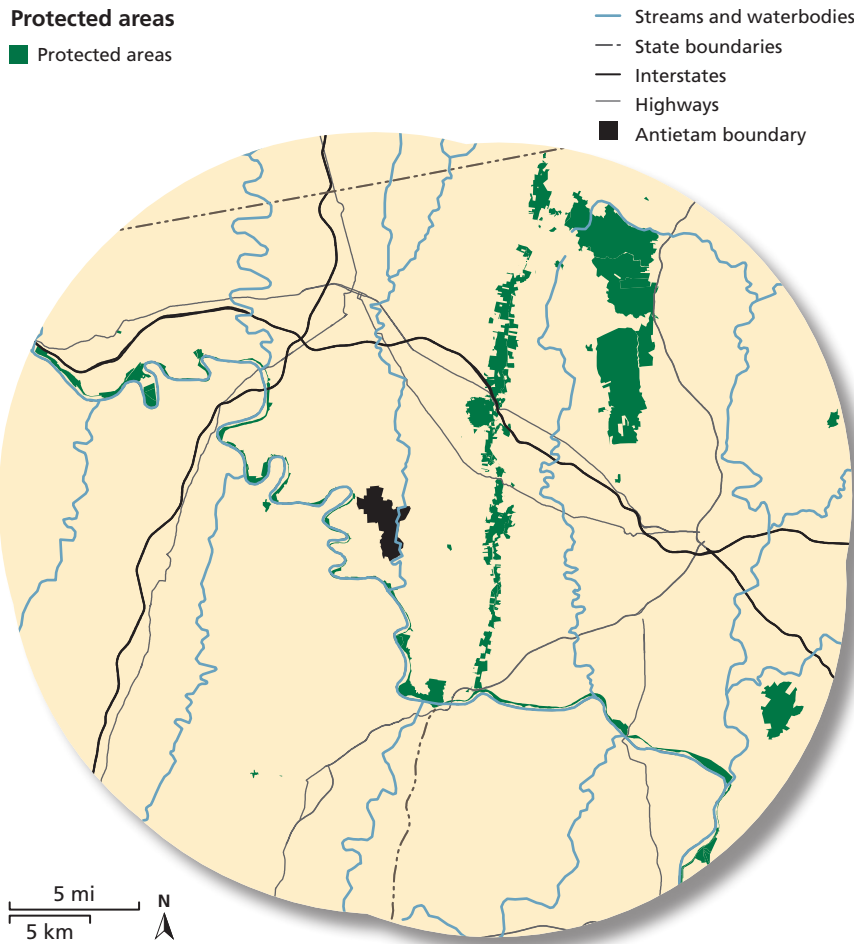


Figure 2.14. GIS data layer²⁶ showing protected areas surrounding the park in 2000.

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). A 2005 inventory of the vascular plants in Antietam National Battlefield showed that of the four most abundant species in the park, three were non-native (Engelhardt 2005). Those three species were multiflora rose (*Rosa multiflora*), Japanese honeysuckle (*Lonicera japonica*), and garlic mustard (*Alliaria petiolata*).

Insect and fungal pathogens have emerged as major stressors to forests in the Mid-Atlantic region in recent decades. Pathogens of interest are the exotic gypsy moth (*Lymantria dispar*), the fungal agent *Discula destructiva* (dogwood anthracnose), the exotic hemlock woolly adelgid (*Adelges tsugae*), the fungal agent *Ophiostoma ulmi* (Dutch elm disease), and the exotic emerald ash borer (*Agrilus planipennis*, USDA 2009a,b, 2010a,b,c). How-

ever, emerald ash borer has not been found in Antietam National Battlefield at this time.

Agriculture

Deer populations in national historical parks in the Mid-Atlantic region have increased as a result of the forage provided by the agricultural landscapes within these parks (Hansen et al. 1997). Antietam National Battlefield is one of several historical parks that have entered into cooperative agricultural easements to maintain the landscape as it was during the historical period commemorated by the park. As such, overabundance of white-tailed deer is a significant resource issue in the park.

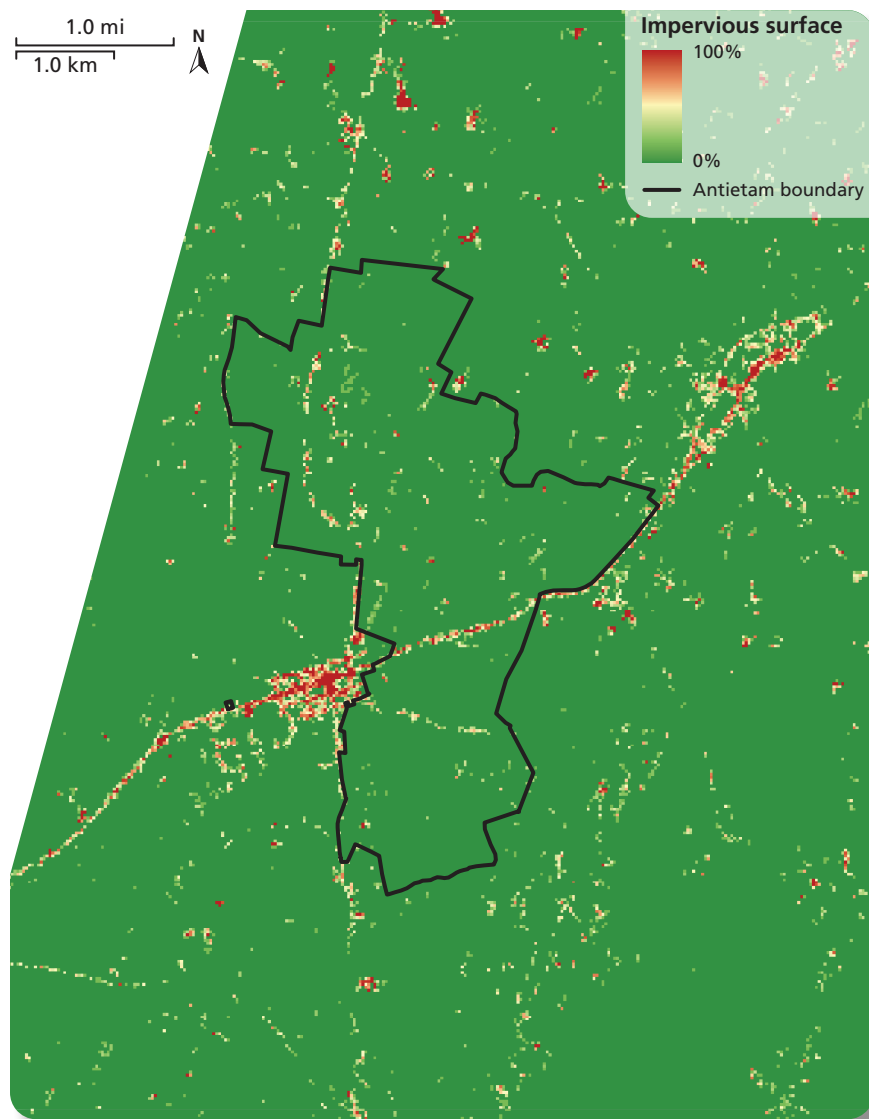
2.2 RESOURCE STEWARDSHIP CONTEXT

2.2.1 Park enabling legislation

Several laws and documents guide natural resource management for Antietam Nation-

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

Figure 2.15. GIS data layer²⁷ showing percent impervious surface in and around Antietam National Battlefield in 2000.



al Battlefield—the National Park Service Organic Act of 1916 (“Organic Act,” Ch. 1, 39 Stat 535), the park’s federal and state founding legislation and follow-on legislation in 1960, the 1992 Antietam National Battlefield General Management Plan (GMP; NPS 1992), 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 Antietam National Battlefield’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.

27. RESAC Impervious Surface Area Time Series, ANTI.

Antietam's 1890 federal founding legislation allowed for the acquisition of lands "For the purpose of surveying, locating, and preserving the lines of battle . . . and for marking the same." A law in the state of Maryland, approved April 7, 1892, allowed federal land acquisition for these purposes and, "for the preservation of the grounds covered by said battlefields for historical or other purposes . . ."

According to Snell and Brown (1982), the U.S. Committee on Military Affairs (1891), in February 27, 1891 issued a report explaining the purpose of the 1890 federal law for Antietam, stating,

"The field on which the battle took place is practically unchanged from what it was on the day of the action, save the cutting down of some trees, and presents to-day, as it did in 1862, the most open field on which was fought any of the great battles of the rebellion—a field of which the eye in one sweep can take in all points. It is proposed to maintain the field in the same condition as to roads, fields, forests, and houses . . ."

Federal legislation in 1960 (16 USC 4300o, April 22, 1960) restated and summarized previous legislation, stating that the Secretary of the Interior was authorized,

"to preserve, protect and improve the Antietam Battlefield . . . to assure the public a full and unimpeded view thereof, and to provide for the maintenance of the site . . . in, or its restoration to, substantially the condition in which it was at the time of the battle of Antietam."

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

Antietam 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. In this context, this natural resource condition assessment addresses natural habitats managed for natural resource values (forests, wetlands and waterways, warm-season grasslands), as well as habitats that are managed for agricultural values (croplands and pastures).

2.2.2 Resource stewardship planning

Antietam's 1992 General Management Plan (GMP; NPS 1992) analyzed and described three alternatives for future management and use of Antietam National Battlefield. They ranged from maintaining existing conditions to restoring most of the historic scene. Alternative B—1862 Scene Restoration—provided for restoration of the battlefield landscape to its approximate appearance on the eve of the battle of September 17, 1862. Restoration actions are in keeping with the 1960 legislative mandate "to provide for the maintenance of the site . . . in, or its restoration to, substantially the condition in which it was at the time of the battle" (Public Law 86-438).

Other actions under alternative B include simplifying the automobile tour route so that it focuses on the three main battle phases, incorporating new interpretive features and media to enhance visitor experiences, and cooperating with state, local, and private entities to ensure preservation of the rural/agricultural landscape inside and adjacent to the battlefield boundary. Restoration actions under alternative B call for the return of the landscape to a more historic appearance by re-establishing many of the farm fields, woods, orchards,

fencelines, and historic trace roads that existed in 1862. These actions would have a beneficial effect on the natural environment by recovering a net total of 2.8 ha (7 acres) of prime and unique farmlands, re-establishing about 140 ha (345 acres) of limestone forest woodlands, increasing habitat diversity, decreasing automobile emissions in the park, and reducing erosion into Antietam Creek at Burnside Bridge.

2.2.3 Resource stewardship science

The 1992 Antietam National Battlefield GMP (NPS 1992), and the NPS Management Policies (U.S. Dept of Interior 2006) are the two primary documents that guide planning at the park, and are discussed in the previous two sections.

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Chapter 3: Study approach

3.1 PRELIMINARY SCOPING

3.1.1 Park involvement

Antietam park staff, including Superintendent John Howard and natural resource staff Ed Wenschhof, Joe Calzarette, and Deb Cohen, initially met in April 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 Monocacy National Battlefield and Manassas National Battlefield Park, 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 Monocacy National Battlefield and Manassas National Battlefield Park 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.

3.1.1 Other NPS involvement

The NCRN I&M was the primary coordinator and leader for the production of this NRCA for Antietam National Battlefield. NCRN staff established a cooperative



agreement with University of Maryland Center for Environmental Science Integration and Application Network (IAN) to work on this document, supplied the majority of the data used in the assessment, and provided knowledge of the larger context of the region’s battlefield parks.

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 introductory 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

Antietam staff regularly monitor water quality.

for Antietam National Battlefield, Monocacy National Battlefield, and Manassas National Battlefield Park. 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 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 1,320 ha (3,263 acres), while the fee boundary is 784 ha (1,937 acres). Six predominant ecological habitat types were identified within Antietam National Battlefield, and these were divided into habitats managed for natural resource values (forests, wetlands and waterways, warm-season grasslands) and those managed for agricultural values (croplands, pastures, developed areas; 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 conditions within Antietam National Battlefield, 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 five main ecological habitats present within Antietam National Battlefield, divided into two broad groups—habitats managed for natural resource values (forests, wetlands and waterways, warm-season grasslands) and those managed for agricultural values (croplands, pastures). Developed areas, although defined as a separate 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

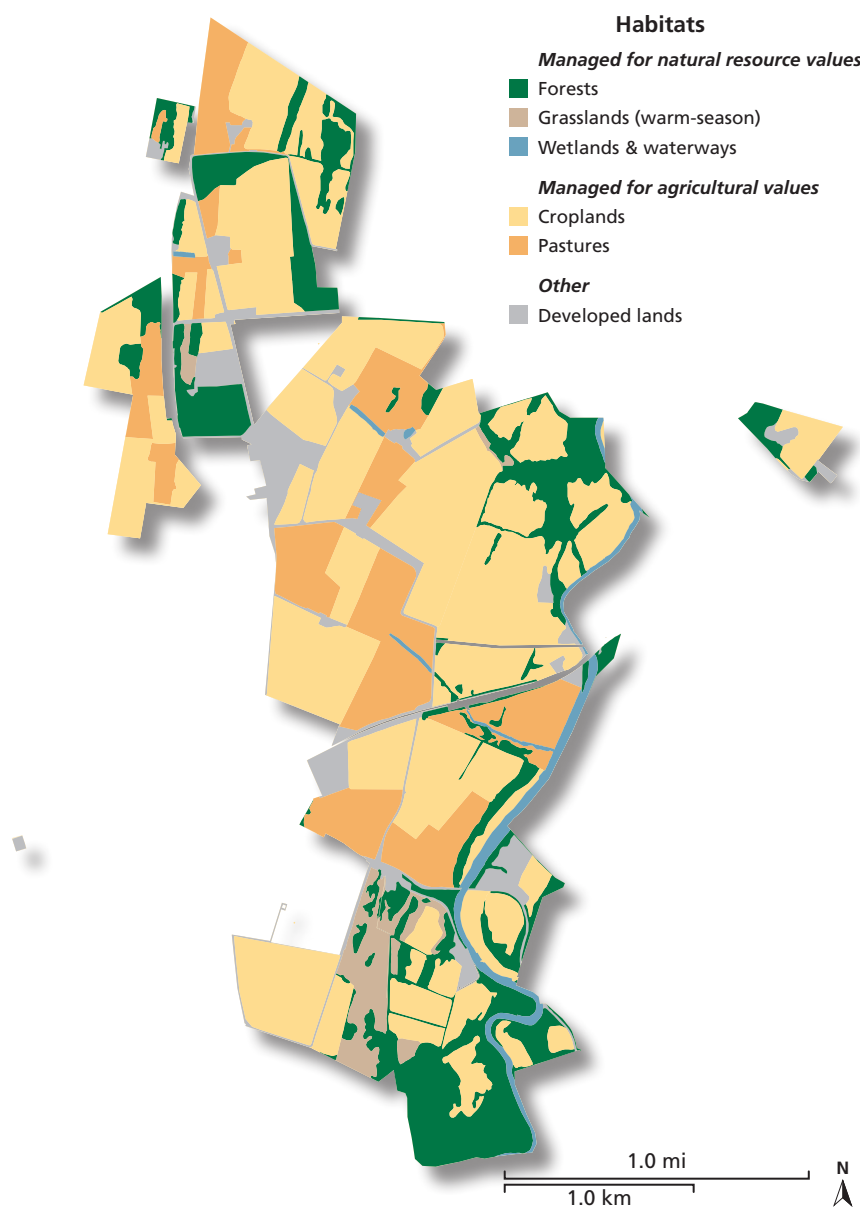


Figure 3.1. GIS data layer²⁸ of major habitat types in Antietam National Battlefield, as defined by aggregation of other GIS data layers.

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 irre-

28. NCRN I&M, ANTI.

versible—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 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.

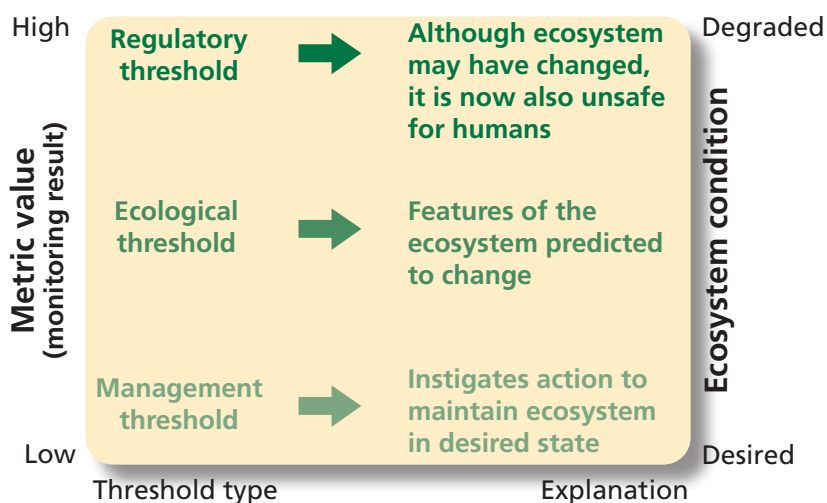
Process of threshold determination within ecological monitoring and habitat frameworks

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 land uses within the park to effectively assess lands managed for natural resource values as well as those managed for agricultural values (Figures 3.1, 3.3, 3.4). In Antietam National Battlefield, as in many battlefield parks, the enabling legislation focuses on maintaining a landscape similar to that on the day of the battle, which includes maintaining cropfields and pastures. Assessing these lands within a habitat context reflects that different land uses within the park create a

mosaic and therefore the natural resource value of the forests, wetlands and waterways, and warm-season grasslands is, to some extent, dependent upon the adjacent agricultural lands. Furthermore, park management goals cover all lands within the park, suggesting that to best integrate a natural resource condition assessment into a relevant park management context, all lands need to be integrated into one assessment.

In the habitat assessment, a different approach was taken for the determination of metrics and thresholds within the two habitat categories (managed for natural resource values/managed for agricultural values). In habitats that are managed for natural resource values (forests, wetlands and waterways, warm-season grasslands), ecosystem or vital sign metrics were used as indicators of ecosystem function (Figure 3.3). For habitats managed for agricultural values (croplands and pastures), the percent of area compliant with Best Management Practices was used as an indicator of effectiveness at minimizing potential impacts of these lands on adjacent or downstream natural habitat areas (through sediment and nutrient inputs) (USDA 2007, Chesapeake Bay Program undated; Figure 3.4).



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 Antietam: bird monitoring (grassland, wetland, forest, birds of prey,

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 (ammonium) and NO ₃ (nitrate) 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	6.5 ≤ pH ≤ 8.5 (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.	COMAR 2007b U.S. EPA freshwater recreation standards
Dissolved oxygen (DO)	≥ 5.0 mg DO L ⁻¹ (monthly instantaneous measurements)	Low concentrations of dissolved oxygen cause limitation and ultimately death of fish, benthic invertebrates and aquatic plants.	COMAR 2007b U.S. EPA freshwater recreation standards
Temperature	< 23.9°C (monthly instantaneous measurements)	Increased stream water temperature is unsuitable for many biota such as brook trout.	COMAR 2007b U.S. EPA freshwater recreation standards
Acid neutralizing capacity (ANC)	> 200 µeq L ⁻¹ (monthly instantaneous measurements)	Threshold based on U.S. EPA "sensitive to acidification" standard of 200 µeq L ⁻¹ (1 mg L ⁻¹ CaCO ₃ = 20 µeq L ⁻¹). Also justified by relationship to stream Benthic IBI.	Southerland et al. 2007
Salinity	< 0.25 (monthly instantaneous measurements)	Threshold based on U.S. EPA human drinking water standards of maximum 250 mg L ⁻¹ chloride ions (equivalent to a salinity of 0.25). Salinity was measured at each sample location for all sampling dates (2005–2006).	U.S. EPA 2009 EPA Standards for Drinking
Nitrate (NO ₃)	< 2 mg NO ₃ L ⁻¹ (monthly instantaneous measurements)	Nitrate threshold based on relationship to benthic invertebrate index.	Southerland et al. 2007
Phosphate (PO ₄)	0.031 mg PO ₄ L ⁻¹ (monthly instantaneous measurements)	Phosphate 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

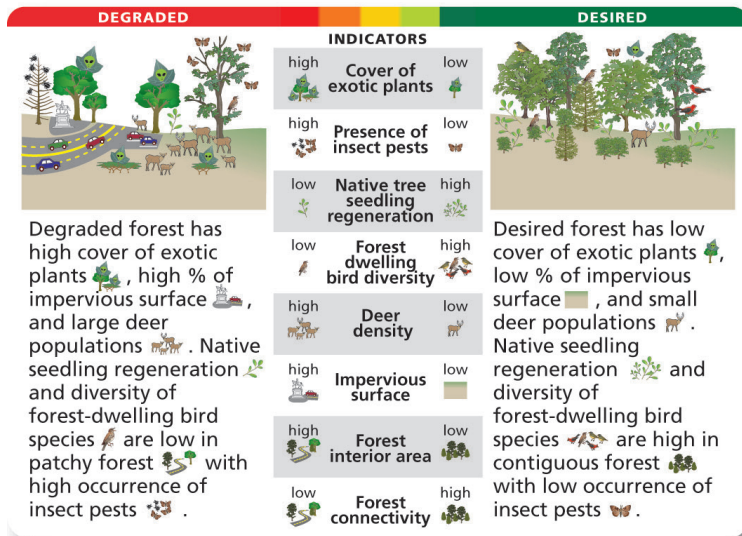
Table 3.3. Thresholds for Biological Integrity metrics.

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
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

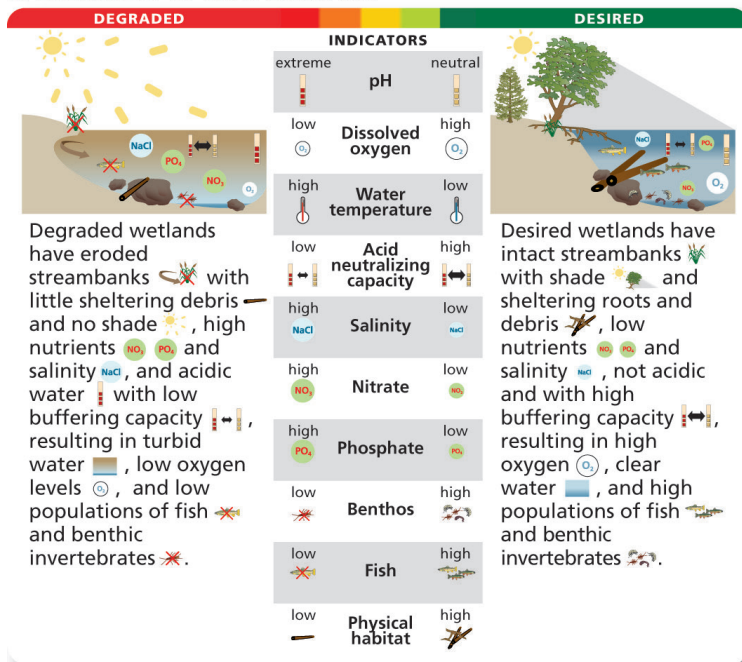
Table 3.4. Thresholds for Landscape Dynamics metrics.

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

FORESTS



WETLANDS & WATERWAYS



GRASSLANDS (WARM-SEASON)

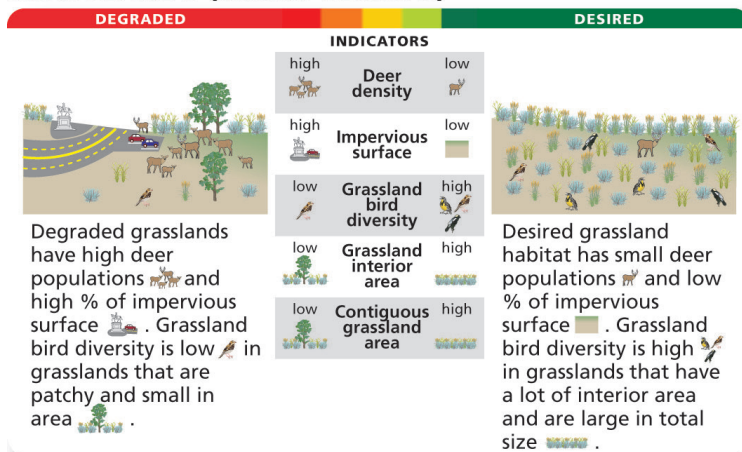
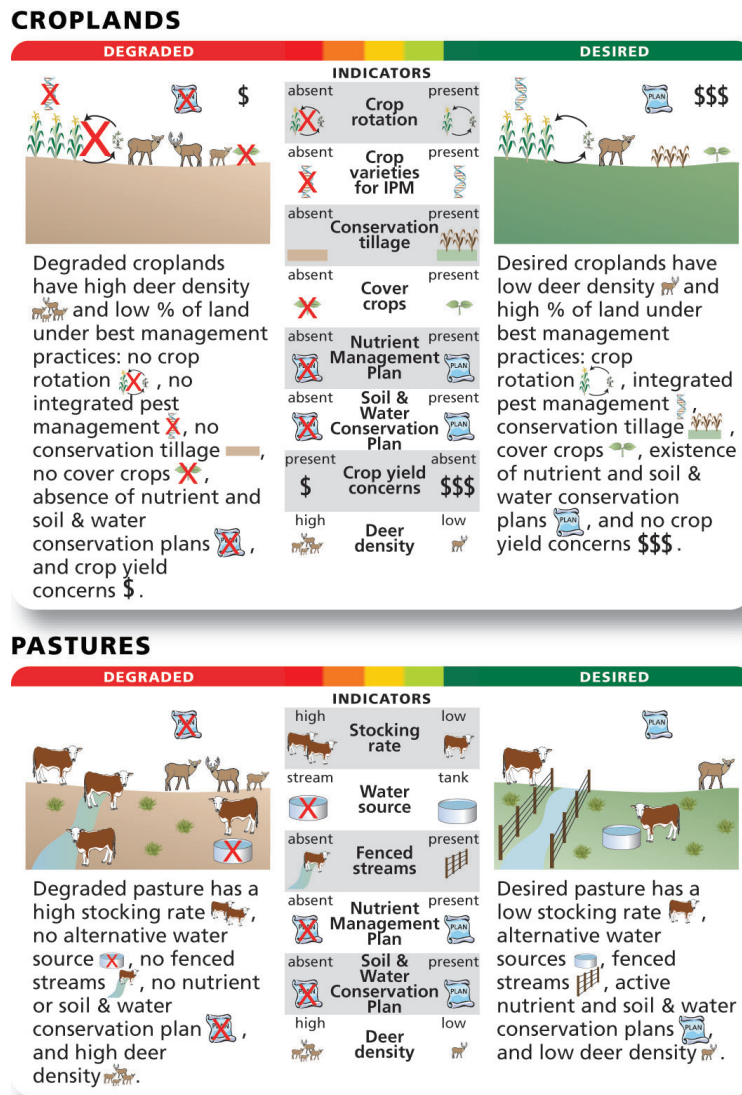


Figure 3.3. Conceptual framework for desired and degraded condition of habitats managed for natural resource values present within Antietam National Battlefield, indicating metrics to track status of condition.

Figure 3.4. Conceptual framework for desired and degraded condition of habitats managed for agricultural values present within Antietam National Battlefield, indicating metrics to track status of condition.



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 3.5). 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).

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

Figure 3.5. Summary of the two frameworks used in this assessment, including metrics.

Ecological monitoring framework

<p>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)</p>	<p>Water Resources pH Dissolved oxygen (mg DO L⁻¹) Water temperature (°C) Acid neutralizing capacity (µeq L⁻¹) Salinity Nitrate (mg NO₃ L⁻¹) Phosphate (mg PO₄ L⁻¹) Benthic index of biological integrity Physical habitat index</p>
<p>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)</p>	<p>Landscape Dynamics Impervious surface (% cover) Forest interior area Forest connectivity (m) Grassland interior area Contiguous grassland area</p>

Habitat framework

—Habitats managed for natural resource values—

<p>Forests Exotic herbaceous species (% cover) Exotic tree/shrub density (% cover) Presence of forest pest species (trees infested) Native seedling regeneration (seedlings ha⁻¹) Presence of forest interior dwelling bird species Deer density (deer km⁻²) Impervious surface (% cover) Forest interior area Forest connectivity (m)</p>	<p>Wetlands & waterways pH Dissolved oxygen (mg DO L⁻¹) Water temperature (°C) Acid neutralizing capacity (µeq L⁻¹) Salinity Nitrate (mg NO₃ L⁻¹) Phosphate (mg PO₄ L⁻¹) Benthic index of biological integrity Fish index of biological integrity Physical habitat index</p>	<p>Warm-season grasslands Deer density (deer km⁻²) Impervious surface (% cover) Grassland bird diversity Grassland interior area (ha) Contiguous grassland area (ha)</p>
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—Habitats managed for agricultural values—

<p>Croplands Crop rotation (yes/no) Crop varieties for IPM (yes/no) Conservation tillage (yes/no) Cover crops (yes/no) Nutrient Management Plan (yes/no) Soil & Water Conservation Plan (yes/no) Crop yield concerns (yes/no) Deer density (deer km⁻²)</p>	<p>Pastures Acceptable stocking rate (yes/no) Alternative water source (yes/no) Fenced streams (yes/no) Nutrient Management Plan (yes/no) Soil & Water Conservation Plan (yes/no) Deer density (deer km⁻²)</p>
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low organic soils, as highly humic soils are known to potentially store large amounts of mercury which can slowly leach into inland waters, in some cases contributing much more to mercury concentrations than current atmospheric deposition (Meili et al. 2003). Currently, the U.S. EPA also has a lower recommended fish tissue regulatory maximum threshold of 0.3 mg methylmercury kg⁻¹ (0.3 ppm) wet weight, which would result in reducing the modeled atmospheric deposition threshold (U.S. EPA 2001). Human and mammalian regulatory thresholds are based on the effects of exposure. In vitro exposure can cause mental retardation, cerebral palsy, deafness, blindness, and dysarthria (speech disorder), and adult exposure can cause motor dysfunction and other neurological and mental impacts (U.S. EPA 2001). Avian species are particularly susceptible as mercury reduces reproductive potential (Wolfe et al. 1998). Measured atmospheric wet and dry mercury deposition trends from west to east across North America can also be measured in the common loon (*Gavia immer*) and throughout North America in mosquitoes (Evers et al. 1998, Hammerschmidt and Fitzgerald 2002). Mercury is also recognized to have a toxic effect on soil microflora, although no ecological depositional threshold is currently available (Meili et al. 2003). Mercury deposition data from 2004–2008 from the two sites closest to the park were obtained from the Maryland Deposition Network website (<http://nadp.sws.uiuc.edu/mdn>). The annual mean was calculated and compared to the threshold.

3.4.2 Water Resources

pH, dissolved oxygen, temperature—regulatory and ecological

The State of Maryland has classified its waterbodies on the basis of their designated uses. Minimum water quality criteria have been established that will maintain these designated uses. Antietam Creek is designated as a Use IV-P waterbody (Recreational Trout Waters and Public Water Supply; COMAR 2007a, c). The thresholds for dissolved oxygen concentration, pH, and water temperature

for this assessment were determined from these water quality criteria.

The acceptable range for pH is between 6.5 and 8.5 pH units (COMAR 2007b). The dissolved oxygen concentration is regulated to be equal to or greater than 5 mg DO L⁻¹ (5 ppm) at all times, which is also a widely accepted ecological threshold to maintain aquatic life (COMAR 2007b). Water temperature is regulated to be less than 23.9°C (75.0°F; COMAR 2007b). All three measurements are taken monthly as instantaneous records. 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.

Salinity was monitored by I&M at one site in Antietam, and at seven sites by Antietam National Battlefield staff. The data was taken as conductivity (ms cm^{-1}). This was converted to general salinity units using the methods of UNESCO (1983).

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 $2 \text{ mg NO}_3 \text{ L}^{-1}$ (2 ppm) indicated stream degradation (Southerland et al. 2007, Norris and Sanders 2009). Instantaneous measurements 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 for total phosphorus. These criteria were developed to prevent eutrophication nationwide and are not regulatory (U.S. EPA 2000). The criteria are developed as baselines for specific geographic regions. Antietam National Battlefield is located in Ecoregion XI or the Central and Eastern Forested Uplands region (U.S. EPA 2000). The ecoregional reference condition value for total phosphorus is $0.010 \text{ mg P L}^{-1}$ (10 ppb), which equates to a phosphate threshold of $0.031 \text{ mg PO}_4 \text{ L}^{-1}$ (31 ppb);

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, the U.S. Department of Interior NPS Management Policies (U.S. Dept of Interior 2006), and Antietam National Battlefield's General Management Plan all 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 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 proposed 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.

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). Throughout Maryland, there was a documented 63% decline in individual birds of neotropical origin (including forest interior dwelling species [FIDS]) between 1980 and 1989 (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 at least 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 six sites for two years (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 four functional groups that were present in the park, based on the species observations from the 2007 and 2008 avian monitoring in the National Capital Region parks (Goodwin and Shriver 2009). Thus, the park was given a rating of 0%, 25%, 50%, 75%, or 100% attainment.

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

The forest threshold for white-tailed deer density (8.0 deer km⁻² [21 deer mi⁻²]) is a well-established ecological threshold (Horsley et al. 2003), and this threshold is also used as the management threshold (Horsley et al. 2003). Species richness and abundance of herbs and shrubs are consistently reduced as deer densities approach 8.0 km⁻² (21 deer mi⁻²), although shown in some studies to change at densities as low as 3.7 deer km⁻² (9.6 deer mi⁻²; Decalesta 1997). One large manipulation study in central Massachusetts found deer densities of 10–17 km⁻² (26–44 deer mi⁻²) inhibited the regeneration of understory species, while densities of 3–6 deer km⁻² (8–16 deer mi⁻²) supported a diverse and abundant forest understory (Healy 1997). There are multiple sensitive species of songbirds that cannot be found in areas where deer grazing has removed the understory vegetation needed for nesting, foraging and protection. Even though songbird species vary in how sensitive they are to increases in deer populations, these changes generally occur at deer densities greater than 8 deer km⁻² (21 deer mi⁻²; Decalesta 1997). In contrast, the grassland (or agricultural land) management threshold for deer abundance is less well-studied or justified and is used as a guiding management threshold, but is currently 20 deer km⁻² (52 deer mi⁻²). However, studies of national parks within the National Capital Region (Antietam and Monocacy National Battlefields and Cheseapeake and Ohio Canal National Historical Park)

have shown that the current abundances of 45–54 deer km⁻² (117–140 deer mi⁻²) cause significant damage to the agricultural crops maintained as grassland habitat (Stewart et al. 2007). Data used represents biannual 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, which is used as the threshold in this assessment (Arnold and Gibbons, 1996). 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 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. There are 31 species of birds that breed in the Ridge and Valley physiographic province of Maryland that require large blocks of mature interior forest (MD DNR undated). Interior forest

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

Forest connectivity index—ecological

The connectivity of forest resources is an important control on species biodiversity (Franklin 1993). The critical dispersal threshold (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.

3.4.5 Agriculture

All metrics for cropland and pasture habitats were taken from Best Management Practices, defined by the U.S. Department of Agriculture's Natural Resources Conservation Service (2007) to be practices that ensure that no significant amount of pollution conveyed by runoff leaves the farm or enters a water body or groundwater (Table 3.5). Each metric was given a 100% or 0% attainment rating, based on whether or not it was in place/being implemented.

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 Antietam National Battlefield, data were available for four of these six data categories: Air & Climate, Water Resources, Biological Integrity, and Landscape Dynamics.

Data used

A total of 29 metrics across the four ecological monitoring framework categories were included from multiple data sources (Table 3.6), each with an established ecological, management, or regulatory threshold and based on a categorical scoring of threshold attainment (Table 3.7). 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 eight sampling sites for Water Resources metrics within Antietam National Battlefield. 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 3.7). All data used in the assessment was collected between 2000 and 2008 (Table 3.7). 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 Antietam National Battlefield monitoring, and Landscape Dynamics data from a collaborative project between NCRN I&M and the University of Maryland Center for Environmental Science (Table 3.6).

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 3.6). A total of eight sites were monitored for water quality (pH, dissolved oxygen, temperature, salinity, nitrate, phosphate [all 2000–2008], and ANC [2005–2008]) in Antietam National Battlefield—one site monitored by NCRN I&M and seven sites monitored by park staff (Figure 3.7). Four sites were monitored during 2004–2006 by NCRN I&M for the Benthic Index of Biotic Integrity, Physical Habitat Index (both Water Resources metrics), and the Fish Index of Biotic Integrity (a Biological Integrity metric; Figure 3.8).

Forest data (exotic species cover and density, native tree seedling regeneration [both 2006–2007], and presence of pest species [2005–2007]) were collected at four sites, and a route for counting deer density was travelled each year from 2001–2008 (Figure 3.9). 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 (imperious surface [2000] and forest 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. 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 780 measurements (nitrate) during the nine-year period (Table 3.7; Appendix A). These data were compared to thresh-

Table 3.5. Thresholds for Cropland and Pasture metrics.

Metric	Threshold	Justification	Threshold source
Crop rotation	In place (yes/no)	Crop rotation is an accepted Best Management Practice (BMP) for agriculture, to reduce erosion, maintain or improve soil organic matter, manage plant nutrient balance, and manage plant pests.	USDA 2007
Conservation tillage	In place (yes/no)	Conservation tillage is an accepted BMP for agriculture, to reduce erosion, reduce soil particulate emissions, improve soil organic matter, increase plant-available moisture, and reduce CO ₂ losses from the soil.	USDA 2007
Cover crops	In place (yes/no)	Cover crops are an accepted BMP for agriculture, to reduce erosion, capture and recycle excess nutrients in the soil, promote biological nitrogen fixation, reduce soil particulate emissions, improve soil organic matter, minimize soil compaction, increase biodiversity, suppress weeds, and manage soil moisture.	USDA 2007
Nutrient Management Plan	In place (yes/no)	A nutrient management plan (NMP) is a comprehensive plan that describes the optimum use of nutrients to minimize nutrient loss while maintaining yield. A NMP details the type, rate, timing, and placement of nutrients for each crop. Soil, plant tissue, manure and/or sludge tests are used to assure optimal application rates.	Chesapeake Bay Program undated
Soil & Water Conservation Plan	In place (yes/no)	Farm conservation plans are a combination of agronomic, management, and engineered practices that protect and improve soil productivity and water quality, and to prevent deterioration of natural resources on all or part of a farm. Plans may be prepared by staff working in conservation districts, natural resource conservation field offices or a certified private consultant. In all cases the plan must meet technical standards.	Chesapeake Bay Program undated
Crop yield concerns	Yes/no	Crop yield concerns indicate that a crop is not performing to its expected yield. In the context of this assessment, crop yield concerns are most often related to the overabundance of deer grazing.	
Stocking rate	1 animal/2 acres	A general guideline for the Mid-Atlantic region is one animal per acre. This has been conservatively modified by Antietam to be one animal per two acres of pasture.	Maryland Cooperative Extension undated
Alternative water sources	Yes/no	Providing alternative water sources for stock is an accepted BMP for pasturelands, to prevent access by stock to environmentally sensitive areas such as streams and other water sources	USDA 2007
Fenced streams	Yes/no	Fencing streams is an accepted BMP for pasturelands, to prevent access by stock to environmentally sensitive areas such as streams and other water sources	USDA 2007
Deer density (grassland)	< 20 deer km ⁻²	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 3.6. Sources of data used in Antietam National Battlefield 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, ANTI	Norris et al. 2007, Norris and Pieper 2010, ANTI
Dissolved oxygen	NCRN I&M, ANTI	Norris et al. 2007, Norris and Pieper 2010, ANTI
Water temperature	NCRN I&M, ANTI	Norris et al. 2007, Norris and Pieper 2010, ANTI
Acid neutralizing capacity	NCRN I&M	Norris et al. 2007, Norris and Pieper 2010
Salinity	NCRN I&M, ANTI	Norris et al. 2007, Norris and Pieper 2010, ANTI
Nitrate	NCRN I&M, ANTI	Norris et al. 2007, Norris and Pieper 2010, ANTI
Phosphate	NCRN I&M	Norris et al. 2007, Norris and Pieper 2010, ANTI
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
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, ANTI
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

Table 3.7. Summary of data used in Antietam National Battlefield 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	396	2004–2008
Water Resources				
pH	6.5 ≥ pH ≥ 8.5	8	767	2000–2008
Dissolved oxygen (DO)	≥ 5.0 mg DO L ⁻¹	8	751	2000–2008
Water temperature	≤ 23.9°C	8	768	2000–2008
Acid neutralizing capacity	≥ 200 µeq L ⁻¹	1	38	2005–2008
Salinity	< 0.25	8	424	2000–2008
Nitrate (NO ₃)	< 2 mg NO ₃ L ⁻¹	8	780	2000–2008
Phosphate (PO ₄)	< 0.031 mg PO ₄ L ⁻¹	8	765	2000–2008
Benthic index biological integrity (BIBI)	> 3	3	4	2004–2006
Physical habitat index (PHI)	> 81	3	4	2004–2006
Biological Integrity				
Cover of exotic herbaceous species	< 5% (of area)	4	4	2006–2007
Cover of exotic trees and shrubs	< 5% (of total basal area)	4	6	2006–2007
Presence of forest pest species	< 1% of trees infested	4	4	2005–2007
Native tree seedling regeneration	> 35,000 seedlings ha ⁻¹	4	4	2006–2007
Fish index biological integrity (FIBI)	> 3	3	4	2004–2006
Presence of forest interior dwelling species (FIDS) of birds	> 1 highly sensitive FIDS > 4 sensitive FIDS	6	14	2007–2008
Grassland bird diversity	% functional groups found translates directly to % attainment	6	1	2007–2008
Deer density	< 8 deer km ⁻² (forest) < 20 deer km ⁻² (grassland)	Park	15	2001–2008
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

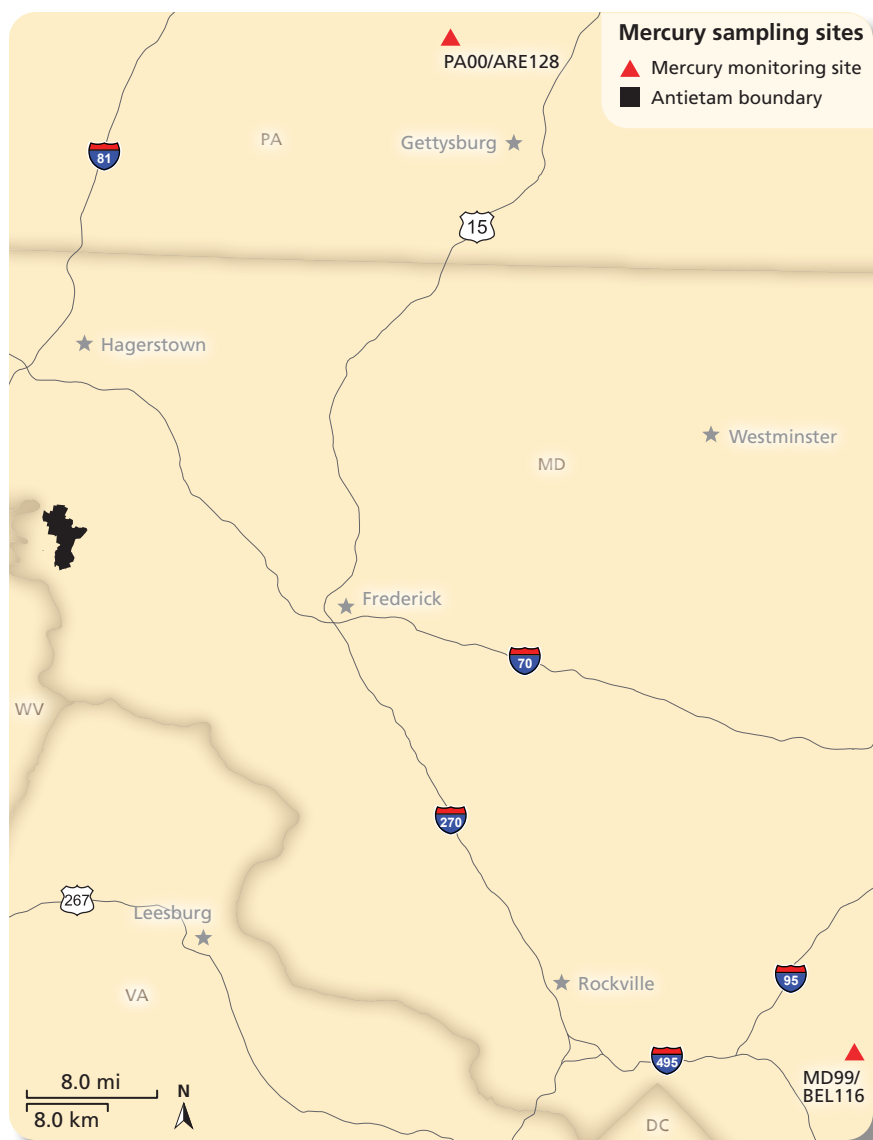


Figure 3.6. Map of sampling stations PA00/ARE128 and MD99/BEL116²⁹ used for measuring mercury concentrations near Antietam National Battlefield.

old 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 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 Antietam National Battlefield. An assessment was made of the whole park by calculating an un-weighted mean of the four category percentage attainment values. For deter-

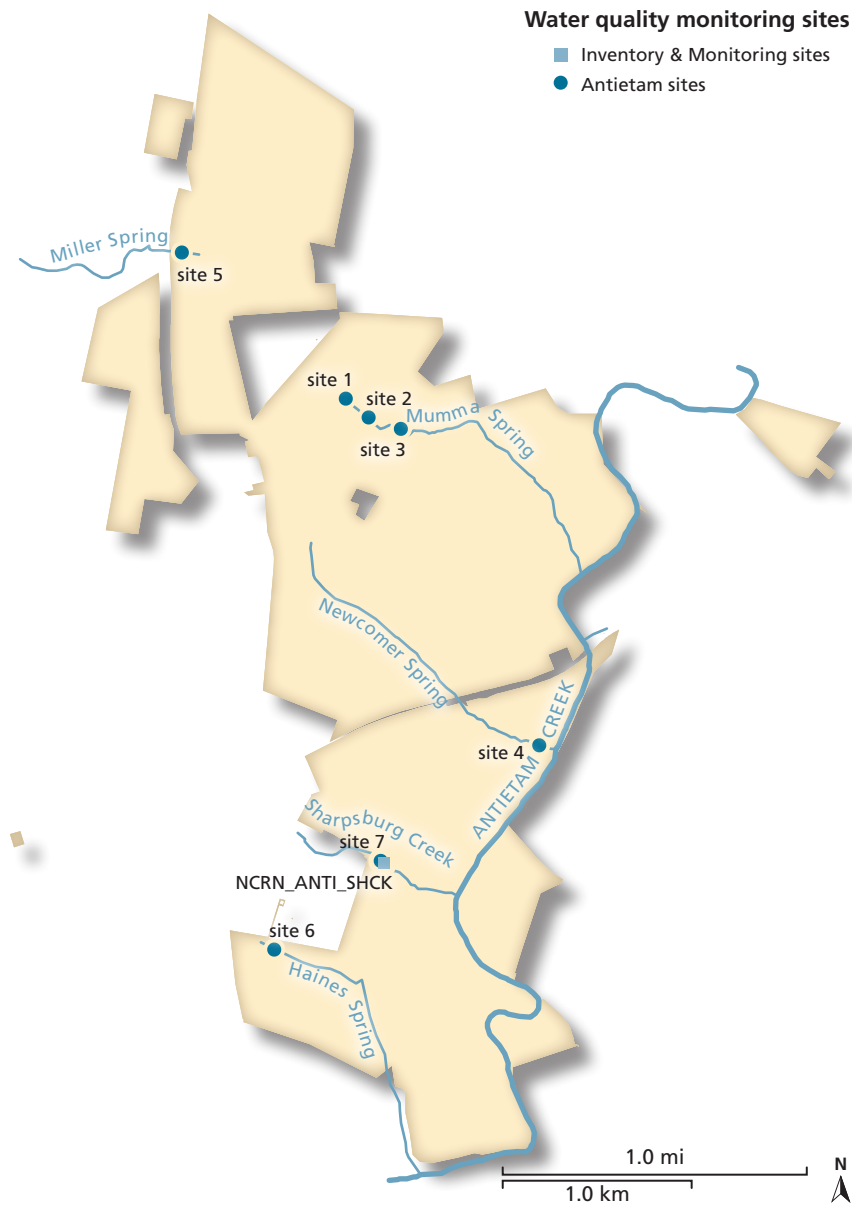
mination of status of metrics, vital sign categories, and the whole park assessment, percentage attainment scores were categorized on a scale from very good to very degraded (Table 3.8).

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 3.9). A total of six general habitat types were identified for Antietam National Battlefield and these were further defined as

29. National Atmospheric Deposition Program: <http://nadp.sws.uiuc.edu/>; Mercury Deposition Network: <http://nadp.sws.uiuc.edu/mdn>

Figure 3.7. Stream sampling locations³⁰ used for long-term water quality monitoring at Antietam National Battlefield.



being either managed for natural resource values (forests, wetlands and waterways, warm-season grasslands) or managed for agricultural values (croplands, pastures, and developed lands) (Figures 3.1, 3.3, 3.4).

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 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.

30. Norris et al. 2007, ANTI.



Figure 3.8. Stream sampling locations³¹ monitored for BIBI, FIBI, and PHI.

To provide a basis for condition assessment for each habitat, the desired versus degraded extremes were conceptually described (Figures 3.3, 3.4) based on a series of 32 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 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 frame-

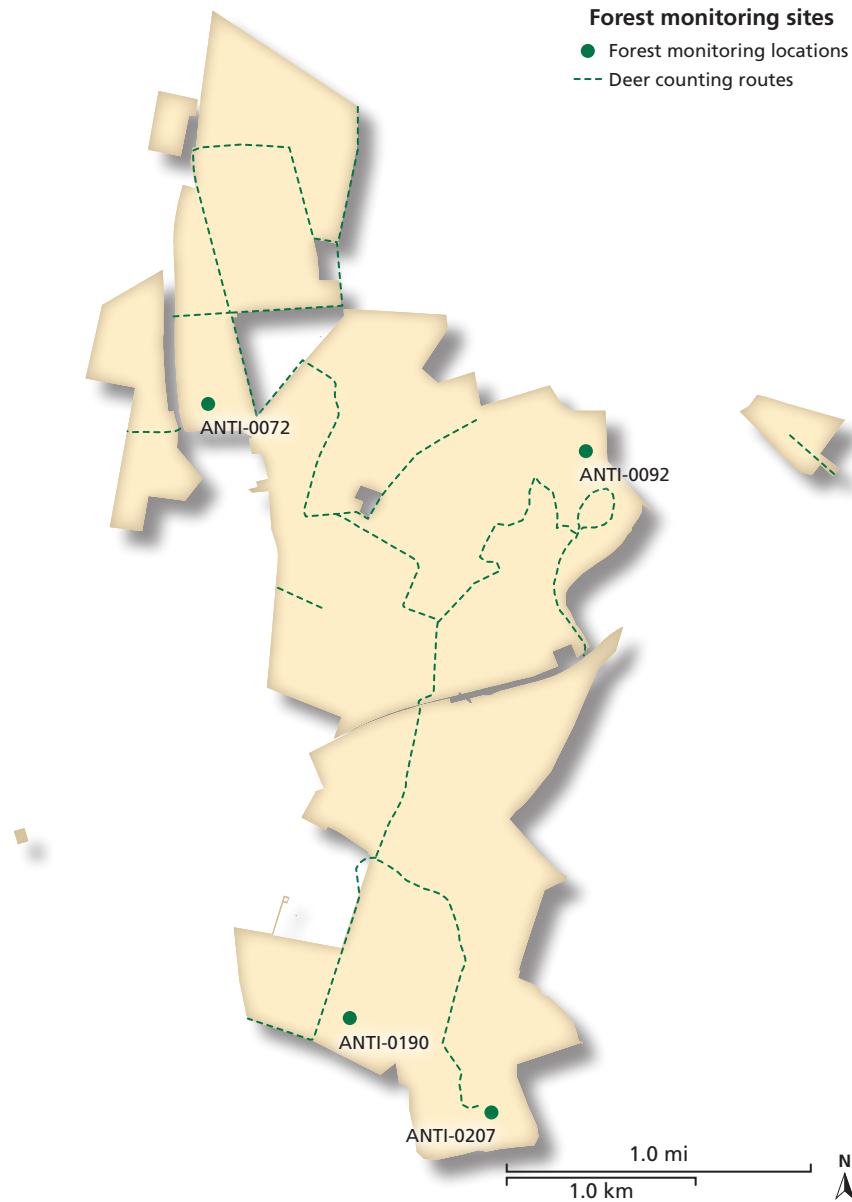
work, so the the threshold justifications are presented in Tables 3.1, 3.2, 3.3, 3.4, and 3.5 and the sources of all data are presented in Table 3.6. Justification for the inclusion of metrics as relevant to a particular habitat assessment is provided below.

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 Antietam National Battlefield was calculated as an un-weighted mean of the attainment scores for the

31. NCRN I&M, ANTI.

Figure 3.9. Forest monitoring sites and deer counting routes³² in Antietam National Battlefield.



metrics used to assess the condition of that particular habitat (Tables 3.10, 3.11). 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 3.12). 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 3.8).

Of the 773 ha (1,910 acres)³³ within the fee boundary of Antietam National Battlefield

used in this assessment, 190 ha (470 acres) were designated as habitats that are managed for natural resource values (forests: 149 ha [368 acres]; wetlands and waterways: 18 ha [44 acres]; and warm-season grasslands: 23 ha [58 acres]; Table 3.12). 518 ha (1,280 acres) were designated as habitats that are managed for agricultural values (croplands: 387 ha [957 acres]; and pastures: 131 ha [323 acres], bringing the total area assessed to 708 ha (1,750 acres). The remaining 65 ha (160 acres) were classified as developed lands and were not assessed.

32. NCRN I&M, ANTI.

33. Note: this area differs from the official fee area of 1,937 acres due to irreconcilable mapping resolution issues.

Table 3.8. 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

Table 3.9. 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	

Table 3.10. Summary of data used in Antietam National Battlefield 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)	4	4	2006–2007
Cover of exotic trees and shrubs	< 5% (of total basal area)	4	6	2006–2007
Presence of forest pest species	< 1% of trees infested	4	4	2005–2007
Native tree seedling regeneration	> 35,000 seedlings ha ⁻¹	4	4	2006–2007
Presence of forest interior dwelling species (FIDS) of birds	> 1 highly sensitive FIDS > 4 sensitive FIDS	6	14	2007–2008
Deer density (forest)	< 8 deer km ⁻² (forest)	Park	15	2001–2008
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	8	767	2000–2008
Dissolved oxygen (DO)	≥ 5.0 mg DO L ⁻¹	8	751	2000–2008
Water temperature	≤ 23.9°C	8	768	2000–2008
Acid neutralizing capacity	≥ 200 µeq L ⁻¹	1	38	2005–2008
Salinity	< 0.25	8	424	2000–2008
Nitrate (NO ₃)	< 2 mg NO ₃ L ⁻¹	8	780	2000–2008
Phosphate (PO ₄)	< 0.031 mg PO ₄ L ⁻¹	8	765	2000–2008
Benthic index biological integrity (BIBI)	> 3	3	4	2004–2006
Fish index biological integrity (FIBI)	> 3	3	4	2004–2006
Physical habitat index (PHI)	> 81	3	4	2004–2006
Grasslands (warm-season)				
Deer density (grassland)	< 20 deer km ⁻² (grassland)	Park	15	2001–2008
Impervious surface (within park)	10%	Park	1	2000
Grassland bird diversity	% functional groups found translates directly to % attainment	6	1	2007–2008
Grassland interior area	% of total grassland area translates to % attainment	Park	1	2008
Contiguous grassland area	≥ 10 ha	Park	1	2008

Table 3.11. Summary of data used in Antietam National Battlefield habitat-based condition assessment of habitats managed for agricultural values.

Metric	Threshold	Sites	Samples	Period
Croplands				
Crop rotation	In place (yes/no)	Park	1	2010
Crop varieties for IPM	In place (yes/no)	Park	1	2010
Conservation tillage	In place (yes/no)	Park	1	2010
Cover crops	In place (yes/no)	Park	1	2010
Nutrient Management Plan	In place (yes/no)	Park	1	2010
Soil & Water Conservation Plan	In place (yes/no)	Park	1	2010
Crop yield concerns	Yes/no	Park	1	2010
Deer density (grassland)	< 20 deer km ⁻²	Park	8	2001–2008
Pastures				
Stocking rate	1 animal / 2 acres	Park	1	2010
Protected water sources	Yes/no	Park	1	2010
Fenced streams	Yes/no	Park	1	2010
Nutrient Management Plan	In place (yes/no)	Park	1	2010
Soil & Water Conservation Plan	In place (yes/no)	Park	1	2010
Deer density (grassland)	< 20 deer km ⁻²	Park	8	2001–2008

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Table 3.12. Area of each habitat type assessed in Antietam National Battlefield. Developed lands make up another 65 ha (160 acres) but were not assessed.

Habitat	Area (ha)	Area (acres)	% of area assessed
Habitats managed for natural resource values			
Forests	149	368	21%
Wetlands and waterways	18	44	3%
Warm-season grasslands	23	58	3%
Total	190	470	27%

Habitat	Area (ha)	Area (acres)	% of area assessed
Habitats managed for agricultural values			
Croplands	387	957	55%
Pastures	131	323	18%
Total	518	1,280	73%

TOTAL AREA ASSESSED 708 ha (1,750 acres)

3.6 LITERATURE CITED (CHAPTER 3)

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Chapter 4: Natural resource conditions

4.1 REGIONAL/LANDSCAPE CONTEXT

As detailed in Section 2.1.2—*Resource management issues overview*, Antietam National Battlefield 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 (Figures 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 Antietam National Battlefield, 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 22 metrics measuring the condition of forest, wetland and waterway, and warm-season grassland habitats, these ‘managed for natural resource values’ habitats were assessed to be in fair condition (53% attainment of threshold condition; Table 4.1). Synthesizing 12 metrics measuring the condition of cropland and pasture habitats, these ‘managed for agricultural values’ habitats were assessed as being in good condition (69% attainment of threshold condition; Table 4.2). Pasture was in very good condition, croplands were assessed as good, forests and wetlands and waterways were in fair condition, and warm-season grasslands were assessed as poor. Overall, the habitats of Antietam National Battlefield were assessed as being in good condition, with 69% attainment of threshold condition (Table 4.3). These results are synthesized in Figure 4.4.



Forests

Forest habitat within Antietam National Battlefield was assessed as being in fair condition, attaining desired condition in 57% of the 50 measurements across all nine metrics, collected between 2000 and 2008 (Tables 3.10, 4.1). Presence of forest pest species, forest interior dwelling bird species, percent impervious surface (Figure 4.5), and forest connectivity (Figure 4.6) within the park all scored as very good (100% attainment), as did exotic tree/shrub density (83% attainment). Cover of exotic herbaceous species scored as degraded (25% attainment) and the remaining metrics (forest interior area [Figure 4.7], native tree seedling regeneration, and deer density) were very degraded, with 4%, 0%, and 0% attainment of desired condition, respectively.

Wetlands and waterways

Wetlands and waterways habitat within Antietam National Battlefield was assessed as being in fair condition, attaining desired condition in 43% of 4,305 measurements across all 10 metrics, collected between 2004 and 2008 (Tables 3.10, 4.1). Water temperature (100% attainment; Figure 4.8), acid neutralizing capacity (100% attainment; Figure 4.9), dissolved oxygen (91% attainment; Figure 4.10), and pH (86%;

The Sherrick Farm trail.

Figure 4.1. Total wet deposition of nitrate (NO_3^-) and ammonium (NH_4^+) (kg ha^{-1}) for the continental United States in 2009.³⁴

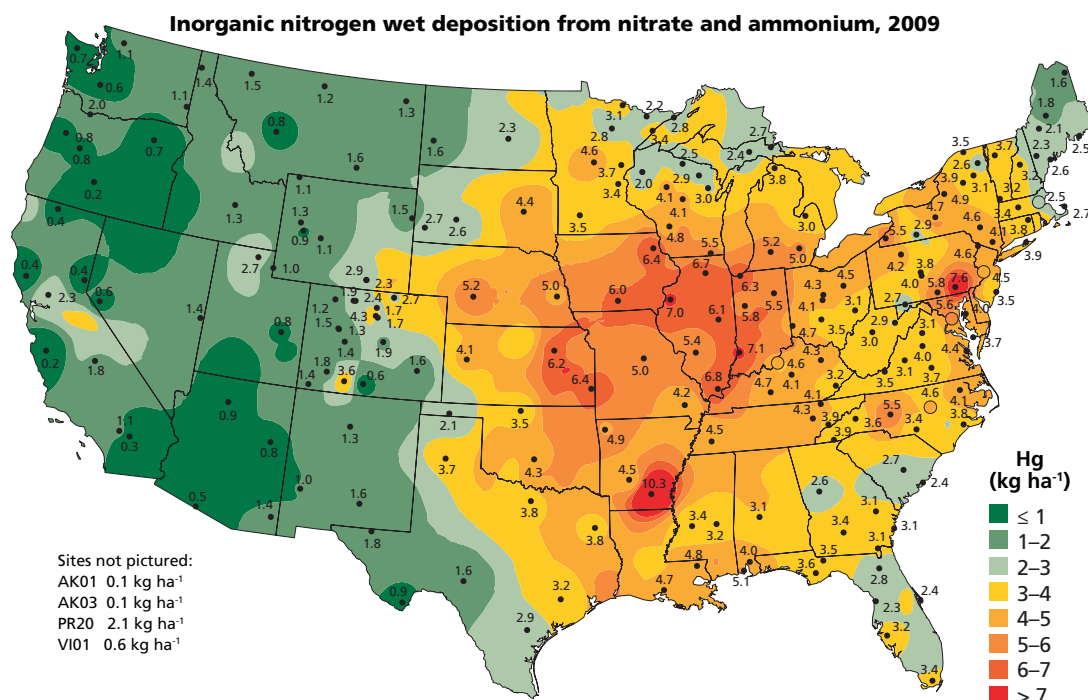
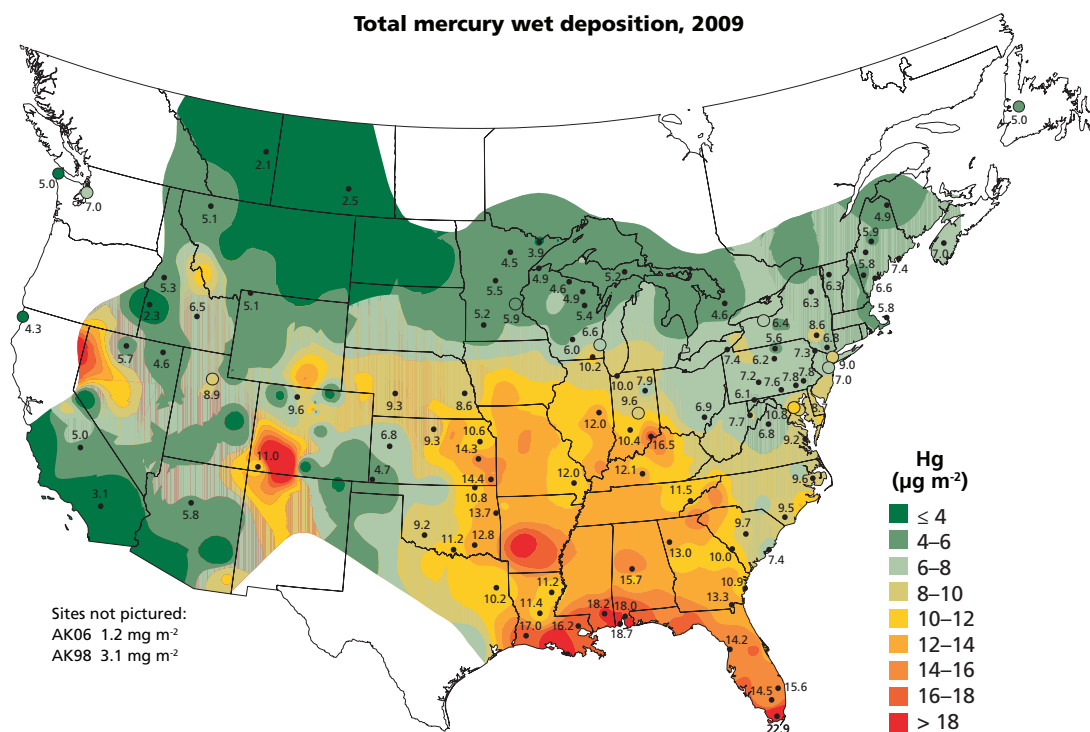


Figure 4.2. Total wet mercury (Hg) deposition ($\mu\text{g m}^{-2}$) for the continental United States in 2009.³⁵



34. National Atmospheric Deposition Program/National Trends Network <http://nadp.sws.uiuc.edu>

35. National Atmospheric Deposition Program/Mercury Deposition Network <http://nadp.sws.uiuc.edu>

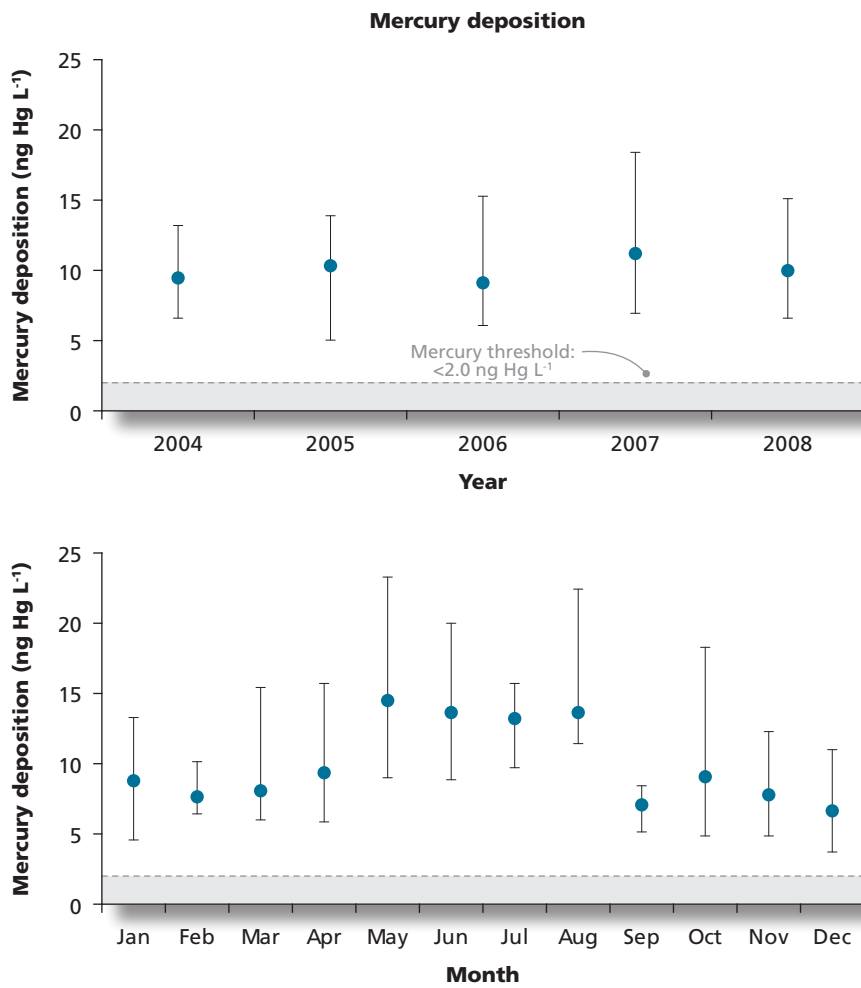


Figure 4.3. Mean monthly mercury deposition (ng Hg L⁻¹) from 2004 to 2007 at sites PA00 and MD99 (see Figure 3.6).³⁶ Acceptable range (Hg ≤ 2 ng L⁻¹) is shown in gray.

36. Mercury Deposition Network, <http://nadp.sws.uiuc.edu/mdn>

Table 4.1. Summary of habitat-based resource condition assessment of Antietam National Battlefield for habitats that are managed for natural resource values. Park score is area-weighted average, based on the area of each habitat (see Table 3.12).

Categories and metrics	Mean	Attainment of threshold condition		
		Metric %	Category %	Park %
Forests				
Cover of exotic herbaceous species	16.5%	25		53
Cover of exotic trees and shrubs	2.7%	83		
Presence of forest pest species	0%	100		
Native tree seedling regeneration	4,375 seedlings ha ⁻¹	0		
Presence of forest interior dwelling species (FIDS) of birds	2 highly sensitive 5 sensitive	100	57	
Deer density (forest)	37.3 deer km ⁻²	0		
Impervious surface (within park)	1.07%	100		
Forest interior area	3%	4		
Forest connectivity (Dcrit; within park)	350 m	100		
Wetlands & waterways				
pH	7.5	-86		53
Dissolved oxygen (DO)	8.6 mg DO L ⁻¹	91		
Water temperature	13.6 °C	100		
Acid neutralizing capacity	4,445 µeq L ⁻¹	100		
Salinity	0.3	8		
Nitrate (NO ₃)	5.3 mg NO ₃ L ⁻¹	11	43	
Phosphate (PO ₄)	0.298 mg PO ₄ L ⁻¹	3		
Benthic index biological integrity (BIBI)	1.9	0		
Fish index biological integrity (FIBI)	2.8	33		
Physical habitat index (PHI)	60.6	0		
Grasslands (warm-season)				
Deer density	37.3 deer km ⁻²	0		53
Impervious surface (within park)	1.07%	100		
Grassland bird diversity	25%	25	36	
Grassland interior area	3%	5		
Contiguous grassland area	15.8 ha	50		

Table 4.2. Summary of habitat-based resource condition assessment of Antietam National Battlefield for habitats that are managed for agricultural values. Park score is area-weighted average, based on the area of each habitat (see Table 3.12).

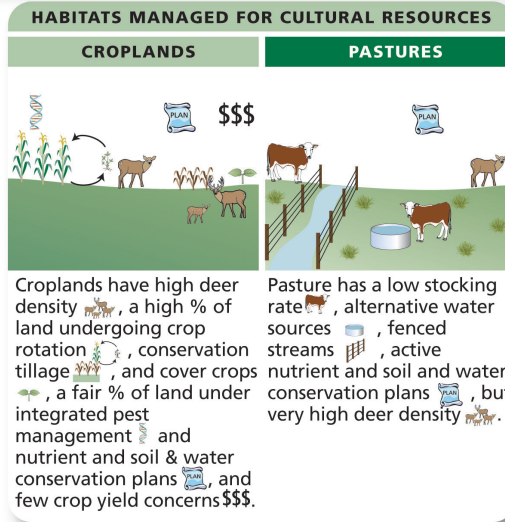
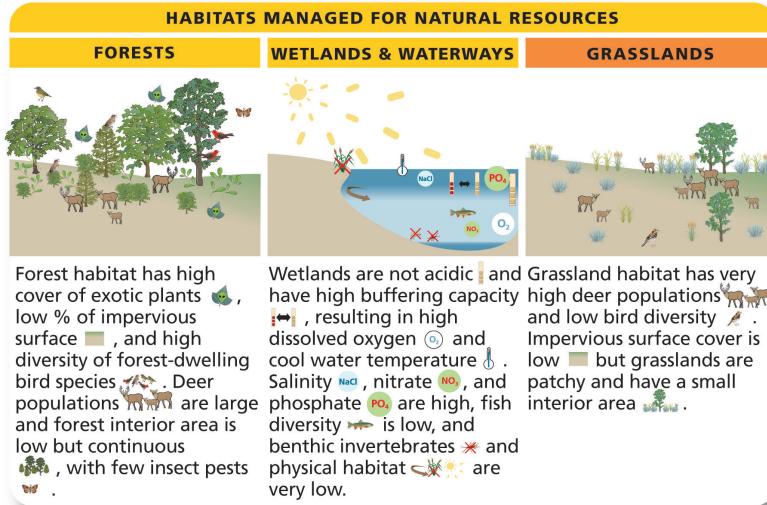
Categories and metrics	Mean	Attainment of threshold condition		
		Metric %	Category %	Park %
Croplands				
Crop rotation		82		69
Crop varieties for IPM		54		
Conservation tillage		91		
Cover crops		100	65	
Nutrient Management Plan		99		
Soil & Water Conservation Plan		73		
Crop yield concerns		18		
Deer density	37.3 deer km ⁻²	0		
Pastures				
Stocking rate		100		81
Water source		100		
Fenced streams		100		
Nutrient Management Plan		100		
Soil & Water Conservation Plan		86		
Deer density (grassland)	37.3 deer km ⁻²	0		

Table 4.3. Area-weighted results of habitat-based resource condition assessment of Antietam National Battlefield.

Habitat	Area (ha)	Score (%)	Area-weighted score (%)
Forests	149	57	65
Wetlands and waterways	18	43	
Warm-season grasslands	23	36	
Croplands	387	65	
Pastures	131	81	

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

HABITAT-BASED NATURAL RESOURCE CONDITION ASSESSMENT OF ANTIETAM NATIONAL BATTLEFIELD



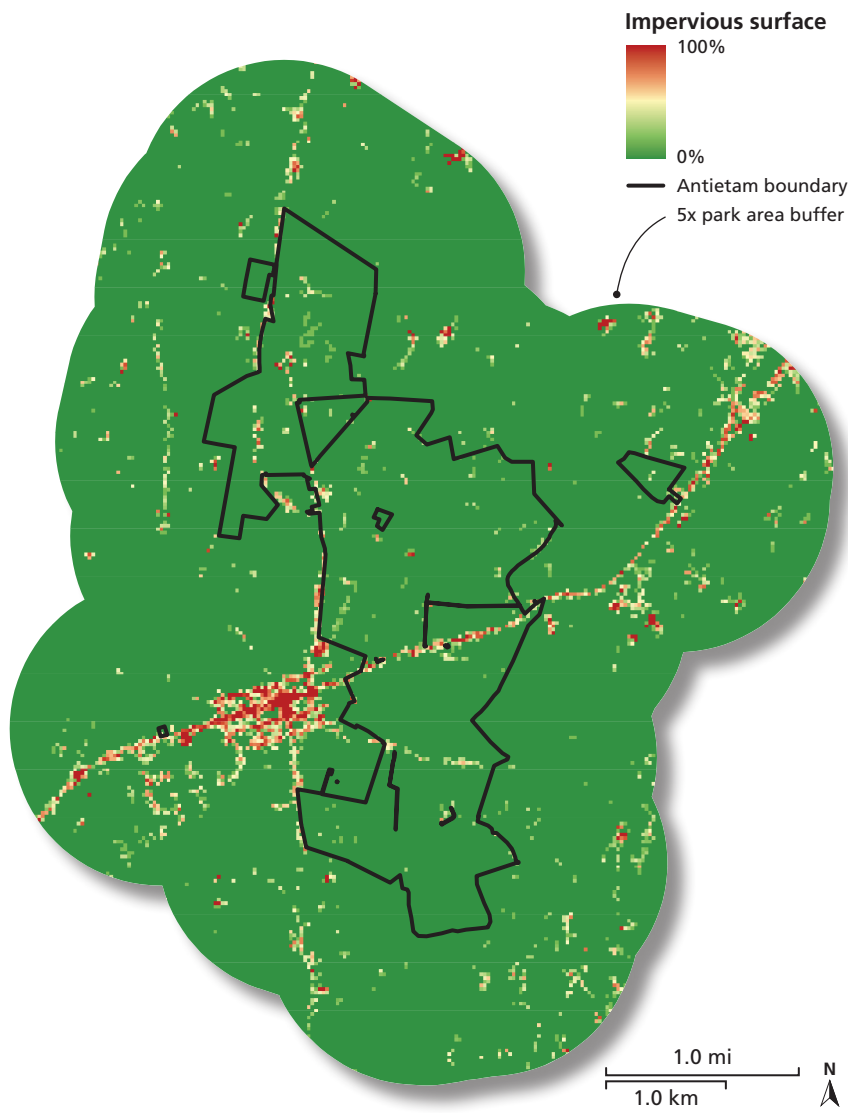
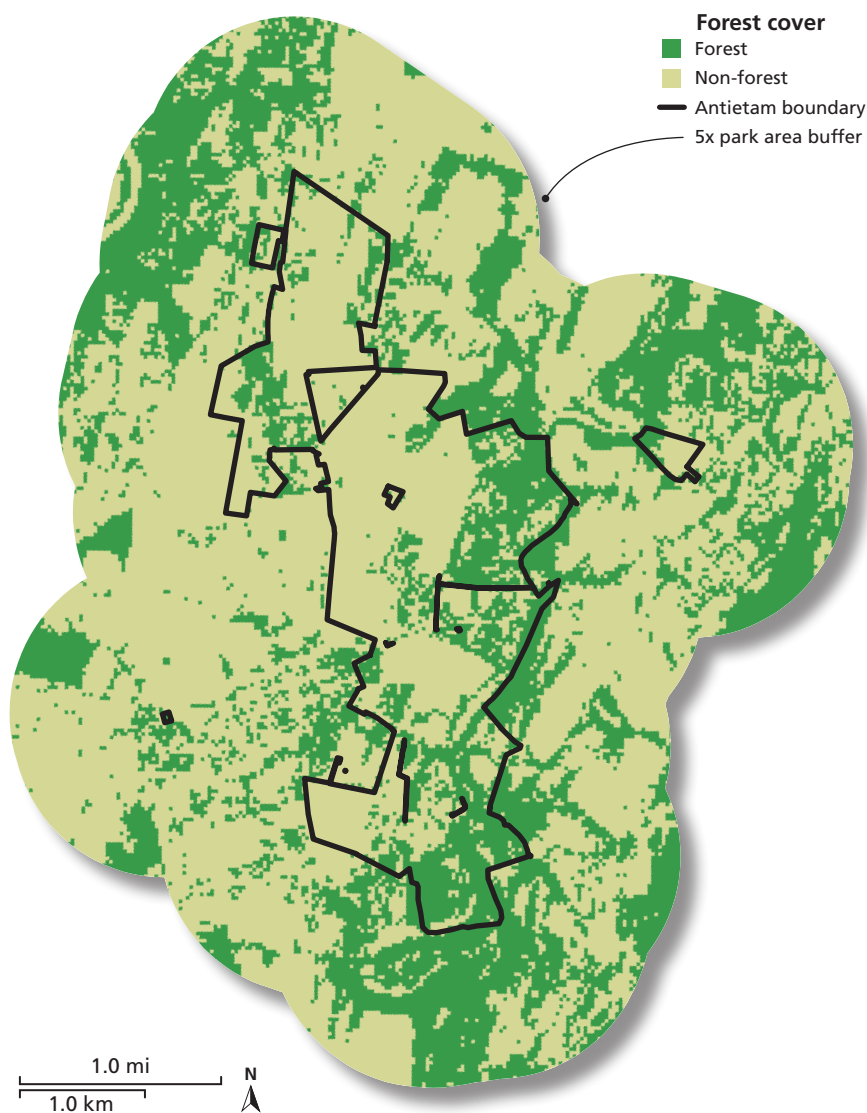


Figure 4.5. GIS data layer showing percent impervious surface in 2000 within and around Antietam National Battlefield.³⁷ The 5x area buffer is an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary.

37. NCRN I&M.

Figure 4.6. Extent of forest and non-forest landcover (Landsat 30-m) within and around Antietam National Battlefield in 2000.³⁸

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.



38. Townsend et al. 2006.

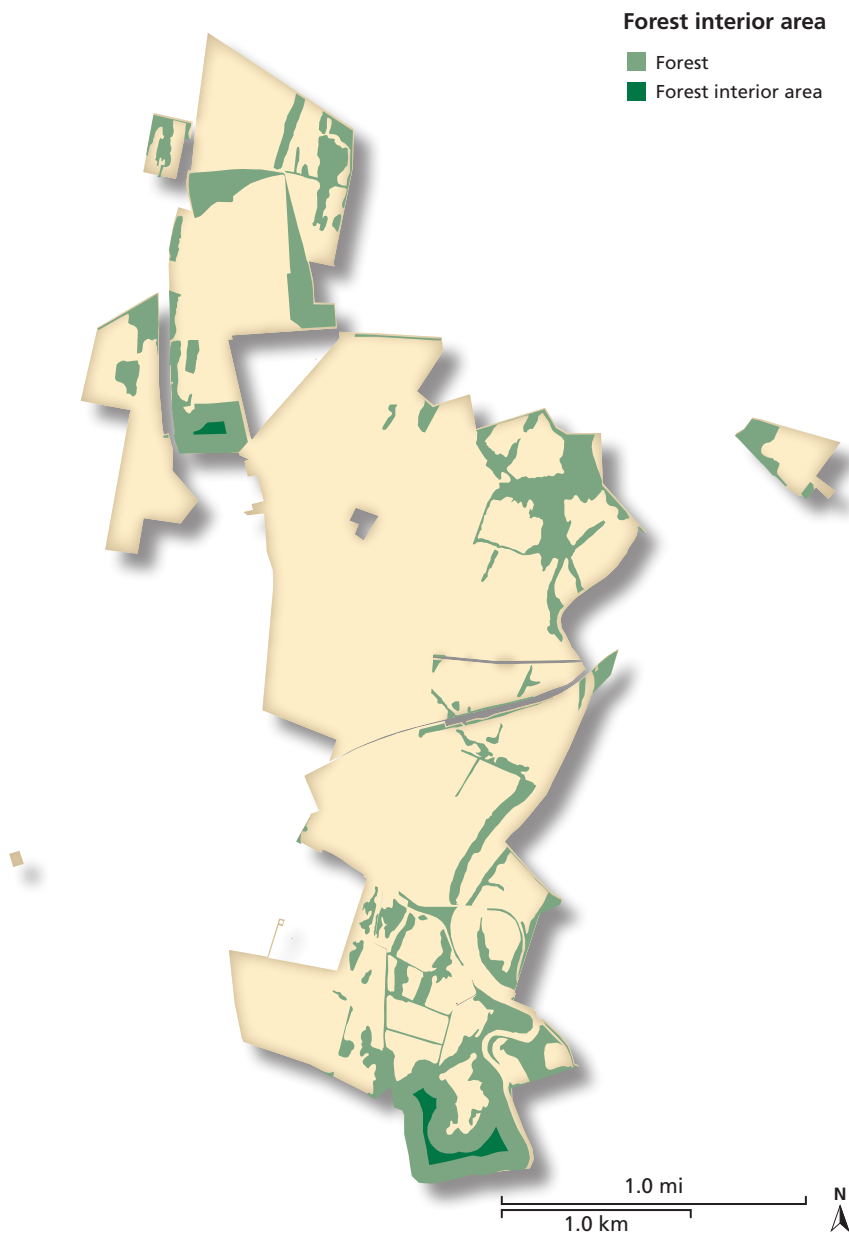
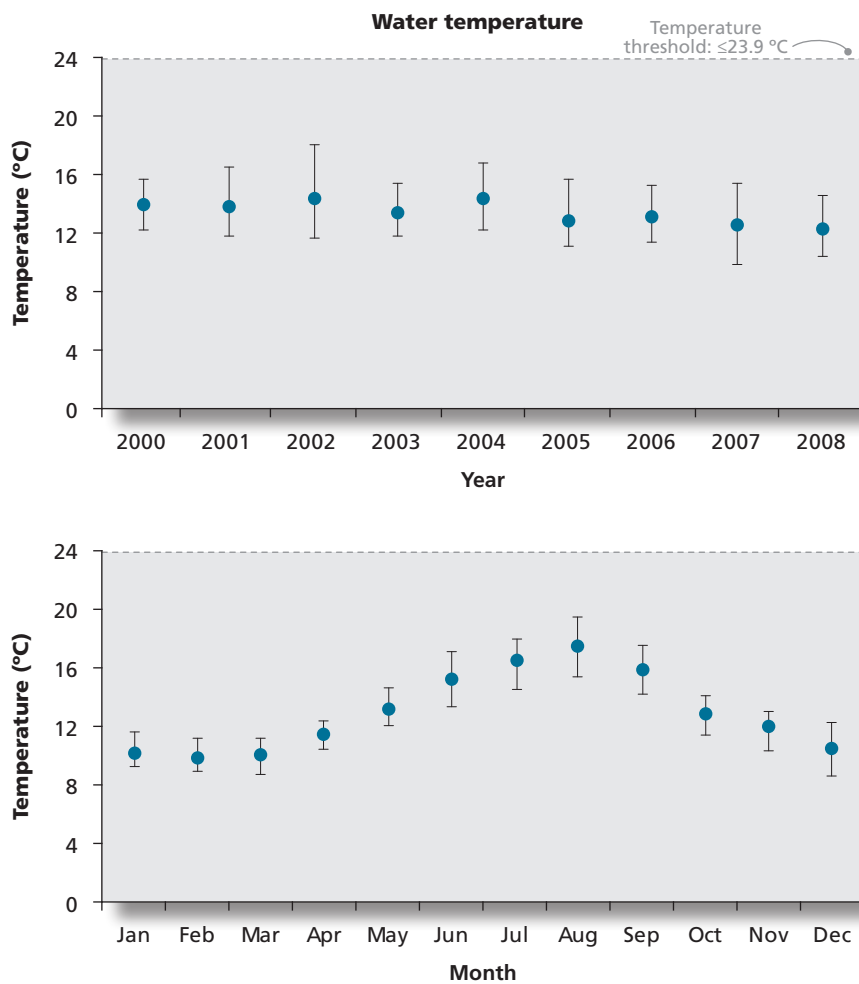


Figure 4.7. Forest area and forest interior area in Antietam National Battlefield.³⁹ Forest interior area is defined as forested land cover ≥ 100 m from non-forest land cover or from primary, secondary, or county roads.

39. NCRN I&M, ANTI.

Figure 4.8. Median, 1st quartile, and 3rd quartile water temperature (°C) from 2000 to 2008 for eight stream sampling locations (see Figure 3.7) in Antietam National Battlefield.⁴⁰ Acceptable range (temp. ≤ 23.9°C) is shown in gray.



40. Norris et al. 2007, ANTI.

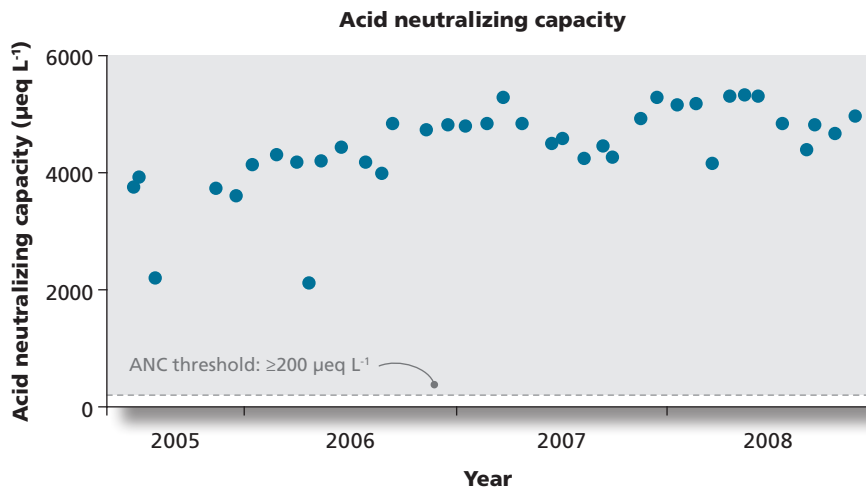


Figure 4.9. Acid neutralizing capacity (ANC; $\mu\text{eq L}^{-1}$) from 2005 to 2008 for one stream sampling location (NCRN_ANTI_SHCK; see Figure 3.7) in Antietam National Battlefield.⁴¹ Acceptable range ($\text{ANC} \geq 200 \mu\text{eq L}^{-1}$) is shown in gray.

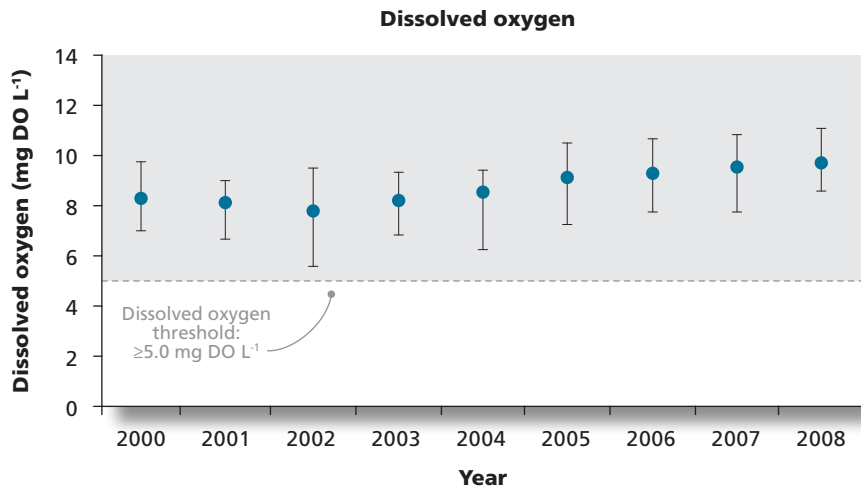
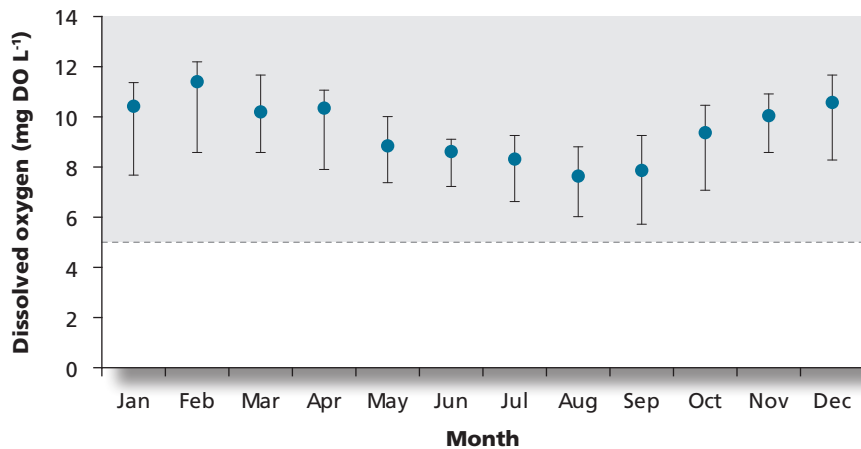


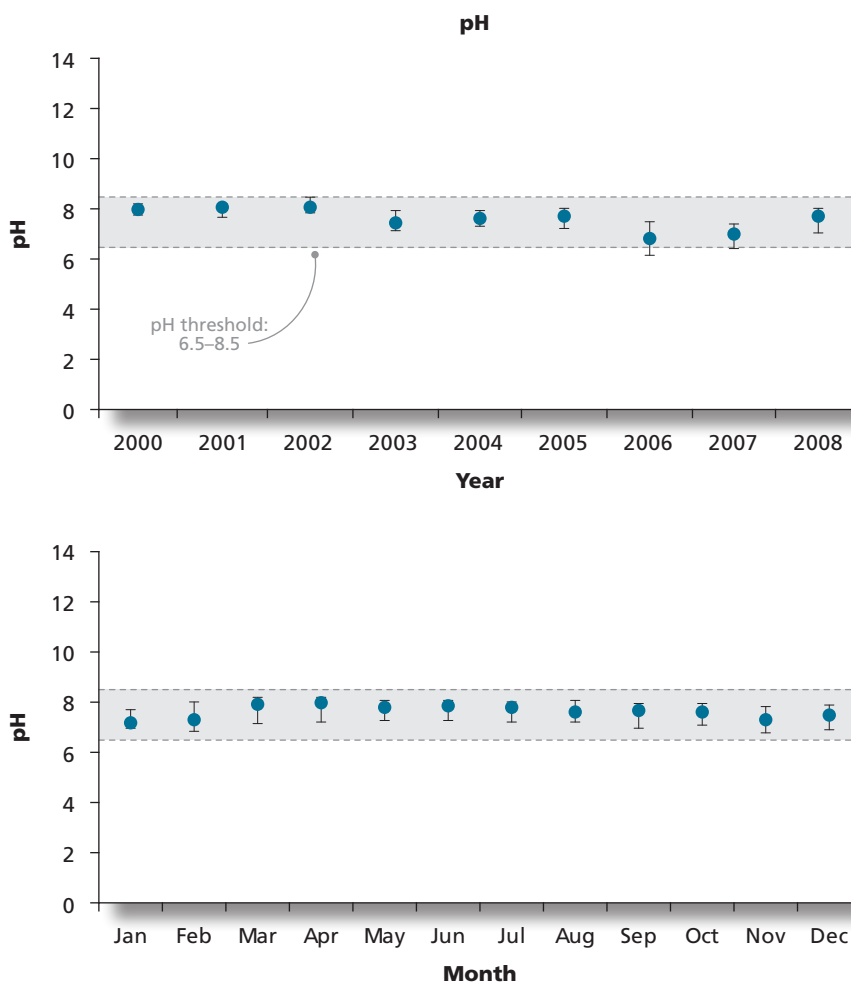
Figure 4.10. Median, 1st quartile, and 3rd quartile dissolved oxygen concentration (mg DO L^{-1}) from 2000 to 2008 for eight stream sampling locations in Antietam National Battlefield (see Figure 3.7).⁴² Acceptable range ($\text{DO} \geq 5.0 \text{ mg L}^{-1}$) is shown in gray.



41. Norris et al. 2007.

42. Norris et al. 2007, ANTI.

Figure 4.11. Median, 1st quartile, and 3rd quartile pH values from 2000 to 2008 for eight stream sampling locations (see Figure 3.7) in Antietam National Battlefield.⁴³ Acceptable ranges ($6.5 \leq \text{pH} \leq 8.5$) are shown in gray.



43. Norris et al. 2007, ANTI.

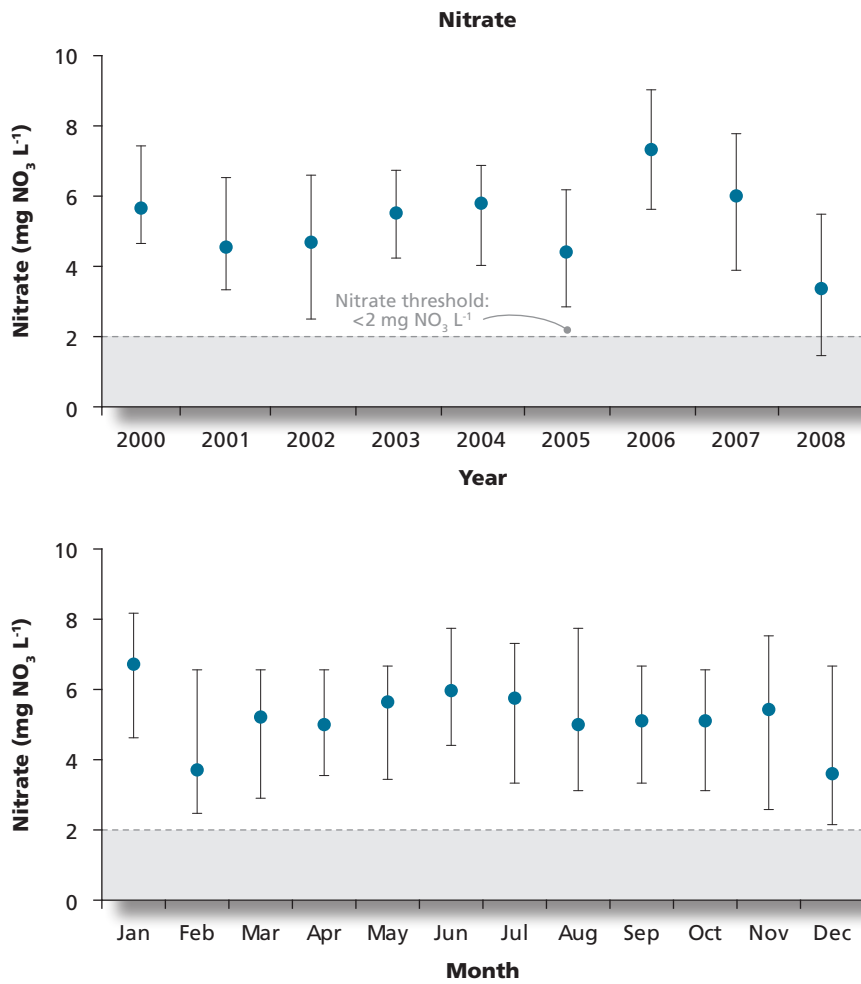


Figure 4.12. Median, 1st quartile, and 3rd quartile nitrate concentration (mg NO₃ L⁻¹) from 2000–2008 for eight stream sampling locations (see Figure 3.7) in Antietam National Battlefield.⁴⁴ Acceptable range (NO₃ ≤ 2.0 mg L⁻¹) is shown in gray.

44. Norris et al. 2007, ANTI.

Figure 4.13. Median, 1st quartile, and 3rd quartile monthly salinity concentration from 2005–2008 for eight stream sampling locations (see Figure 3.7) in Antietam National Battlefield.⁴⁵ Acceptable range (salinity ≤ 0.25) is shown in gray.

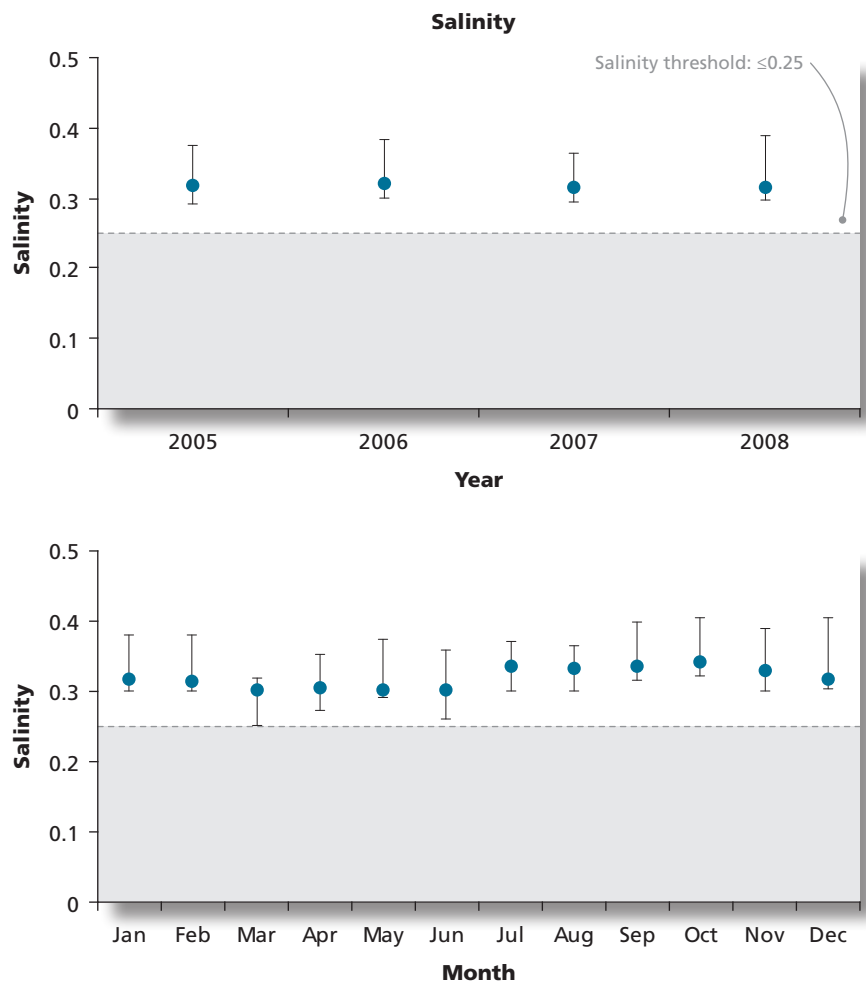


Figure 4.11) were in very good (desired) condition. Stream fish were in degraded condition (33% attainment). The remaining metrics—nitrate (11% attainment; Figure 4.12), salinity (8% attainment; Figure 4.13), phosphate (3% attainment; Figure 4.14), Physical Habitat Index (0% attainment), and the Benthic Index of Biotic Integrity (0% attainment) were in very degraded condition.

Grasslands (warm-season)

Warm-season grasslands in Antietam National Battlefield were assessed as being in degraded condition overall, attaining desired condition in 36% of 19 measurements across five metrics, collected between 2000 and 2008 (Tables 3.10, 4.1). Impervious surface cover within the park was well below the desired threshold of 10% (Figure 4.5). Contiguous grassland area was assessed as fair (50% attainment) while grassland bird diversity was degraded (25% attainment).

Grassland interior area (5% attainment; Figure 4.15) and deer density (0% attainment) were very degraded.

Croplands

Cropland in Antietam National Battlefield was assessed as being in good condition, with 65% attainment of desired condition across eight metrics (Tables 3.11, 4.2). Best management practices (BMPs) are widely implemented on agricultural lands within the park, with cover crops (100% attainment), Nutrient Management Plans (99% attainment), conservation tillage (91% attainment), and crop rotation (82% attainment) were all assessed as being in very good condition. Existence of Soil and Water Conservation Plans was in good condition (73% attainment), use of crop varieties for integrated pest management was fair (54% attainment), while crop yield concerns (18% attainment) and deer density (0% attainment) were in very degraded condition.

45. Norris et al. 2007, ANTI.

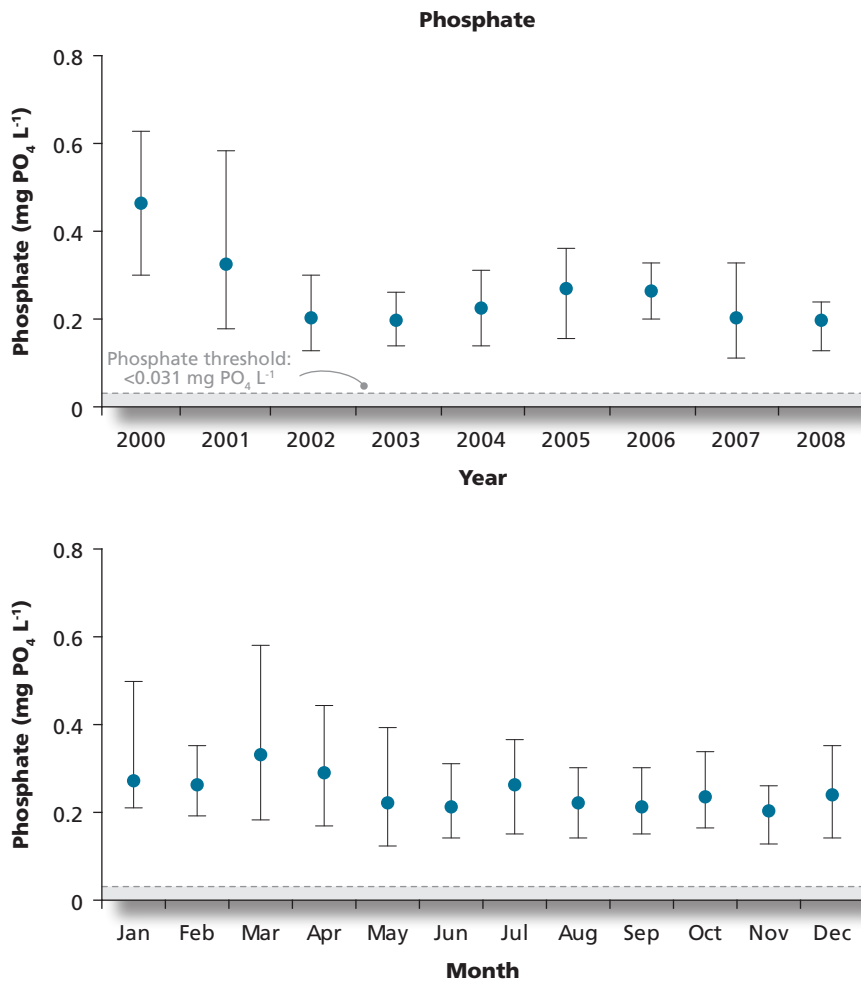


Figure 4.14. Median, 1st quartile, and 3rd quartile phosphate concentrations (mg PO₄ L⁻¹) from 2000 to 2008 for eight stream sampling locations (see Figure 3.7) for Antietam National Battlefield.⁴⁶ Acceptable range (PO₄ < 0.031 mg L⁻¹) is also shown in gray.

46. Norris et al. 2007, ANTI.

Figure 4.15. Grassland area and grassland interior area in Antietam National Battlefield.⁴⁷ Grassland interior area is defined as grassland ≥ 60 m from other land uses.



Pastures

Pasture lands in Antietam National Battlefield was assessed as being in very good condition, with 81% attainment of desired condition across six metrics (Tables 3.11, 4.2). BMPs are widely implemented on pastured lands in the park, with animal stocking rate (100% attainment), alternative water sources (100% attainment), fenced streams (100% attainment), Nutrient Management Plans (100% attainment), and Soil and Water Conservation Plans (86% attainment) all in very good condition. Deer density was in very degraded condition, with 0% attainment of desired condition.

4.3 PARK-WIDE CONDITIONS

4.3.1 Ecological monitoring framework

Using an ecological monitoring framework to synthesize 29 metrics measuring the condition of Air & Climate, Water Resources, Biological Integrity, and Landscape Dynamics, natural resources within Antietam National Battlefield were assessed to be in a degraded condition (39% attainment of threshold condition; Tables 3.7, 4.4). Air & Climate were in a very degraded condition, while Landscape Dynamics were in good condition and Water Resources and Bio-

47. NCRN I&M, ANTI.

logical Integrity were assessed as being in fair condition.

Air & Climate

Using the interpolated results from NPS Air Resources Division and mercury monitoring data, Air & Climate in Antietam National Battlefield were measured to be in a very degraded condition (0% attainment of threshold condition; Table 4.4). 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 3.7).

Water Resources

Water Resources within Antietam National Battlefield were assessed as being in fair condition, attaining desired condition in 44% of the 4,301 measurements across all nine metrics, collected between 2000 and 2008 (Tables 3.7, 4.4). Water temperature (100% attainment; Figure 4.8), acid neutralizing capacity (100% attainment; Figure 4.9), dissolved oxygen (91% attainment; Figure 4.10), and pH (86% attainment; Figure 4.11) were all in very good condition, with high attainment of desired conditions. In contrast, several metrics were in very degraded condition—nitrate (11% attainment; Figure 4.12), salinity (8% attainment; Figure 4.13), phosphate (3% attainment; Figure 4.14), Physical Habitat Index (0% attainment), and the Benthic Index of Biotic Integrity (0% attainment) were all very degraded.

Biological Integrity

Biological Integrity within Antietam National Battlefield attained desired threshold condition in 46% of 52 measures over eight metrics, resulting in an assessment of degraded condition (Tables 3.7, 4.4). Exotic tree and shrub density and presence of forest pest species were low (83% and 100% attainment of threshold, respectively), and presence of forest interior bird species was high (100%), resulting in very good condition for those three metrics. Fish communities (33% attainment), cover of exotic herbaceous species, and grassland bird diversity (both 25% attainment) were all degraded. Native tree seedling regeneration was very low (0% attainment) and

deer density was extremely high (0% attainment), with 37 deer km⁻² (96 deer mi⁻²) compared to the threshold of 8 deer km⁻² (21 deer mi⁻²; forest) and 20 deer km⁻² (52 deer mi⁻²; grassland), resulting in a very degraded assessment for these two metrics.

Landscape Dynamics

Landscape Dynamics were assessed both within and just surrounding Antietam National Battlefield, and overall were in good condition, attaining desired threshold condition in 66% of seven measurements over the seven metrics (Tables 3.7, 4.4). Percentage of impervious surface both within and surrounding the park was acceptably low and well below the threshold of 10% impervious cover (Figure 4.5). The forest that is present is well connected and so attained desired condition for forest connectivity (Figure 4.6); however, the proportion of forest interior area was very low (4% of potential forest interior area; Figure 4.7), as was grassland interior area (5% of potential grassland interior area; Figure 4.15).

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/nrcr/pdfs/nrm_booklet.pdf

Table 4.4. Summary resource condition assessment for Antietam National Battlefield by metric categories.

Categories and metrics	Mean	Attainment of threshold condition		
		Metric %	Category %	Park %
Air & Climate				
Ozone	0.078 ppm	0		
Wet nitrogen deposition	4.6 kg N ha ⁻¹ yr ⁻¹	0		
Wet sulfur deposition	5.8 kg S ha ⁻¹ yr ⁻¹	0	0	
Visibility	13.75 dv	0		
Hg deposition	13.1 ng Hg L ⁻¹	0		
Water Resources				
pH	7.5	86		
Dissolved oxygen (DO)	8.6 mg DO L ⁻¹	91		
Water temperature	13.6 °C	100		
Acid neutralizing capacity	4,445 µeq L ⁻¹	100		
Salinity	0.3	8	44	
Nitrate (NO ₃)	5.3 mg NO ₃ L ⁻¹	11		
Phosphate (PO ₄)	0.298 mg PO ₄ L ⁻¹	3		
Benthic index biological integrity (BIBI)	1.9	0		
Physical habitat index (PHI)	60.6	0		
Biological Integrity				
Cover of exotic herbaceous species	16.5%	25		39
Cover of exotic trees and shrubs	2.7%	83		
Presence of forest pest species	0%	100		
Native tree seedling regeneration	4,375 seedlings ha ⁻¹	0		
Fish index biological integrity (FIBI)	2.8	33	46	
Presence of forest interior dwelling species (FIDS) of birds	2 highly sensitive 5 sensitive	100		
Grassland bird diversity	25%	25		
Deer density (forest)	37.3 deer km ⁻²	0		
Deer density (grassland)	37.3 deer km ⁻²			
Landscape Dynamics				
Impervious surface (within park)	1.07%	100		
Impervious surface (within park) + 5X buffer	1.07%	100		
Forest interior area	3%	4		
Forest connectivity (Dcrit; within park)	350 m	100	66	
Forest connectivity (within park) + 5X buffer	130 m	100		
Grassland interior area	3%	5		
Contiguous grassland area	15.8 ha	50		

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 crop and pasture lands are commercially viable farming lands managed using agricultural leases, which are interspersed with natural wetland and waterway, forest, and warm-season grassland areas. 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. To address this challenge and in recognition of the vastly different land management goals for different habitats within the park, it was decided to conceptually divide habitats into two groups. Firstly, those ‘managed for natural resource values’ being the natural habitats (forests, wetlands and waterways, warm-season grasslands) whose ecological value was assessed using vital sign metrics from the National Park Service (NPS) Inventory & Monitoring (I&M) Program in the National Capital Region Network (NCRN), and secondly those ‘managed for agricultural values’ (croplands and pastures) were assessed for being the most ecologically sustainable croplands and pastures possible.

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.

Prescribed burning in Antietam National Battlefield.

5.2 KEY FINDINGS AND MANAGEMENT IMPLICATIONS

To synthesize multiple diverse data sets, a habitat framework was used to assess current condition of natural resources for Antietam National Battlefield (Chapters 3, 4), therefore key findings and management implications are summarized using the same framework (Tables 5.1, 5.2, 5.3, 5.4, 5.5).

5.2.1 Forests

Patches of forest within Antietam National Battlefield are well connected; however, forest interior area is small, providing moderate habitat potential for native fauna including forest interior dwelling bird species (FIDS; Table 5.1). It is recommended to preserve this forest structure by limiting future fragmentation (such as roads, trails, and structures) of these forest patches, as

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

Key findings	Management implications	Recommended next steps
Forests		
<ul style="list-style-type: none"> • Deer overpopulation reducing forest regeneration capacity 	<ul style="list-style-type: none"> • Increased herbivory reducing desired plant and bird species • More road collisions 	<ul style="list-style-type: none"> • Implement deer population control measures
<ul style="list-style-type: none"> • Presence of exotic plants 	<ul style="list-style-type: none"> • Displacement of native species, reducing biodiversity 	<ul style="list-style-type: none"> • Early detection • Exotic control measures (spraying and mechanical) • Prioritize control strategies
<ul style="list-style-type: none"> • Well-connected forest but with small patch sizes 	<ul style="list-style-type: none"> • Acts as a refuge for forest interior dwelling species of birds, amphibians 	<ul style="list-style-type: none"> • 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 Antietam National Battlefield.

Key findings	Management implications	Recommended next steps
Wetlands and waterways		
<ul style="list-style-type: none"> • Antietam Creek and tributaries have degraded water quality (nitrate, phosphate, salinity) 	<ul style="list-style-type: none"> • Affects stream flora and fauna • Reduces quality of visitor experience 	<ul style="list-style-type: none"> • Reduce non-point source nutrient inputs from watershed (partnership with agencies) • Continue riparian buffer establishment (woody or herbaceous, depending upon cultural resources/viewshed present)
<ul style="list-style-type: none"> • Stream benthos (IBI) very poor 	<ul style="list-style-type: none"> • Reduced biodiversity • Reduced support of higher trophic levels 	<ul style="list-style-type: none"> • Revise thresholds to be relevant for karst streams • Improve water quality

Table 5.3. Key findings, management implications, and recommended next steps for warm-season grassland habitat in Antietam National Battlefield.

Key findings	Management implications	Recommended next steps
Grasslands (warm-season)		
<ul style="list-style-type: none"> • General lack of comprehensive data for grasslands 	<ul style="list-style-type: none"> • Difficulties in assessing the health of grasslands 	<ul style="list-style-type: none"> • Implement grassland monitoring, particularly diversity, invasive species, birds, mammals, and insects • Carry out a baseline grassland plant inventory
<ul style="list-style-type: none"> • Grassland areas are not contiguous and are limited in interior area 	<ul style="list-style-type: none"> • Decreases habitat value for avian fauna and mammals (by increasing potential predation) 	<ul style="list-style-type: none"> • Remove tree lines where historically appropriate • Expand area of native grasses

Table 5.4. Key findings, management implications, and recommended next steps for cropland habitat in Antietam National Battlefield.

Key findings	Management implications	Recommended next steps
Croplands		
<ul style="list-style-type: none"> Deer overpopulation 	<ul style="list-style-type: none"> Reduced productivity and viability of cropland 	<ul style="list-style-type: none"> Implement deer population control measures
<ul style="list-style-type: none"> Croplands are in high compliance with best management practice 	<ul style="list-style-type: none"> Suggests that croplands are being managed sustainably 	<ul style="list-style-type: none"> Organize and document compliance monitoring Research new techniques in sustainable agriculture
<ul style="list-style-type: none"> Nutrient management plan is in place but implementation and effectiveness not documented 	<ul style="list-style-type: none"> While compliant with regulations, nutrient impacts on surrounding habitats managed for natural resource values are unknown 	<ul style="list-style-type: none"> Park-wide agricultural best management practice effectiveness survey Monitor and enforce Nutrient Management Plans and required soil testing.

Table 5.5. Key findings, management implications, and recommended next steps for pasture habitat in Antietam National Battlefield.

Key findings	Management implications	Recommended next steps
Pastures		
<ul style="list-style-type: none"> Deer overpopulation 	<ul style="list-style-type: none"> Degrading value of pasture, impacting surrounding habitats 	<ul style="list-style-type: none"> Implement deer population control measures
<ul style="list-style-type: none"> Nutrient management plan is in place but implementation and effectiveness not documented 	<ul style="list-style-type: none"> While compliant with regulations, nutrient impacts on surrounding habitats managed for natural resource values are unknown 	<ul style="list-style-type: none"> Park-wide agricultural best management practices effectiveness survey Comprehensive soil nutrient assessment and monitoring

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 over 37 deer km⁻² (96 deer mi⁻²). The abundant presence of exotic herbaceous and woody species displaces native species and reduces habitat value. Continued 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 or low oxygen; however, high salinity and nutrients indicate degraded wetland and waterway habitat value, which is reflected in the regionally low benthic index of biotic integrity and fish diversity (Table 5.2).

The karst geology of Antietam and the surrounding landscape has implications for water quality of the streams within the park. The acid neutralizing capacity (ANC) of streams in Antietam National Battlefield was higher (better buffering capacity) than streams in the nearby Monocacy National

Battlefield and Manassas National Battlefield park, due to the dissolution of the limestone and dolomite bedrock underlying the park by surface and groundwater (White 1993, Norris and Pieper 2010). This high ANC resulted in a stable and near-neutral pH in the park's streams.

The temperature of Antietam's streams showed a smaller range with less seasonal fluctuation than streams in Monocacy National Battlefield and Manassas National Battlefield Park. This is due to the relatively large influence of groundwater on karst systems—in Antietam, the groundwater discharge of the basin is about 85% of the total (Thorneberry–Ehrlich 2005).

The high salinity observed in Antietam is likely also a result of the karst landscape surrounding the park. Water passing through karst systems contains high levels of dissolved materials due to the dissolution of the bedrock. As salinity measures dissolved salts, karst streams are likely to return high salinity readings (Norris and Pieper 2010). These high levels of dissolved material may also impact the benthic invertebrate communities, which were very degraded in Antietam. This dissolved material can clog the gills of these animals, limiting their survival and reproduction (R. Hilderbrand, pers. comm.).

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). Assessment of these habitats could be improved by inclusion of metrics indicative of groundwater condition, due to the karst geology of the area—the carbonate rocks in karst landscapes are particularly susceptible to dissolution from both surface water and groundwater (Thorneberry–Ehrlich 2005). This results in high connectivity between groundwater and surface expression in streams and surface water.

5.2.3 Grasslands (warm-season)

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). Warm-season grassland areas are currently not contiguous, limiting the habitat value to birds, mammals, and insects. It is recommended to remove tree lines and expand areas of native 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.

5.2.4 Croplands

The croplands within Antietam National Battlefield are susceptible to the very high deer populations (Table 5.4), which are the primary cause of the crop yield concerns. It is recommended to implement deer population controls to ensure that these leased croplands are viable. These land use areas are in high compliance with best management practice—it is recommended to organize and document compliance monitoring as well as to research new techniques of sustainable agriculture that would maintain historical land use while maintaining maximum resource condition in habitats managed for natural resource values within the park. Currently, assessment of implementation and effectiveness of Nutrient Management Plans and Soil & Water Conservation Plans have not been carried out. It is recommended to monitor and enforce implementation as well as to investigate soil nutrients within these habitats to provide for better productivity and resource preservation. These additional data would improve future resource condition assessments for this habitat.

5.2.5 Pastures

The pastures within Antietam National Battlefield are susceptible to the very high deer populations (Table 5.5). It is recommended to implement deer population controls to ensure that these leased lands are viable. Pasture habitat within Antietam National Battlefield includes areas of cool-season grassland, which are currently managed as pasture with no immediate management goal to transition these areas to native warm-season grassland. Warm-season grassland supports greater habitat value for grassland birds, native grass species, small mammals, and insect pollinators, so transitioning these grassland habitats would maximize the natural resource value of these areas. Currently, assessment of implementation and effectiveness of Nutrient Management Plans as well as Soil and Water Conservation Plans have not been carried out. It is recommended to monitor implementation as well as to investigate soil nutrients within these habitats to provide for better productivity and resource preservation. These additional data would improve future resource condition assessments for this habitat.

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 Antietam National Battlefield (Chapters 3, 4), therefore key data gaps and research needs were summarized using the same framework (Tables 5.6, 5.7, 5.8, 5.9).

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 5.6). 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.

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 5.7). 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 also provide a greater understanding of current features and potential threats to park resources. One of the key challenges to water quality is high nutrients—identification of nutrient sources, both within the park and throughout the watershed, would assist in assessing potential threats, and working with watershed partners and agencies would ultimately be highly beneficial to address broader water quality concerns within the park. 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.

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 5.8). 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

Table 5.6. Data gaps, justification, and research needs for Air & Climate in Antietam National Battlefield.

Data gaps	Justification	Research needs
Air & Climate		
<ul style="list-style-type: none"> Ecological thresholds (for atmospheric effects on water and grasslands—deposition of nitrogen, sulfur, and mercury) 	<ul style="list-style-type: none"> Ecosystem impacts from deposition and human influence (acid rain and fertilization) unknown 	<ul style="list-style-type: none"> Investigating habitat-specific effects Deposition impacts to wetlands and grasslands Prevailing wind patterns within the park
<ul style="list-style-type: none"> Park-scale air quality data 	<ul style="list-style-type: none"> Need to implement park-specific management actions 	<ul style="list-style-type: none"> Using transport and deposition models Calibrating with roadside data within the park

Table 5.7. Data gaps, justification, and research needs for Water Resources in Antietam National Battlefield.

Data gaps	Justification	Research needs
Water Resources		
<ul style="list-style-type: none"> Stream channel morphology, and changes due to erosion 	<ul style="list-style-type: none"> Biodiversity relies on maintenance of stable wetland morphology 	<ul style="list-style-type: none"> Research engineering solutions to reduce water energy and erosion
<ul style="list-style-type: none"> Water quality, including groundwater 	<ul style="list-style-type: none"> Degraded water quality reduces habitat value of wetlands for native flora and fauna 	<ul style="list-style-type: none"> Identify nutrient sources, especially phosphate, as this nutrient is consistently high throughout the region and sources are non-point
<ul style="list-style-type: none"> Detailed wetland delineation 	<ul style="list-style-type: none"> In this pervious karst landscape, all habitats are connected by water flows 	<ul style="list-style-type: none"> Fine-scale mapping including surface and sub-surface flows 'Groundwatershed' maps of flow throughout park
<ul style="list-style-type: none"> Nutrient and salt sources are poorly defined both within and outside the park 	<ul style="list-style-type: none"> Need to know where to prioritize management actions 	<ul style="list-style-type: none"> Tracers, models and budgets needed (inside and outside the park) Identify inputs (point and diffuse)
<ul style="list-style-type: none"> Comprehensive assessment of stream physical habitat condition 	<ul style="list-style-type: none"> High spatial variability of condition 	<ul style="list-style-type: none"> Mapping and assessing streambank condition
<ul style="list-style-type: none"> Watershed condition 	<ul style="list-style-type: none"> Strong connectivity in water resources within the park to external stressors throughout the watershed 	<ul style="list-style-type: none"> Work with watershed partners and agencies to assess watershed and stream condition

Table 5.8. Data gaps, justification, and research needs for Biological Integrity in Antietam National Battlefield.

Data gaps	Justification	Research needs
Biological Integrity		
<ul style="list-style-type: none"> • Bird community thresholds and management goals 	<ul style="list-style-type: none"> • The park contains increasingly rare habitat for neotropical and grassland birds 	<ul style="list-style-type: none"> • Inventory and monitor types of birds, particularly grassland birds, within the park
<ul style="list-style-type: none"> • Acoustic and vibration monitoring 	<ul style="list-style-type: none"> • Traffic vibrations and noise can impact bird populations 	<ul style="list-style-type: none"> • Monitor noise and vibrations and assess impacts to bird communities
<ul style="list-style-type: none"> • Understanding grazing impacts on multiple habitats (grassland, cropland, pasture) 	<ul style="list-style-type: none"> • Intense herbivory impacts habitat structure and function 	<ul style="list-style-type: none"> • Impacts of different deer densities on different habitats, including establishing deer density thresholds
<ul style="list-style-type: none"> • Importance of maintaining late successional warm-season grasslands 	<ul style="list-style-type: none"> • Grassland diversity can enhance diversity of birds, mammals and insect pollinators 	<ul style="list-style-type: none"> • Actively monitor effects of different grassland management actions, including burn strategy
<ul style="list-style-type: none"> • Small mammal dynamics and populations in grasslands 	<ul style="list-style-type: none"> • Park contains increasingly rare grassland habitat important to declining populations of mammals dependent on early successional habitats 	<ul style="list-style-type: none"> • Inventory and monitor small mammals specific to grasslands
<ul style="list-style-type: none"> • Grassland insect and pollinator populations and roles 	<ul style="list-style-type: none"> • Park contains increasingly rare grassland habitat 	<ul style="list-style-type: none"> • Inventory and monitor insects, particularly those that are important food sources for grassland birds
<ul style="list-style-type: none"> • Sustainability of raptor populations and affects on grassland birds 	<ul style="list-style-type: none"> • Park contains increasingly rare grassland habitat 	<ul style="list-style-type: none"> • Inventory and monitor raptors that prey on neotropical and grassland birds • Establish baseline for sound levels and types of sounds within park

Table 5.9. Data gaps, justification, and research needs for Landscape Dynamics in Antietam National Battlefield.

Data gaps	Justification	Research needs
Landscape Dynamics		
<ul style="list-style-type: none"> • Implications of external land use changes on park resources 	<ul style="list-style-type: none"> • Connectivity of ecological processes from park to watershed 	<ul style="list-style-type: none"> • Landscape analysis at multiple scales
<ul style="list-style-type: none"> • Wetland corridor function 	<ul style="list-style-type: none"> • Needed for migration and movement of fauna 	<ul style="list-style-type: none"> • Assessment of current and potential use by fauna
<ul style="list-style-type: none"> • Cultural requirements for tree heights 	<ul style="list-style-type: none"> • Vegetating streamsidess needs to be carried out in a way that maintains cultural viewscapes 	<ul style="list-style-type: none"> • Assess maximum acceptable plant height and species

in the park have contributed to very low native tree seedling regeneration, although the seedling regeneration data did not take reforestation activities into account. 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 5.9). This is true for forest, grassland, and wetland and waterway habitats within the park. As a battlefield park, vegetating streamsides to reduce nutrient runoff from agricultural and pasture lands into waterways needs to be carried out in a way that maintains the cultural viewshed of the park. Studies to identify plant species that are small enough to maintain viewsheds but large enough to remove maximum nutrient content from surface and subsurface waters flowing from agricultural and pastoral lands would assist in improving compliance with best management practices for these habitats.

5.4 LITERATURE CITED (CHAPTER 5)

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Appendix A: Raw data used in Antietam National Battlefield 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	65	11.01
2005	81	11.97
2006	82	12.84
2007	86	15.28
2008	82	13.55
Overall	396	13.09
Std error		0.58

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Table A-2. Water quality data. Values that do not meet the thresholds are in bold. Site locations are shown in Figure 3.7 and thresholds are shown in Table 3.2.

Site	Date	pH	DO	Temp	ANC	Sal	NO ₃	PO ₄
I&M data								
NCRN_ANTI_SHCK	5/23/2005	8.09	10.50	13.30			4.6	
NCRN_ANTI_SHCK	6/2/2005	8.14	10.85	14.75	3740		4.9	
NCRN_ANTI_SHCK	6/30/2005	8.13	9.97	16.77	3920		5.0	
NCRN_ANTI_SHCK	10/11/2005	8.18	9.81	14.60	2200		9.3	
NCRN_ANTI_SHCK	11/17/2005	8.27	8.60	10.20	3720		9.3	
NCRN_ANTI_SHCK	12/14/2005	8.03	5.81	7.50	3592	0.3	5.4	
NCRN_ANTI_SHCK	1/26/2006	7.83	11.55	10.40	4120	0.3	11.7	
NCRN_ANTI_SHCK	2/28/2006	8.25	8.56	10.85	4300	0.3	9.9	
NCRN_ANTI_SHCK	3/23/2006	8.36	9.00	11.50	4180	0.3	9.8	
NCRN_ANTI_SHCK	4/12/2006	8.32	3.53	14.30	2100	0.3	14.3	
NCRN_ANTI_SHCK	5/18/2006	8.26	1.98	13.30	4200	0.3	8.8	
NCRN_ANTI_SHCK	6/28/2006	8.11	8.98	16.00	4420	0.3	9.0	
NCRN_ANTI_SHCK	7/26/2006	8.26	9.33	16.60	4180	0.3	10.6	
NCRN_ANTI_SHCK	8/14/2006	7.67	8.46	17.90	3980	0.3	10.2	
NCRN_ANTI_SHCK	10/12/2006	8.22	9.32	14.30	4820	0.2	10.3	
NCRN_ANTI_SHCK	11/17/2006	8.26	9.27	13.05	4720	0.3	10.9	
NCRN_ANTI_SHCK	12/18/2006	8.27	8.30	13.05	4800	0.3	2.1	
NCRN_ANTI_SHCK	1/25/2007	7.38	9.90	10.10	4780	0.3	1.6	1.070
NCRN_ANTI_SHCK	2/22/2007	8.41	9.41	11.60	4820	0.3	2.4	0.370
NCRN_ANTI_SHCK	3/27/2007	8.30	8.98	13.10	5280	0.3	5.5	0.150
NCRN_ANTI_SHCK	5/16/2007	8.2	8.72	15.80	4820	0.3	6.0	0.060
NCRN_ANTI_SHCK	6/5/2007	8.24	7.83	15.30	4500	0.3	4.4	0.360
NCRN_ANTI_SHCK	7/11/2007	8	10.34	15.60	4580	0.3	7.8	0.180
NCRN_ANTI_SHCK	8/13/2007	8.15	8.27	17.90	4240	0.3	3.9	0.310
NCRN_ANTI_SHCK	8/30/2007	8.23	7.77	17.30	4440	0.3	5.0	0.230
NCRN_ANTI_SHCK	10/17/2007	8.24	8.66	14.40	4260	0.3	5.3	0.220
NCRN_ANTI_SHCK	11/14/2007	8.41	8.84	13.10	4920	0.3	7.9	0.210
NCRN_ANTI_SHCK	12/19/2007	8.41	10.23	9.50	5280	0.3	9.3	0.330
NCRN_ANTI_SHCK	1/22/2008		9.45	7.40	5140	0.3	8.9	0.230
NCRN_ANTI_SHCK	2/19/2008	8.1	10.69	10.30	5180	0.3	8.0	0.300
NCRN_ANTI_SHCK	3/20/2008	8.24	8.65	10.70	4140	0.3	9.3	0.290
NCRN_ANTI_SHCK	4/14/2008	8.29	11.61	12.95	5300	0.3	8.3	0.220
NCRN_ANTI_SHCK	5/7/2008	8.27	12.09	15.55	5320	0.3	8.3	0.200
NCRN_ANTI_SHCK	6/18/2008	8.07	9.91	14.82	5300	0.3	7.9	0.170
NCRN_ANTI_SHCK	7/30/2008	8.02	9.57	15.55	4824	0.3	6.2	0.270
NCRN_ANTI_SHCK	8/13/2008	7.53	9.55	14.80	4380	0.3	8.0	0.170
NCRN_ANTI_SHCK	9/18/2008	7.96	9.47	14.40	4800	0.3	6.7	0.190
NCRN_ANTI_SHCK	10/22/2008	8.21	10.44	10.80	4660	0.3	6.3	0.230
NCRN_ANTI_SHCK	11/19/2008	8.28	11.79	7.50	4960	0.3	6.3	0.240

Site	Date	pH	DO	Temp	ANC	Sal	NO ₃	PO ₄
ANTI data								
Site 1	3/24/2000	7.93	9.3	13.3			8.5	0.690
Site 1	4/27/2000	8.11	8.7	11.2			6.0	0.270
Site 1	5/17/2000	7.98	8.2	12.1			6.0	0.200
Site 1	5/31/2000	8.12	8.2	11.2			4.2	0.450
Site 1	6/9/2000	7.98	7.4	12.2			8.5	0.220
Site 1	6/22/2000	7.8	7.1	12.1			10.3	0.800
Site 1	7/11/2000	7.01	7.1	11.8			10.0	0.940
Site 1	7/25/2000	7.82	8.1	12.5			8.0	0.670
Site 1	8/16/2000	7.87	6.6	12.9			9.0	0.300
Site 1	9/21/2000	7.84	6.1	16			9.0	0.340
Site 1	10/20/2000	7.75	6.9	12.4			6.6	0.250
Site 1	3/15/2001	8.35		7.9			5.6	0.630
Site 1	4/19/2001	7.73	7.8	11			3.5	0.520
Site 1	5/8/2001	7.68	8	11.7			4.4	0.650
Site 1	5/23/2001	7.5	6.8	12			7.7	0.270
Site 1	6/14/2001	7.6	4.6	16.63			3.9	0.150
Site 1	6/29/2001	7.6	6.3	13			7.6	0.330
Site 1	7/11/2001	7.5	6.7	13			7.2	0.270
Site 1	7/24/2001	7.5	5.8	13.2			6.9	0.110
Site 1	8/15/2001	7.42	7.3	13.7			10.2	1.440
Site 1	9/19/2001	7.45	5.67	13.7			5.9	0.150
Site 1	10/12/2001	7.5	6.08	13.2			7.8	0.180
Site 1	3/14/2002	8.11	4.88	10			6.1	0.430
Site 1	4/5/2002	7.7	6	9			3.8	0.450
Site 1	4/23/2002	8.45	5.65	10.4			2.8	0.260
Site 1	5/8/2002	7.7	4.04	13			7.7	0.200
Site 1	5/29/2002	7.66	5.05	12.9			6.6	0.270
Site 1	6/12/2002	7.66	6.08	14			7.7	0.160
Site 1	6/26/2002	7.63	7.05	13.8			7.0	0.110
Site 1	7/12/2002	7.83	5.96	13.5			6.4	0.160
Site 1	7/24/2002	7.68	5.33	14			4.7	0.120
Site 1	8/14/2002	7.71	4.42	14.4			9.6	0.260
Site 1	9/11/2002	7.62	3.64	14.2			9.2	0.340
Site 1	10/21/2002	7.22	5.45	13.3			6.3	0.090
Site 1	3/17/2003	7.2	5.71	12.1			7.8	0.170
Site 1	4/7/2003	7.21	5.91	11.3			6.8	0.140
Site 1	4/23/2003	7.19	5.1	11.5			6.2	0.300
Site 1	5/8/2003	6.98	5.23	12.2			7.7	0.270
Site 1	5/20/2003	7.07	5.43	12.5			8.1	0.260
Site 1	6/10/2003	6.92	6.80	12.9			5.2	0.140
Site 1	6/24/2003	6.99	7.00	12.8			9.0	0.200
Site 1	7/7/2003	7.11	7.20	12.8			8.4	0.140
Site 1	7/21/2003	7.19	4.18	12.9			7.4	0.090
Site 1	8/4/2003	7.32	6.82	13.1			4.8	0.080

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Site	Date	pH	DO	Temp	ANC	Sal	NO ₃	PO ₄
ANTI data								
Site 1	8/18/2003	7.35	4.29	13			5.2	0.130
Site 1	9/22/2003	7.06	4.61	12.9			5.1	0.170
Site 1	10/16/2003	7.2	4.4	13.3			4.4	0.090
Site 1	3/17/2004	7.03	6.05	10.55			5.9	0.690
Site 1	4/6/2004	7.28	6.35	11.67			4.0	0.580
Site 1	4/21/2004	7.15	6.1	11.67			5.8	0.290
Site 1	5/11/2004	7.32	5.77	12.22			6.5	0.280
Site 1	5/26/2004	7.33	6.55	12.78			7.3	0.120
Site 1	6/9/2004	7.24	6.21	12.78			7.5	0.220
Site 1	6/25/2004	7.27	7.97	12.78			5.3	0.210
Site 1	7/14/2004	7.4		13.6			5.0	0.120
Site 1	7/28/2004	7.3		12.6			9.0	0.260
Site 1	8/16/2004	7.53	7.11	14.1			7.6	0.210
Site 1	8/31/2004	7	5.52	14			8.8	0.110
Site 1	9/27/2004	6.85	5.64	13.9			6.7	0.130
Site 1	10/21/2004	7.08	6.23	12.5			7.1	0.360
Site 1	2/8/2005	7.09	8.32	11.63		0.309	7.2	0.350
Site 1	2/23/2005	7.26	6.59	11.66		0.312	4.5	0.330
Site 1	3/7/2005	7.19	7.49	11.59		0.311	5.7	0.270
Site 1	3/25/2005	7.21	6.57	11.27		0.266	5.6	0.160
Site 1	4/15/2005	7.05	7.07	11.86		0.241	6.4	0.680
Site 1	4/28/2005	7.30	7.85	12.83		0.238	7.5	0.340
Site 1	5/12/2005	7.35	7.76	12.75		0.285	3.2	0.470
Site 1	5/27/2005	7.26	7.99	12.43		0.290	5.8	0.060
Site 1	6/10/2005	7.45	7.17	12.52		0.292	7.7	0.380
Site 1	6/24/2005	7.28	6.91	12.67		0.297	8.5	0.060
Site 1	7/13/2005	7.27	6.87	12.73		0.332	7.9	0.110
Site 1	7/26/2005	7.11	6.12	12.84		0.336	6.9	0.310
Site 1	8/12/2005	7.28	6.40	12.96		0.343	8.8	0.100
Site 1	8/30/2005	7.20	5.78	13.16		0.350	8.0	0.030
Site 1	9/14/2005	7.38	5.73	13.12		0.332	7.5	0.090
Site 1	9/30/2005	7.4	6.16	12.69		0.335	3.3	0.250
Site 1	10/19/2005	7.24	8.2	13.05		0.325	3.9	0.340
Site 1	11/3/2005	7.19	7.94	13.05		0.322	5.6	0.160
Site 1	11/14/2005	6.86	7.27	12.96		0.325	8.3	0.170
Site 1	11/30/2005	7.08	7.25	12.75		0.315	7.3	0.130
Site 1	12/21/2005	5.81	11.63	7.98		0.320	8.3	1.090
Site 1	12/28/2005	7.1	6.78	12.24		0.317	7.1	0.260
Site 1	1/20/2006	7.12	6.71	12.2		0.308	13.7	0.290
Site 1	1/30/2006	7.16	7.49	12.28		0.307	8.9	0.270
Site 1	2/24/2006	7.3	7.62	11.86		0.307	7.6	0.190
Site 1	3/27/2006	6.82	8.18	12.04		0.307	9.1	0.290
Site 1	4/26/2006	6.9	6.98	12.34		0.314	6.6	0.260
Site 1	5/30/2006	5.44	7.17	12.63		0.319	1.2	0.220

Site	Date	pH	DO	Temp	ANC	Sal	NO ₃	PO ₄
ANTI data								
Site 1	6/29/2006	5.22	9.67	13.09		0.311	9.2	0.320
Site 1	7/29/2006	4.95	8.59	12.71		0.319	11.1	0.190
Site 1	8/28/2006	5.47	6.98	12.91		0.329	10.2	0.240
Site 1	9/27/2006	5.18	6.83	13		0.339	9.8	0.330
Site 1	10/30/2006	5.74	7.69	12.88		0.340	13.7	0.360
Site 1	11/28/2006	6.74	7.7	12.99		0.330	10.8	0.170
Site 1	1/9/2007	7.05	7.36	12.4		0.323	6.5	0.480
Site 1	1/30/2007	7.01	7.23	12.18		0.321	2.1	2.100
Site 1	3/6/2007	7.08	7.88	11.67		0.315	6.8	0.170
Site 1	3/20/2007					0.008	10.3	0.050
Site 1	4/24/2007	6.08	7.75	12.34		0.298	14.4	0.120
Site 1	5/24/2007	5.67	7.37	12.65		0.298	9.8	0.240
Site 1	6/22/2007					0.008	12.6	0.230
Site 1	7/24/2007	5.26	7.11	13		0.314	10.4	0.150
Site 1	8/28/2007	5.24	6.46	13.15		0.326	11.4	0.200
Site 1	9/27/2007	5.3	5.25	13.32		0.332	11.3	0.250
Site 1	10/31/2007	6.46	5.76	12.23		0.344	7.0	0.080
Site 1	11/29/2007	5.63	4.71	11.98		0.347	3.9	0.140
Site 1	12/21/2007	6.88	12.16	8.18		0.305	10.9	0.080
Site 1	2/5/2008	6.86	8.61	12.2		0.326	3.7	0.230
Site 1	2/28/2008	6.98	7.78	11.92		0.325	3.0	0.390
Site 1	4/7/2008	7.25	8.18	12.19		0.305	6.7	0.060
Site 1	4/30/2008	6.74	7.65	12.45		0.301	5.5	0.320
Site 1	5/23/2008	7	7.38	12.6		0.294	8.1	0.130
Site 1	6/20/2008	6.74	7.14	12.66		0.284	6.8	0.130
Site 1	7/22/2008	8.04	9.41	17.35		0.304	0.3	0.010
Site 1	8/22/2008	6.47	8.18	13.46		0.311	3.1	0.210
Site 1	9/29/2008	7.05	7.41	13.85		0.323	3.4	0.150
Site 1	10/30/2008	7.2	8.50	12.16		0.327	1.8	0.180
Site 1	11/25/2008	7.41	8.97	11.14		0.330	1.3	0.210
Site 1	12/15/2008	6.93	8.99	12.65		0.326	2.4	0.170
Site 2	3/24/2000	8.34	11	13.3			5.0	0.630
Site 2	4/27/2000	8.6	11.6	10			2.5	0.630
Site 2	5/17/2000	8.68	10.5	12.7			5.3	0.470
Site 2	5/31/2000	8.82	10.6	13.2			2.6	0.160
Site 2	6/9/2000	8.68	10.9	14.3			6.5	0.200
Site 2	6/22/2000	8.54	8	15.7			5.2	0.750
Site 2	7/11/2000	7.88	8.7	13.8			7.0	0.600
Site 2	7/25/2000	8.1	10.1	15.2			10.5	0.600
Site 2	8/16/2000	8.17	8.7	15			8.6	0.570
Site 2	9/21/2000	8.05	9.5	13.2			5.6	0.180
Site 2	10/20/2000	8.28	10.2	12.8			2.9	0.760
Site 2	3/15/2001	8.4	11.5	7.4			2.5	1.140
Site 2	4/19/2001	8.4	11.4	6.8			7.1	0.580

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Site	Date	pH	DO	Temp	ANC	Sal	NO ₃	PO ₄
ANTI data								
Site 2	5/8/2001	8.49	16	11.4			4.1	1.070
Site 2	5/23/2001	8.28	9.7	13.8			0.9	0.630
Site 2	6/14/2001	8.16	8.8	16.5			3.5	0.140
Site 2	6/29/2001	8.1	8.6	17.5			5.2	0.460
Site 2	7/11/2001	8.39	8.82	16			7.3	0.460
Site 2	7/24/2001	8.4	8.19	18			2.9	0.300
Site 2	8/15/2001	8.22	8.08	18.7			3.3	1.530
Site 2	9/19/2001	8.2	7.86	17			3.5	0.250
Site 2	10/12/2001	8.24	8.6	12			5.6	0.370
Site 2	4/5/2002	6.95	13.2	6.9			2.5	0.610
Site 2	4/23/2002	9.13	11.7	9.7			1.1	0.360
Site 2	5/8/2002	8.56	20	7.61			4.1	0.340
Site 2	5/29/2002	8.51	8.81	17.7			0.1	0.250
Site 2	6/12/2002	8.43	8.84	16.8			6.8	0.320
Site 2	6/26/2002	8.38	8.97	18.1			7.7	0.140
Site 2	7/12/2002	8.7	9.3	16.1			2.3	0.460
Site 2	7/24/2002	8.15	8.28	19.8			1.0	0.240
Site 2	8/14/2002	8.47	6.11	25.5			4.6	0.780
Site 2	9/11/2002							0.110
Site 2	10/21/2002	7.77	10.43	12			4.0	0.260
Site 2	3/17/2003	8.06	9.12	11.12			5.4	0.650
Site 2	4/8/2003	8.08	10.48	8.7			3.7	0.190
Site 2	4/23/2003	8.09	8.39	10.9			3.5	0.150
Site 2	5/8/2003	7.84	8.11	13.7			2.0	0.270
Site 2	5/20/2003	7.72	8.92	10.7			6.4	0.100
Site 2	6/10/2003	7.41	8.70	14.1			5.3	0.300
Site 2	6/24/2003	7.62	9.30	15.2			5.8	0.300
Site 2	7/7/2003	7.87	8.80	16.9			6.5	0.260
Site 2	7/21/2003	7.95	9.39	16.6			6.3	0.250
Site 2	8/4/2003	8.02	9.26	16.2			6.8	0.300
Site 2	8/18/2003	7.97	9.15	17.2			4.4	0.210
Site 2	9/22/2003	7.57	9.14	16.5			4.7	0.190
Site 2	10/16/2003	7.83	10.03	13.8			5.1	0.190
Site 2	3/17/2004	7.9	10.9	7.78			2.5	0.450
Site 2	4/6/2004	8.15	11.09	10			9.8	0.330
Site 2	4/21/2004	7.97	10.1	12.22			6.6	0.310
Site 2	5/11/2004	7.99	9.57	14.44			6.7	0.130
Site 2	5/26/2004	7.96	8.47	15.56			5.9	0.010
Site 2	6/9/2004	7.84	8.28	17.22			5.4	0.090
Site 2	6/25/2004	7.97	8.77	15.56			6.5	0.220
Site 2	7/14/2004	8.1		17			6.3	0.140
Site 2	7/28/2004	7.88		16.1			3.8	0.260
Site 2	8/16/2004	8	9.33	17.9			5.8	0.170
Site 2	8/31/2004	7.39	6.49	20.9			3.0	0.190

Site	Date	pH	DO	Temp	ANC	Sal	NO ₃	PO ₄
ANTI data								
Site 2	9/27/2004	7.66	8.83	16.8			5.1	0.200
Site 2	10/21/2004	7.72	8.54	13			3.6	0.440
Site 2	2/8/2005	8.08	14.63	8.91		0.309	5.8	0.010
Site 2	2/23/2005	7.72	11.41	7.79		0.315	3.5	0.220
Site 2	3/7/2005	8.15	12.02	8.31		0.315	2.7	0.410
Site 2	3/25/2005	6.98	11.21	8.83		0.255	3.0	0.170
Site 2	4/15/2005	7.94	11.19	10.98		0.244	3.9	0.800
Site 2	4/28/2005	8.16	10.29	13.16		0.248	4.5	0.630
Site 2	5/12/2005	7.45	10.20	11.96		0.295	1.3	0.640
Site 2	5/27/2005	8.16	10.30	14.64		0.295	3.4	0.283
Site 2	6/10/2005	8.07	9.05	17.28		0.299	4.6	0.060
Site 2	6/24/2005	8.09	8.80	17.11		0.302	5.4	0.680
Site 2	7/13/2005	8.03	8.43	19.19		0.341	4.1	0.320
Site 2	7/26/2005	8.05	8.15	20.05		0.342	4.0	0.270
Site 2	8/12/2005	8.04	8.46	20.09		0.348	6.1	0.220
Site 2	8/30/2005	8.01	8.38	19.68		0.354	2.7	0.280
Site 2	9/14/2005	8.16	8.75	17.97		0.332	7.2	0.300
Site 2	9/30/2005	8.14	10.2	13.57		0.335	0.5	0.260
Site 2	10/19/2005	7.7	10.42	12.91		0.324	1.8	0.180
Site 2	11/3/2005	7.26	10.55	11.7		0.316	5.7	0.038
Site 2	11/14/2005	7.67	9.72	12.37		0.327	5.1	0.230
Site 2	11/30/2005	7.61	9.9	11.7		0.286	4.6	0.330
Site 2	12/21/2005	7.11	7.19	12.26		0.321	2.9	0.180
Site 2	12/28/2005	7.86	10.63	9.06		0.317	6.7	0.360
Site 2	1/20/2006	7.56	10.57	9.46		0.205	0.8	0.240
Site 2	1/30/2006	8.06	11.09	10.16		0.306	8.6	0.240
Site 2	2/24/2006	5.79	12.58	6.33		0.289	7.8	0.260
Site 2	3/27/2006	6.35	12.11	9.17		0.306	8.6	0.330
Site 2	4/26/2006	6.75	10.64	11.24		0.313	5.6	0.370
Site 2	5/30/2006	6.84	9.15	16.42		0.320	2.0	0.230
Site 2	6/29/2006	5.93	8.93	16.95		0.303	8.5	0.310
Site 2	7/29/2006	6.19	9.28	18.63		0.322	10.9	0.290
Site 2	8/28/2006	6.39	8.85	19.15		0.334	8.0	0.210
Site 2	9/27/2006	6.59	9.94	14.36		0.340	7.7	0.310
Site 2	10/30/2006	6.16	9.68	13.01		0.327	9.5	0.340
Site 2	11/28/2006	6.77	10.96	12.28		0.322	7.8	0.200
Site 2	1/9/2007	7.31	11.37	9.06		0.315	5.4	0.660
Site 2	1/30/2007	7.74	12.2	6.12		0.321	7.4	0.200
Site 2	3/6/2007	7.58	13.03	5.37		0.315	7.2	0.820
Site 2	3/20/2007					0.008	6.3	0.230
Site 2	4/24/2007	6.88	10.38	13.66		0.303	8.2	0.160
Site 2	5/24/2007	6.65	9.94	13.97		0.302	7.2	0.190
Site 2	6/22/2007					0.008	8.6	0.160
Site 2	7/24/2007	6.82	9.24	17.24		0.314	8.1	0.260

Antietam National Battlefield Natural Resource Condition Assessment

Site	Date	pH	DO	Temp	ANC	Sal	NO ₃	PO ₄
ANTI data								
Site 2	8/28/2007	6.46	8.82	18.5		0.327	9.1	0.070
Site 2	9/27/2007	6.74	7.97	18.44		0.327	3.7	0.210
Site 2	10/31/2007	6.5	10.71	10.28		0.339	4.7	0.010
Site 2	11/29/2007	5.98	10.48	7.37		0.339	3.7	0.100
Site 2	12/21/2007	7.6	11.71	9.54		0.315	4.4	0.110
Site 2	2/5/2008	6.49	12.3	10.09		0.314	3.2	0.130
Site 2	2/28/2008	7.76	11.97	6.91		0.320	3.6	0.230
Site 2	4/7/2008	7.7	11.14	10.2		0.306	6.0	0.160
Site 2	4/30/2008	7.21	10.39	11.48		0.303	4.1	0.250
Site 2	5/23/2008	7.64	10.13	13.01		0.297	6.1	0.060
Site 2	6/20/2008	8.16	9.13	17.22		0.297	0.3	0.180
Site 2	7/22/2008	7.09	8.29	12.64		0.294	4.0	0.180
Site 2	8/22/2008	8.14	9.55	16.51		0.282		0.210
Site 2	9/29/2008	8.21	9.2	17.45		0.324	1.6	0.210
Site 2	10/30/2008	7.19	11.07	7.71		0.332	0.0	0.120
Site 2	11/25/2008	7.97	12.74	5.12		0.332	0.3	0.440
Site 2	12/15/2008	7.54	10.33	11.84		0.312	1.6	0.200
Site 3	3/24/2000	8.4	11.2	14			4.3	0.540
Site 3	4/27/2000	8.55	11	9			3.1	0.500
Site 3	5/17/2000	8.46	9.9	14			6.5	0.380
Site 3	5/31/2000	8.38	9.3	13.9			3.4	0.280
Site 3	6/9/2000	8.34	10.2	13.9			6.5	0.740
Site 3	6/22/2000	8.25	8	16			5.6	0.740
Site 3	7/11/2000	7.93	7.8	17.5			5.1	1.450
Site 3	7/25/2000	7.9	8.8	18.7			9.3	0.350
Site 3	8/16/2000	7.94	8.3	17.4			5.8	0.140
Site 3	9/21/2000	8.05	9	13.6			6.8	0.160
Site 3	10/20/2000	8.29	9.8	11.4			6.1	0.440
Site 3	3/15/2001	8.3	-	6.9			4.3	1.030
Site 3	4/19/2001	8.28	-	10.8			2.9	0.320
Site 3	5/8/2001	8.2	9.8	12			3.4	0.430
Site 3	5/23/2001	8.03	8.5	14.7			5.9	0.540
Site 3	6/14/2001	8	8.2	17.4			4.6	0.300
Site 3	6/29/2001	8	8.6	17.5			3.1	0.240
Site 3	7/11/2001	8.07	8.12	17.3			5.5	0.290
Site 3	7/24/2001	8.9	7.6	18			3.4	0.160
Site 3	8/15/2001	8.07	7.4	19.6			2.7	0.370
Site 3	9/19/2001	8.17	8.01	18.8			4.1	0.320
Site 3	4/5/2002	8.57	15.47	7.7			1.5	0.500
Site 3	4/23/2002	8.75	12.33	10.5			3.3	0.310
Site 3	5/8/2002	8.42	8.43	18.3			6.5	0.030
Site 3	5/29/2002	8.22	9.35	14.8			4.4	0.180
Site 3	6/12/2002	8.16	8.55	16.8			8.3	0.020
Site 3	6/26/2002	8.07	8.22	18.1			8.7	0.210

Site	Date	pH	DO	Temp	ANC	Sal	NO ₃	PO ₄
ANTI data								
Site 3	7/12/2002	8.28	8	17.9			3.3	0.220
Site 3	7/24/2002	7.96	7.34	19.2			1.9	0.300
Site 3	8/14/2002	8.18	6.39	24			2.4	0.260
Site 3	9/11/2002	0		0			6.2	0.320
Site 3	10/21/2002	7.82	9.04	12.7			6.9	0.200
Site 3	3/17/2003	8.06	10	11.1			6.6	0.150
Site 3	4/8/2003	8.36	10.58	8.4			6.2	0.150
Site 3	4/23/2003	8.19	7.9	12.6			4.7	1.370
Site 3	5/8/2003	7.9	8.16	14.4			1.1	0.150
Site 3	5/20/2003	7.77	8.91	13.1			6.4	0.110
Site 3	6/10/2003	7.56	9.50	14.4			7.0	0.230
Site 3	6/24/2003	7.77	9.70	15.7			5.6	0.230
Site 3	7/7/2003	7.96	9.60	17.8			5.4	0.250
Site 3	7/21/2003	8	6.85	22.1			3.9	0.290
Site 3	8/4/2003	8.15	8.11	19			4.2	0.250
Site 3	8/18/2003	8.05	9.06	18.4			3.1	0.110
Site 3	9/22/2003	7.77	9.55	17.3			4.2	0.250
Site 3	10/16/2003	7.98	14.5	10.37			7.3	0.380
Site 3	3/17/2004	8.28	11	7.22			1.0	0.760
Site 3	4/9/2004	8.22	10.94	11.67			5.7	0.380
Site 3	4/21/2004	8.18	10.24	12.22			9.1	0.300
Site 3	5/11/2004	8.19	9.35	15.56			6.7	0.170
Site 3	5/26/2004	8.09	8.75	17.22			5.6	0.180
Site 3	6/9/2004	8.01	8.43	17.22			6.0	0.180
Site 3	6/25/2004	8.08	8.58	17.78			5.6	0.220
Site 3	7/14/2004	8.08		18.9			6.2	0.270
Site 3	7/28/2004	7.91		18.6			7.4	0.290
Site 3	8/16/2004	8.08	11.44	16.9			5.4	0.240
Site 3	8/31/2004	7.92	8.67	20.3			3.7	0.310
Site 3	9/27/2004	7.76	9.3	17			6.0	0.010
Site 3	10/21/2004	7.77	9.3	12.7			4.0	0.590
Site 3	2/8/2005	8.37	14.97	9.08		0.301	6.6	0.320
Site 3	2/23/2005	7.7	11.94	6.5		0.309	2.1	0.190
Site 3	3/7/2005	8.13	12.39	7.72		0.302	2.4	0.260
Site 3	3/25/2005	7.9	11.93	8.57		0.247	3.1	0.090
Site 3	4/15/2005	8.17	10.68	13.05		0.236	6.7	0.710
Site 3	4/28/2005	8.27	10.52	14.14		0.238	5.0	0.170
Site 3	5/12/2005	8.09	10.38	11.85		0.290	2.5	0.480
Site 3	5/27/2005	8.04	10.21	15.05		0.167	1.5	0.077
Site 3	6/10/2005	7.99	8.64	18.33		0.299	3.6	0.240
Site 3	6/24/2005	8.01	8.77	19.78		0.304	3.2	0.410
Site 3	7/13/2005	8.06	8.56	21.24		0.339	2.4	0.330
Site 3	7/26/2005	8.07	8.36	21.60		0.342	1.6	0.210
Site 3	8/12/2005	7.93	7.20	23.51		0.350	3.0	0.370

Antietam National Battlefield Natural Resource Condition Assessment

Site	Date	pH	DO	Temp	ANC	Sal	NO ₃	PO ₄
ANTI data								
Site 3	8/30/2005	8.08	7.90	21.03		0.351	3.4	0.260
Site 3	9/14/2005	8.25	8.78	19.90		0.330	5.6	0.110
Site 3	9/30/2005	8.2	9.37	19.75		0.337	3.3	0.640
Site 3	10/19/2005	8.14	11.04	10.96		0.439	2.5	0.100
Site 3	11/3/2005	8.04	10.69	12.45		0.307	11.4	0.090
Site 3	11/14/2005	7.98	10.13	12.89		0.321	5.1	0.090
Site 3	11/30/2005	7.69	10.04	11.94		0.281	3.2	0.230
Site 3	12/21/2005	7.69	12.93	6.3		0.312	1.0	0.470
Site 3	12/28/2005	8.06	11.59	8.63		0.307	7.1	0.190
Site 3	1/20/2006	7.55	10.16	9.54		0.297	12.8	0.320
Site 3	1/30/2006	8.1	11.31	10.29		0.298	7.1	0.180
Site 3	2/24/2006	7.62	12.62	6.5		0.291	5.7	0.370
Site 3	3/27/2006	6.1	12.65	10.66		0.276	6.3	0.350
Site 3	4/26/2006	7.93	10.58	12.21		0.308	4.3	0.190
Site 3	5/30/2006	6.1	8.05	18.9		0.322	7.7	0.480
Site 3	6/29/2006	5.7	9.16	17.19		0.298	9.9	0.200
Site 3	7/29/2006	6.81	8.91	21.01		0.319	6.9	0.280
Site 3	8/28/2006	6.87	8.26	21.6		0.327	7.9	0.320
Site 3	9/27/2006	6.22	7.39	16.74		0.346	6.5	1.230
Site 3	10/30/2006	6.46	9.62	13.77		0.321	8.7	0.280
Site 3	11/28/2006	7.68	11.02	12.34		0.315	8.1	0.250
Site 3	1/9/2007	7.73	11.77	9.25		0.310	5.9	0.510
Site 3	1/30/2007	7	13.46	4.92		0.317	15.4	0.230
Site 3	3/6/2007	7.13	13.04	6.5		0.294	6.5	0.480
Site 3	3/20/2007					0.008	7.0	0.160
Site 3	4/24/2007	6.95	10.48	14.17		0.292	9.6	0.150
Site 3	5/24/2007	6.92	9.47	16.65		0.297	6.4	0.150
Site 3	6/22/2007					0.008	4.2	0.150
Site 3	7/24/2007	7.4	8.95	20.9		0.305	8.6	0.520
Site 3	8/28/2007	7.24	9.05	20.34		0.330	8.2	0.040
Site 3	9/27/2007	6.78	7.8	20.95		0.312	5.7	0.810
Site 3	10/31/2007	7.88	9.78	15.94		0.342	6.0	0.480
Site 3	11/29/2007	6.75	10.53	10.56		0.345	3.7	0.160
Site 3	12/21/2007	6.88	12.16	8.18		0.305	5.7	0.210
Site 3	2/5/2008	7.2	12.73	9.1		0.286	5.0	0.100
Site 3	2/28/2008	6.93	12.72	6.37		0.310	6.8	0.200
Site 3	4/7/2008	7.92	11.79	9.71		0.297	2.8	0.170
Site 3	4/30/2008	7.98	10.74	11.86		0.287	5.4	0.410
Site 3	5/23/2008	7.99	9.76	14.2		0.284	5.9	0.010
Site 3	6/20/2008	8.12	9.08	18.49		0.294	4.5	0.080
Site 3	7/22/2008	8.1	9.27	20.18		0.300	2.8	0.270
Site 3	8/22/2008	8.16	9.65	17.97		0.311	3.8	0.210
Site 3	9/29/2008	7.86	6.45	18.63		0.327	1.3	0.270
Site 3	10/30/2008	8.02	11.29	8.73		0.332	2.2	0.210

Site	Date	pH	DO	Temp	ANC	Sal	NO ₃	PO ₄
ANTI data								
Site 3	11/25/2008	8.14	12.99	6.45		0.327	0.8	0.260
Site 3	12/25/2008	7.57	10.54	11.91		0.304	0.3	0.240
Site 4	3/24/2000	8.35	9.1	11.2			4.4	0.570
Site 4	4/27/2000	7.9	8.5	11.4			4.8	0.450
Site 4	5/17/2000	7.59	9.4	14			7.7	0.380
Site 4	5/31/2000	7.84	8.3	13.4			3.5	0.220
Site 4	6/9/2000	7.9	8.2	14.2			5.5	0.300
Site 4	6/22/2000	7.78	7	14.2			7.7	0.510
Site 4	7/11/2000	7.86	8.4	17.3			7.4	0.570
Site 4	7/25/2000	7.44	8.4	15.6			6.7	0.690
Site 4	8/16/2000	7.37	5.8	17			7.9	0.230
Site 4	9/21/2000	7.58	6.7	15.5			7.5	0.300
Site 4	10/20/2000	7.9	7.9	14.9			5.1	0.550
Site 4	3/15/2001	8.34	11.5	8.4			1.1	0.950
Site 4	4/19/2001	8.17	10.3	14.5			4.3	0.500
Site 4	5/8/2001	8.4	10.4	12.7			2.8	0.320
Site 4	5/23/2001	8.38	14.8	14.9			2.0	0.410
Site 4	6/14/2001	8.17	9	19.3			3.3	0.200
Site 4	6/29/2001	8.2	8.9	15.9			3.2	0.180
Site 4	7/11/2001	8.35	8.80	15.1			2.6	0.170
Site 4	7/24/2001	8.25	8.73	18			1.4	0.120
Site 4	8/15/2001	8.15	8.76	18.8			1.9	0.320
Site 4	9/19/2001	8.35	9.8	14.9			1.7	0.180
Site 4	10/12/2001	8.32	9.65	10.7			2.9	0.180
Site 4	3/14/2002	8.27	14.85	9.3			2.8	1.310
Site 4	4/5/2002	8.45	15	9.3			1.3	0.080
Site 4	4/23/2002	8.96	13.05	11.7			2.1	0.150
Site 4	5/8/2002	8.93	10.1	15.4			3.5	0.100
Site 4	5/29/2002	8.92	7.67	20.1			4.6	0.090
Site 4	6/12/2002	8.89	9.36	16.4			2.0	0.080
Site 4	6/26/2002	8.86	7.32	22.3			2.2	0.170
Site 4	7/12/2002	9.02	9.85	15.2			1.8	0.160
Site 4	7/24/2002	8.23	7.88	20.8			1.2	0.060
Site 4	8/14/2002	8.77	6.89	21.8			0.7	0.270
Site 4	9/11/2002	8.76	5.84	21.7			0.3	0.130
Site 4	10/21/2002	8.05	10.12	11.6			2.5	0.450
Site 4	3/17/2003	7.97	10.33	14.7			2.9	0.110
Site 4	4/8/2003	8.27	9.47	10.5			2.3	0.490
Site 4	4/23/2003	7.93	8.88	11.1			4.8	0.170
Site 4	5/8/2003	7.91	8.33	13.2			2.7	0.450
Site 4	5/20/2003	7.74	8.86	12.8			3.1	0.390
Site 4	6/10/2003	7.5	10.10	14.8			3.3	0.050
Site 4	6/24/2003	7.74	10.10	15.4			2.9	0.130
Site 4	7/7/2003	7.71	9.70	14.3			3.0	0.100

Antietam National Battlefield Natural Resource Condition Assessment

Site	Date	pH	DO	Temp	ANC	Sal	NO ₃	PO ₄
ANTI data								
Site 4	7/21/2003	8.02	9.34	16			2.1	0.140
Site 4	8/4/2003	8.15	9.59	15.9			0.8	0.120
Site 4	8/18/2003	8.14	9.64	15.6			0.3	0.100
Site 4	9/22/2003	7.75	9.95	14.2			3.1	0.090
Site 4	10/16/2003	7.74	10.34	11.3			2.6	0.390
Site 4	3/17/2004	8.12	10.61	9.44			2.0	0.360
Site 4	4/6/2004	8.3	10.42	14.4			2.3	0.300
Site 4	4/21/2004	7.97	10.38	12.78			5.4	0.150
Site 4	5/11/2004	8.03	9.41	14.44			2.5	0.180
Site 4	5/26/2004	7.77	8.88	14.44			3.5	0.090
Site 4	6/9/2004	7.83	9.19	13.33			4.2	0.320
Site 4	6/25/2004	7.87	8.84	14.44			2.8	0.190
Site 4	7/14/2004	8.07		15.4			1.9	0.140
Site 4	7/28/2004	7.99		16.3			1.8	0.510
Site 4	8/16/2004	8.16	13.04	16.5			1.5	0.230
Site 4	8/31/2004	7.92	8.46	19			0.6	0.430
Site 4	9/27/2004	7.82	9.64	16.8			1.2	0.210
Site 4	10/21/2004	7.95	8.94	12.1			3.2	0.240
Site 4	2/8/2005	8.1	13.9	11.28		0.369	2.7	0.340
Site 4	2/23/2005	8.06	11.31	8.55		0.325	1.0	0.140
Site 4	3/7/2005	8.13	11.77	9.77		0.388	1.5	0.140
Site 4	3/25/2005	7.91	10.79	10.49		0.327	1.6	0.090
Site 4	4/15/2005	11.32	8.01	13.84		0.310	3.2	0.500
Site 4	4/28/2005	8.08	10.01	15.16		0.308	2.4	0.330
Site 4	5/12/2005	8.09	10.54	12.02		0.365	0.7	0.360
Site 4	5/27/2005	8.10	10.77	14.31		0.374	1.0	0.010
Site 4	6/10/2005	8.10	9.48	17.27		0.376	2.1	0.010
Site 4	6/24/2005	8.13	9.69	17.04		0.373	1.3	0.270
Site 4	7/13/2005	8.08	9.41	17.78		0.437	2.0	0.430
Site 4	7/26/2005	8.00	9.07	16.67		0.426	3.4	0.370
Site 4	8/12/2005	8.06	9.20	17.98		0.427	1.6	0.100
Site 4	8/30/2005	8.13	9.23	18.86		0.422	1.8	0.070
Site 4	9/14/2005	8.03	9.23	15.66		0.400	8.0	0.220
Site 4	9/30/2005	7.98	11.16	10.67		0.399	2.0	0.410
Site 4	10/19/2005	8.14	11.04	10.96		0.439	2.5	0.100
Site 4	11/3/2005	7.74	11.18	9.94		0.416	9.5	0.330
Site 4	11/14/2005	7.92	10.87	11.33		0.411	2.1	0.170
Site 4	11/30/2005	7.21	10.31	11.24		0.402	3.0	0.330
Site 4	12/21/2005	8.1	12.7	6.73		0.389	1.7	1.170
Site 4	12/28/2005	6.46	11.43	7.55		0.404	4.3	0.340
Site 4	1/30/2006	8.08	11.62	9.82		0.384	3.1	0.200
Site 4	2/24/2006	8.22	12.15	9.07		0.374	3.0	0.230
Site 4	3/27/2006	5.95	14.16	7.28		0.364	2.9	0.330
Site 4	4/26/2006	6.77	11.29	13.67		0.386	3.6	0.190

Site	Date	pH	DO	Temp	ANC	Sal	NO ₃	PO ₄
ANTI data								
Site 4	5/30/2006	6.46	9.53	17.96		0.393	1.9	0.190
Site 4	6/29/2006	6.52	9.22	14.27		0.386	4.4	0.440
Site 4	7/29/2006	6.22	9.62	17.13		0.392	2.7	0.180
Site 4	8/28/2006	6.65	8.53	19.05		0.389	2.7	0.320
Site 4	9/27/2006	6.47	9.58	14.17		0.412	2.1	0.260
Site 4	10/30/2006	6.22	10.96	10.16		0.412	5.5	0.160
Site 4	11/28/2006	7.54	10.9	12.42		0.398	7.8	0.200
Site 4	1/9/2007	6.65	11.3	8.99		0.383	5.0	0.540
Site 4	1/30/2007	6.85	12.51	5.09		0.380	8.2	0.350
Site 4	3/6/2007	7.14	11.92	9.72		0.389	1.1	0.430
Site 4	3/20/2007					0.008	3.5	0.220
Site 4	4/24/2007	7.08	10.59	15.3		0.377	3.7	0.210
Site 4	5/24/2007	6.88	9.78	13.84		0.378	3.7	0.080
Site 4	6/22/2007					0.008	3.1	0.200
Site 4	7/24/2007	6.95	8.83	17.72		0.366	3.0	0.160
Site 4	8/28/2007	7.01	7.42	18.37		0.429	2.2	0.120
Site 4	9/27/2007	7.53	5.91	19.11		0.463		0.150
Site 4	10/31/2007	6.17	10.69	7.79		0.345	1.5	0.150
Site 4	11/29/2007	6.25	11.78	6.67		0.438	1.1	0.330
Site 4	12/21/2007	7.63	12.37	8.84		0.452	2.6	0.060
Site 4	2/5/2008	6.53	11.71	8.8		0.436	1.6	0.130
Site 4	2/28/2008	7.75	11.77	7.22		0.417	2.0	0.260
Site 4	4/7/2008	8.17	11.48	10.86		0.396	0.9	0.160
Site 4	4/30/2008	8.01	12.75	12.66		0.398	1.5	0.320
Site 4	5/23/2008	7.96	9.98	14.65		0.387	3.2	0.090
Site 4	6/20/2008	8	9.56	16.39		0.386	3.0	0.060
Site 4	7/22/2008	7.97	8.64	18.57		0.411	0.8	0.160
Site 4	8/22/2008	7.91	9.71	15.3		0.254	0.2	0.200
Site 4	9/29/2008	7.94	8.84	17.44		0.417	2.1	0.540
Site 4	10/30/2008	7.71	11.04	7.22		0.418	0.5	0.130
Site 4	11/25/2008	8.01	13.27	4.76		0.427	0.0	0.070
Site 4	12/15/2008	7.72	10.86	10.46		0.439	1.1	0.240
Site 5	3/24/2000	7.9	11.1	11.2			5.2	1.200
Site 5	4/27/2000	8.29	12.1	12			7.4	0.570
Site 5	5/17/2000	7.93	8.9	18.2			8.2	0.710
Site 5	5/31/2000	7.96	7	15.7			5.6	0.520
Site 5	6/9/2000	8.07	8.2	17.7			3.4	0.310
Site 5	6/22/2000	7.96	7.3	16.1			7.1	1.190
Site 5	7/11/2000	7.5	4.6	17.7			4.9	0.430
Site 5	7/25/2000	7.7	10.9	18.8			8.4	0.960
Site 5	8/16/2000	7.57	7.9	20			4.6	0.580
Site 5	9/21/2000	7.64	7.2	15.9			5.7	0.380
Site 5	10/20/2000	7.75	11.4	19.2			4.5	0.170
Site 5	3/15/2001	7.94	12.4	6.2			4.2	0.480

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Site	Date	pH	DO	Temp	ANC	Sal	NO ₃	PO ₄
ANTI data								
Site 5	4/19/2001	7.95	11.2	11.5			7.7	0.790
Site 5	5/8/2001	7.9	7.2	10.5			4.1	0.500
Site 5	5/23/2001	7.85	6.8	11.8			5.9	0.670
Site 5	6/14/2001	7.8	9.8	15.2			13.2	1.810
Site 5	6/29/2001	7.46	7.83	16.3			8.6	0.320
Site 5	7/11/2001	7.85	6.5	15.4			6.4	0.410
Site 5	8/15/2001	7.6	4.77	19.4			4.8	0.280
Site 5	9/19/2001	7.88	7.11	17.7			3.6	0.170
Site 5	10/12/2001	8.15	7.66	14			5.5	0.240
Site 5	4/5/2002	8.25	13.68	8.7			6.3	0.360
Site 5	4/23/2002	8.69	12.12	12.2			2.1	0.170
Site 5	5/8/2002	7.97	9.27	16.2			1.4	0.250
Site 5	5/29/2002	7.75	10.19	14.8			3.2	0.500
Site 5	6/12/2002	7.85	7.88	18.8			6.2	0.220
Site 5	6/26/2002	7.68	8.89	18.8			11.0	0.140
Site 5	7/12/2002	8.38	10	18			5.3	0.380
Site 5	7/24/2002	7.77	7.4	20.4			9.9	0.200
Site 5	8/14/2002	7.92	5.98	22.7			9.2	0.150
Site 5	9/11/2002	8.22	7.27	20			8.9	0.080
Site 5	10/21/2002	6.86	9.08	16			4.8	0.290
Site 5	3/17/2003	7.18	8.62	10.1			6.6	0.210
Site 5	4/8/2003	7.52	8.51	10.1			7.8	0.270
Site 5	4/23/2003	7.37	7.63	11			5.1	0.210
Site 5	5/8/2003	7.13	8.48	13.1			10.0	0.190
Site 5	5/20/2003	6.94	7.82	12.1			8.7	0.200
Site 5	6/10/2003	7.19	6.6	13.2			6.9	0.460
Site 5	6/24/2003	7.12	7.50	13.6			9.0	0.220
Site 5	7/7/2003	7.02	7.80	14.8			9.6	0.060
Site 5	7/21/2003	7.17	8.58	16.8			9.0	0.220
Site 5	8/4/2003	7.33	7.49	17.8			5.9	0.240
Site 5	8/18/2003	7.06	7.97	17.2			7.8	0.220
Site 5	9/22/2003	6.9	7.44	16.6			7.7	0.160
Site 5	10/16/2003	7.14	7.35	17.6			6.6	0.100
Site 5	3/17/2004	7.96	10.2	10.55			4.9	0.590
Site 5	4/6/2004	7.34	12	12.22			2.5	0.590
Site 5	4/21/2004	7.37	10	11.67			8.5	0.140
Site 5	5/11/2004	7.31	8.45	11.67			7.7	0.280
Site 5	5/26/2004	7.28	7.68	13.33			8.1	0.020
Site 5	6/9/2004	7.18	7.87	13.33			5.1	0.260
Site 5	6/25/2004	7.14	7.45	14.44			7.2	0.110
Site 5	7/14/2004	7.34		19.1			7.8	0.200
Site 5	7/28/2004	7.39		18.4			7.0	0.260
Site 5	8/16/2004	7.54	6.56	20.2			6.4	0.240
Site 5	8/31/2004	7.33	5.53	21.9			5.6	0.340

Site	Date	pH	DO	Temp	ANC	Sal	NO ₃	PO ₄
ANTI data								
Site 5	9/27/2004	7.12	9.24	18.3			4.6	0.100
Site 5	10/21/2004	6.95	7.18	15.8			5.3	0.310
Site 5	2/8/2005	7.28	12.53	10.31		0.419	6.5	0.210
Site 5	2/23/2005	6.57	9.93	9.28		0.411	3.7	0.390
Site 5	3/7/2005	6.89	9.26	9.7		0.413	3.9	0.130
Site 5	3/25/2005	6.97	9.2	10.53		0.315	5.2	0.330
Site 5	4/15/2005	5.54	9.08	10.72		0.308	4.8	0.310
Site 5	4/28/2005	6.28	10.84	12.40		0.315	6.2	0.290
Site 5	5/12/2005	6.66	10.19	11.95		0.381	3.7	0.420
Site 5	5/27/2005	7.44	10.68	13.29		0.379	1.8	0.290
Site 5	6/10/2005	6.98	8.81	16.56		0.395	4.7	0.050
Site 5	6/24/2005	7.60	8.40	18.23		0.394	5.4	0.240
Site 5	7/13/2005	7.02	8.83	16.67		0.453	5.7	0.270
Site 5	7/26/2005	7.25	7.94	18.46		0.448	3.8	0.610
Site 5	8/12/2005	7.31	7.61	20.77		0.464	4.2	0.120
Site 5	8/30/2005	7.52	7.27	21.50		0.460	3.5	0.390
Site 5	9/14/2005	7.82	7.37	20.21		0.426	3.1	0.370
Site 5	9/30/2005	8	8.29	16.64		0.401	1.0	0.030
Site 5	10/19/2005	7.48	9.5	15.95		0.449	2.7	0.250
Site 5	11/3/2005	6.94	9.12	15.41		0.437	5.7	0.100
Site 5	11/14/2005	7.57	10.67	15.04		0.436	4.1	0.270
Site 5	11/30/2005	5.6	9.06	11.68		0.383	0.0	1.540
Site 5	12/21/2005	6.07	10.1	11.64		0.431	0.4	1.300
Site 5	12/28/2005	7.1	7.59	11.76		0.262	7.3	0.260
Site 5	1/20/2006	7.07	11.29	11.77		0.384	8.1	0.450
Site 5	1/20/2006	6.35	8.25	9.2		0.389	4.2	0.250
Site 5	1/30/2006	7.23	9.81	11.55		0.393	8.0	0.150
Site 5	2/24/2006	6.27	10.72	9.51		0.400	10.1	0.160
Site 5	3/27/2006	6.3	12.73	10.21		0.399	7.8	
Site 5	4/26/2006	5.97	10.74	11.35		0.413	6.3	0.430
Site 5	5/30/2006	6.52	9.1	16.21		0.418	8.4	0.070
Site 5	6/29/2006	5.76	8.17	15.36		0.384	9.0	0.260
Site 5	7/29/2006	5.49	9.66	18.9		0.413	6.4	0.600
Site 5	8/28/2006	6.31	7.38	20.39		0.415	9.7	0.370
Site 5	9/27/2006	5.61	8.92	16.83		0.432	4.9	0.160
Site 5	10/30/2006	7.03	8.85	15.69		0.419	9.9	0.300
Site 5	11/28/2006	6.34	9.11	14.18		0.401	6.2	0.120
Site 5	1/9/2007	6.92	7.86	12.47		0.407	5.5	0.700
Site 5	1/30/2007	5.92	9.73	9.68		0.410	5.1	0.500
Site 5	3/6/2007	6.28	10.1	9.53		0.376	2.3	0.270
Site 5	3/20/2007					0.008	8.5	0.190
Site 5	4/24/2007	5.74	8.85	11.36		0.386	10.0	0.190
Site 5	5/24/2007	6.06	10	13.42		0.402	11.9	0.050
Site 5	6/22/2007					0.008	9.6	0.420

Antietam National Battlefield Natural Resource Condition Assessment

Site	Date	pH	DO	Temp	ANC	Sal	NO ₃	PO ₄
ANTI data								
Site 5	7/24/2007	6.42	4.92	20.27		0.405	7.6	2.150
Site 5	8/28/2007	5.84	8.34	19.38		0.459	8.3	0.730
Site 5	9/27/2007	7.51	12.01	23.77		0.425	9.8	0.200
Site 5	10/31/2007	6.07	9.67	15.62		0.463	7.3	0.260
Site 5	11/29/2007	6.39	10.29	12.09		0.458	4.2	0.350
Site 5	12/21/2007	6.04	9.47	12.93		0.424	2.9	0.080
Site 5	2/5/2008	6.84	10.09	11.13		0.425	1.2	0.370
Site 5	2/28/2008	6.08	9.93	9.98		0.445	4.0	01.17
Site 5	4/7/2008	5.49	10.03	10.55		0.408	5.1	0.100
Site 5	4/30/2008	6.64	9.34	11.87		0.388	5.9	0.210
Site 5	5/23/2008	6.7	9.29	12.89		0.383	5.4	0.030
Site 5	6/20/2008	7.28	9.15	19.34		0.404	1.1	0.180
Site 5	7/22/2008	6.09	7.9	17.04		0.418	2.7	0.070
Site 5	8/22/2008	7.3	6.51	21.36		0.422	7.5	0.200
Site 5	9/29/2008	7.59	8.04	19.62		0.447	1.2	0.090
Site 5	10/30/2008	5.84	10.76	11.39		0.417	2.0	0.220
Site 5	11/25/2008	6.39	9.69	9.07		0.410	1.0	0.220
Site 5	12/15/2008	6.82	9.53	13.02		0.413	1.5	0.410
Site 6	3/24/2000	9.8	9.8	12			5.1	0.340
Site 6	4/27/2000	8.15	8.1	10.1			2.5	0.280
Site 6	5/17/2000	7.85	5.8	11.7			3.7	0.200
Site 6	5/31/2000	7.84	4.8	12.2			4.6	0.640
Site 6	6/9/2000	7.88	3.4	13.1			4.2	0.420
Site 6	6/22/2000	7.78	5	14.2			3.3	0.500
Site 6	7/11/2000	7.67	3.3	14.6			5.2	0.870
Site 6	7/25/2000	7.77	5.2	15.6			6.5	0.520
Site 6	8/16/2000	7.57	2.6	16.4			4.9	0.300
Site 6	9/21/2000	7.62	5.7	15.6			5.3	0.230
Site 6	10/20/2000	7.69	3.3	13.7			5.1	0.330
Site 6	3/15/2001	7.57	7.2	8.7			8.2	0.770
Site 6	4/19/2001	7.65	8.2	10.2			6.4	0.630
Site 6	5/8/2001	7.68	5.4	10.8			5.4	0.360
Site 6	5/23/2001	7.68	10.2	11.9			7.6	0.600
Site 6	6/14/2001	7.78	5.8	13.4			9.7	0.140
Site 6	6/29/2001	7.6	4.7	13.8			7.1	0.100
Site 6	7/11/2001	7.4	2.5	13.6			7.2	0.240
Site 6	7/24/2001	7.6	0.95	14.4			4.2	0.170
Site 6	8/15/2001	7.61	1.16	15.4			5.6	1.970
Site 6	9/19/2001	7.57	1.25	14			5.0	0.130
Site 6	10/12/2001	7.66	2.11	11.8			5.2	0.170
Site 6	3/14/2002	7.88	3.21	6.9			2.8	0.210
Site 6	4/5/2002	8.02	3.25	7.7			2.6	0.240
Site 6	4/23/2002	8.13	4.33	9.8			3.6	0.130
Site 6	5/8/2002	7.86	5.8	11.1			6.4	0.150

Site	Date	pH	DO	Temp	ANC	Sal	NO ₃	PO ₄
ANTI data								
Site 6	5/29/2002	8.03	4.31	12.2			7.2	0.170
Site 6	6/12/2002	7.83	14.46	13.8			9.3	0.090
Site 6	6/26/2002	7.92	3.33	14.3			6.7	0.140
Site 6	7/12/2002	8.04	3.02	14.3			5.2	0.090
Site 6	7/24/2002	7.88	1.43	16			5.4	0.170
Site 6	8/14/2002	7.86	2.06	16.4			5.4	0.020
Site 6	9/11/2002	8.06	0.58	15			5.9	0.210
Site 6	10/21/2002	7.26	6.3	14.2			6.0	0.100
Site 6	3/17/2003	7.26	7.99	13.3			5.0	0.510
Site 6	4/8/2003	7.36	6.8	9.9			4.3	0.200
Site 6	4/23/2003	7.18	6.36	10.4			4.3	0.300
Site 6	5/8/2003	7.12	5.5	11.2			5.6	0.200
Site 6	5/20/2003	7.08	7.63	11.2			6.1	0.140
Site 6	6/10/2003	6.87	7.90	11.7			5.8	0.230
Site 6	6/24/2003	6.94	7.50	12.6			5.6	0.190
Site 6	7/7/2003	7.1	4.80	13.4			6.2	0.180
Site 6	7/21/2003	7.22	3.5	14.1			8.0	0.080
Site 6	8/4/2003	7.28	3.23	14.5			6.3	0.170
Site 6	8/18/2003	7.24	3.2	14.9			4.3	0.170
Site 6	9/22/2003	6.92	3.52	15.2			4.3	0.120
Site 6	10/16/2003	7.2	4.31	14.3			5.8	0.290
Site 6	3/17/2004	7.36	6.05	8.89			4.4	0.380
Site 6	4/6/2004	7.29	8.1	10			6.9	0.510
Site 6	4/21/2004	7.37	7.87	11.11			10.0	0.200
Site 6	5/11/2004	7.45	5.78	11.11			5.8	0.060
Site 6	5/26/2004	7.33	4.8	12.22			6.9	0.090
Site 6	6/9/2004	7.29	5.50	12.78			8.6	0.170
Site 6	6/25/2004	7.29	4.70	12.22			7.7	0.170
Site 6	7/14/2004	7.19		14.9			4.3	0.140
Site 6	7/28/2004	7.21		15.5			6.2	0.120
Site 6	8/16/2004	7.5	3.3	16.4			5.9	0.140
Site 6	8/31/2004	7.02	1.86	17.4			4.8	0.140
Site 6	9/27/2004	6.87	0.62	16.4			6.8	0.000
Site 6	10/21/2004	7.02	2.7	13			4.8	0.390
Site 6	2/8/2005	6.48		9.88		0.264	6.5	0.670
Site 6	2/23/2005	7.2	5.37	9.31		0.276	9.2	0.350
Site 6	3/7/2005	7.3	6.74	9.44		0.268	5.6	0.220
Site 6	3/25/2005	7.17	8.52	10.17		0.210	5.5	0.180
Site 6	4/15/2005	7.12	8.25	10.57		0.209	6.7	0.490
Site 6	4/28/2005	7.29	6.75	11.77		0.217	5.3	0.440
Site 6	5/12/2005	7.45	6.15	11.23		0.259	3.6	0.560
Site 6	5/27/2005	7.28	4.84	11.31		0.263	5.2	0.020
Site 6	6/10/2005	7.38	2.78	12.62		0.263	4.7	0.190
Site 6	6/24/2005	7.26	2.45	13.32		0.268	7.4	0.270

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Site	Date	pH	DO	Temp	ANC	Sal	NO ₃	PO ₄
ANTI data								
Site 6	7/13/2005	7.36	2.33	15.61		0.295	4.0	0.150
Site 6	7/26/2005	7.18	1.68	15.74		0.297	3.3	0.270
Site 6	8/12/2005	7.26	2.34	15.73		0.304	4.5	0.240
Site 6	8/30/2005	7.31	3.51	16.50		0.303	5.5	0.280
Site 6	9/14/2005	6.97	3.40	15.43		0.287	4.0	0.200
Site 6	9/30/2005	7.74	4.86	13.15		0.286	3.4	0.350
Site 6	10/19/2005	7.5	6.57	14.22		0.276	7.0	0.170
Site 6	11/3/2005	7.18	6.42	13.2		0.273	11.0	0.160
Site 6	11/14/2005	7.15	4.76	13.27		0.274	7.0	0.290
Site 6	11/30/2005	6.94	8.6	13.29		0.237	5.4	0.050
Site 6	12/21/2005	7.14	6.64	11.35		0.277	12.3	0.090
Site 6	12/28/2005	8.09	10.78	8.68		0.406	2.8	0.620
Site 6	1/20/2006	6.99	7.13	11.6		0.253	6.8	0.200
Site 6	1/30/2006	5.86	7.02	11.48		0.259	7.4	0.140
Site 6	2/24/2006	7.27	6.82	10.24		0.262	2.5	0.410
Site 6	3/27/2006	6.76	6.48	9		0.271	7.1	0.410
Site 6	4/26/2006	5.63	6.63	10.59		0.279	6.0	0.320
Site 6	5/30/2006	5.21	4.03	11.87		0.277	7.2	0.400
Site 6	6/29/2006	5.72	9.04	12.75		0.239	8.1	0.190
Site 6	7/29/2006	4.9	4.07	14.55		0.264	6.4	0.360
Site 6	8/28/2006	5.1	3.43	15.14		0.275	2.8	0.190
Site 6	9/27/2006	4.96	3.8	14.45		0.282	5.9	0.260
Site 6	10/30/2006	6.86	6.61	14.05		0.270	7.6	0.250
Site 6	11/28/2006	7.16	6.05	13.43		0.267	6.0	0.310
Site 6	1/9/2007	6.99	7.58	12.19		0.256	6.9	0.210
Site 6	1/30/2007	6.98	6.05	9.47		0.275	0.1	0.160
Site 6	3/6/2007	7.06	8.69	9.94		0.269	3.9	0.670
Site 6	3/20/2007					0.008	2.2	0.040
Site 6	4/24/2007	5.65	7.55	10.77		0.270	7.2	0.020
Site 6	5/24/2007	5.84	3.45	11.69		0.270	6.3	0.100
Site 6	6/22/2007					0.008	6.6	0.100
Site 6	7/24/2007	5.72	2.83	13.91		0.282	6.1	0.140
Site 6	8/28/2007	5.52	1.47	15.23		0.288	5.7	0.200
Site 6	9/27/2007					0.008		
Site 6	10/31/2007	6.56	5.09	13.37		0.309	4.4	0.080
Site 6	11/29/2007	5.94	5.96	11.8		0.300	5.8	0.090
Site 6	12/21/2007	6.93	7.57	12.8		0.280	6.2	0.070
Site 6	2/5/2008	6.73	9.16	11.51		0.267	4.9	0.120
Site 6	2/28/2008	6.75	7.44	9.96		0.276	2.4	0.300
Site 6	4/7/2008	7.25	7.65	10.75		0.271	4.3	0.010
Site 6	4/30/2008	7.14	10.5	11.42		0.247	5.0	0.160
Site 6	5/23/2008	7.09	7.46	11.79		0.250	7.0	0.270
Site 6	6/20/2008	7.24	6.57	12.48		0.251	7.3	0.010
Site 6	7/22/2008	7.04	5.9	13.27		0.258	4.8	0.030

Site	Date	pH	DO	Temp	ANC	Sal	NO ₃	PO ₄
ANTI data								
Site 6	8/22/2008	7.13	3.97	13.75		0.266	3.7	0.130
Site 6	9/29/2008	7.03	3.47	14.39		0.276	5.7	0.190
Site 6	10/30/2008	7.24	3.78	10.69		0.288	1.4	0.140
Site 6	11/25/2008	7.29	5.07	9.58		0.293	0.4	0.230
Site 6	12/15/2008	6.92	7.8	12.82		0.269	5.5	0.190
Site 7	1/30/2006	7.38	11.11	11.24		0.378	6.3	0.240
Site 7	2/24/2006	8.3	12.04	9.61		0.369	1.9	0.260
Site 7	3/27/2006	8.24	12.28	11.34		0.347	6.4	0.190
Site 7	4/26/2006	7.35	10.82	13.72		0.366	4.7	0.330
Site 7	5/30/2006	6.67	10.08	17.68		0.354	6.4	0.180
Site 7	6/29/2006	6.41	10	14.96		0.401	6.8	0.320
Site 7	7/29/2006	6.17	10.31	16.39		0.361	5.7	0.440
Site 7	8/28/2006	6.21	10.38	16.22		0.284	2.3	0.450
Site 7	9/27/2006	6.88	10.24	14.65		0.258	5.7	0.310
Site 7	10/30/2006	7.43	10.62	12.72		0.378	3.4	0.370
Site 7	11/28/2006	7.72	11.15	13		0.386	6.9	0.130
Site 7	1/9/2007	7.87	11.04	11.43		0.334	4.5	0.620
Site 7	1/30/2007	7.88	11.53	8.9		0.358	1.3	0.470
Site 7	3/6/2007	7.93	11.46	11.02		0.387	5.3	0.310
Site 7	3/20/2007					0.008	5.8	0.090
Site 7	4/24/2007	6.95	11.03	14.13		0.366	6.5	0.050
Site 7	5/24/2007	7.06	10.3	14.16		0.357	4.6	0.410
Site 7	6/22/2007					0.008	6.7	0.090
Site 7	7/24/2007	6.9	10.15	17.06		0.334	6.4	0.040
Site 7	8/28/2007	6.7	9.78	16.62		0.364	6.5	0.110
Site 7	9/27/2007	6.73	8.95	17.56		0.220	6.9	0.280
Site 7	10/31/2007	7.11	11.37	11.33		0.384	4.6	0.120
Site 7	11/29/2007	6.69	11.1	10.49		0.339	1.6	0.020
Site 7	12/21/2007	7.48	12.2	9.7		0.409	3.6	0.110
Site 7	2/5/2008	7.55	11.38	10.36		0.404	1.1	0.430
Site 7	2/28/2008	8	11.62	9.01		0.402	2.4	0.150
Site 7	4/7/2008	8.24	11.12	11.89		0.299	4.9	0.120
Site 7	4/30/2008	8.01	12.46	12.83		0.389	5.0	0.190
Site 7	5/23/2008	7.88	10.37	13.85		0.373	4.7	0.200
Site 7	6/20/2008	8.01	10.44	15.23		0.355	4.1	0.080
Site 7	7/22/2008	8.01	10.11	16.49		0.351	0.9	0.500
Site 7	8/22/2008	8.1	9.07	16.26		0.346	1.6	0.210
Site 7	9/29/2008	7.87	10.50	14.57		0.358	0.4	0.240
Site 7	10/30/2008	8.1	10.58	11.5		0.358	4.1	0.170
Site 7	11/25/2008	8.25	11.99	9.22		0.361	0.8	0.190
Site 7	12/15/2008	7.95	11.25	11.73		0.400	2.8	0.290
Mean		7.51	8.62	13.57	4445	0.32	5.31	0.298
Std error		0.03	0.09	0.13	117.74	0.003	0.1	0.01

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 3.8.

Site name	BIBI
NCRW-120-N-2004	2.25
ANTI-101-N-2006	2.50
ANTM-101-N-2004	1.50
ANTM-112-N-2004	1.50
Mean	1.94
Std error	0.26

Table A-4. Physical Habitat Index. Values that do not meet the threshold (<81) are in bold. Site locations are shown in Figure 3.8.

Site name	PHI
NCRW-120-N-2004	63.00
ANTI-101-N-2006	57.17
ANTM-101-N-2004	72.35
ANTM-112-N-2004	49.91
Mean	60.61
Std error	4.74

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 3.9.

Site	Year	Mean cover (%)
ANTI-0072	2006	1.3
ANTI-0092	2007	27.8
ANTI-0190	2007	31.5
ANTI-0207	2007	5.4
Mean		16.5
Std error		7.7

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 3.9.

Site	Year	Invasive basal area	Total basal area	% invasive by basal area
Shrubs				
ANTI-0072	2006	0	0	
ANTI-0092	2007	0	355.5	0.00
ANTI-0190	2007	0	0	
ANTI-0207	2007	0	247.9	0.00
Trees				
ANTI-0072	2006	0	243.5	0.00
ANTI-0092	2007	0	19742.4	0.00
ANTI-0190	2007	3510.3	21336.0	16.45
ANTI-0207	2007	0	27549.7	0.00
Mean				2.74
Std error				2.74

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 3.9.

Site	Year	Mean cover (%)
ANTI-0072	2006	0.00
ANTI-0092	2007	0.00
ANTI-0190	2007	0.00
ANTI-0207	2007	0.00
Mean		0.00

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 3.9.

Site	Year	All seedlings	Native seedlings
ANTI-0072	2006	5833	5833
ANTI-0092	2007	1666	1666
ANTI-0190	2007	7500	7500
ANTI-0207	2007	2500	2500
Mean			4375
Std error			1377

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 3.8.

Site	Date	Fish IBI
NCRW-120-N-2004	2004	4.67
ANTI-101-N-2006	2006	4.67
ANTM-101-N-2004	2004	1.00
ANTM-112-N-2004	2004	1.00
Mean		2.84
Std error		1.06

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>Dendroica caerulescens</i>	Black-throated blue warbler	✓	—	
<i>Dryocopus pileatus</i>	Pileated woodpecker	—	✓	
<i>Empidonax virescens</i>	Acadian flycatcher	✓	✓	
Number of species		2	2	
Mean				2.00
Std error				0.00
Sensitive				
<i>Dendroica magnola</i>	Magnolia 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>Vireo flavifrons</i>	Yellow-throated vireo	—	✓	
<i>Wilsonia citrina</i>	Hooded warbler	✓	—	
Number of species		6	4	
Mean				5.00
Std error				1.00

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		✓		

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 3.9.

Year	Deer density (deer km ⁻²)	95% confidence interval	95% confidence interval
2001 (fall)	29.76	24.14	36.69
2002 (spring)	23.18	20.22	26.57
2002 (fall)	33.91	31.18	36.87
2003 (spring)	25.61	18.05	36.33
2003 (fall)	47.50	38.10	59.22
2004 (spring)	40.94	27.94	60.00
2004 (fall)	49.29	44.93	54.07
2005 (spring)	28.74	17.81	46.37
2005 (fall)	35.14	34.37	59.28
2006 (spring)	32.77	26.27	40.87
2006 (fall)	43.66	27.43	69.50
2007 (spring)	41.84	28.26	61.95
2007 (fall)	38.82	20.52	73.43
2008 (spring)	34.43	28.01	42.33
2008 (fall)	53.21	41.00	69.06
Mean	37.25		
Std error	2.28		

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

Scientific name	Common name/s	Status
Vascular plants		
<i>Abies balsamea</i>	balsam fir	Native
<i>Abies concolor</i>	balsam fir, colorado fir, concolor fir, silver fir, white balsam, white fir	Non-Native
<i>Abies nordmanniana</i>	Caucasian fir, Nordmann fir	Non-Native
<i>Abutilon theophrasti</i>	butterprint, buttonweed, Indian mallow, velvetleaf, velvetleaf (or butterprint), velvetleaf Indian mallow	Non-Native
<i>Acalypha gracilens</i>	slender copperleaf, slender threeseed mercury	Native
<i>Acalypha rhomboidea</i>	Virginia threeseed mercury	Native
<i>Acer negundo</i>	ashleaf maple, box elder, boxelder, boxelder maple, california boxelder, manitoba maple, western boxelder	Native
<i>Acer nigrum</i>	black maple, black sugar maple, hard maple, rock maple, sugar maple	Native
<i>Acer palmatum dissectum</i>		Non-Native
<i>Acer platanoides</i>	Norway maple	Non-Native
<i>Acer pseudoplatanus</i>	sycamore, sycamore maple	Non-Native
<i>Acer rubrum</i>	red maple	Native
<i>Acer saccharinum</i>	silver maple	Native
<i>Acer saccharum</i>	sugar maple	Native
<i>Achillea millefolium</i>	bloodwort, carpenter's weed, common yarrow, hierba de las cortaduras, milfoil, plumajillo, western yarrow, yarrow (common)	Native
<i>Achillea millefolium ssp. lanulosa</i>		Native
<i>Adiantum pedatum</i>	maidenfern, maidenhair, maidenhair fern, northern maidenhair	Native
<i>Aesculus hippocastanum</i>	horse chestnut	Non-Native
<i>Agastache nepetoides</i>	catnip giant hyssop, yellow giant hyssop, yellow gianthyssop	Native
<i>Ageratina altissima var. altissima</i>	white snakeroot	Native
<i>Agrimonia gryposepala</i>	agrimony, tall hairy agrimony, tall hairy grooveburr	Native
<i>Agrimonia pubescens</i>	groovebur, roadside agrimony, soft agrimony, soft groovebur	Native
<i>Agrimonia rostellata</i>	beaked agrimony, woodland groovebur	Native
<i>Agropyron repens</i>	couchgrass, dog grass, quackgrass	Non-Native
<i>Agrostis stolonifera</i>	carpet bentgrass, creeping bent, creeping bentgrass, redtop, redtop bent, seaside bentgrass, spreading bent	Native
<i>Agrostis stolonifera var. palustris</i>		Native
<i>Ailanthus altissima</i>	ailanthus, copal tree, tree of heaven, tree-of-heaven	Non-Native
<i>Alliaria officinalis</i>		Non-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 cernuum</i>	nodding onion	Native
<i>Allium tricoccum</i>	ramp, small white leek, wild leek	Native
<i>Allium vineale</i>	wild garlic	Non-Native
<i>Alopecurus geniculatus</i>	marsh meadow-foxtail, water foxtail	Non-Native
<i>Amaranthus blitoides</i>	mat amaranth, prostrate amaranth, prostrate pigweed	Native
<i>Amaranthus hybridus</i>	green pigweed, slim amaranth, smooth amaranth, smooth pigweed	Non-Native
<i>Ambrosia artemisiifolia</i>	annual ragweed, common ragweed, low ragweed, ragweed, Roman wormwood, short ragweed, small ragweed	Native
<i>Ambrosia trifida</i>	blood ragweed, giant ragweed, great ragweed, horseweed, perennial ragweed (great), tall ragweed	Native

Scientific name	Common name/s	Status
Vascular plants		
<i>Ampelopsis brevipedunculata</i>	Amur peppervine, creeper, porcelainberry, wild grape	Non-Native
<i>Amphicarpaea bracteata</i>	American hogpeanut, hog-peanut	Native
<i>Anagallis arvensis</i> var. <i>arvensis</i>		Non-Native
<i>Anagallis arvensis</i>	pimpernel, scarlet pimpernel	Non-Native
<i>Andropogon gerardii</i>	big bluestem, bluejoint, turkeyfoot	Native
<i>Andropogon scoparius</i>		Native
<i>Andropogon virginicus</i>	Broomsedge bluestem	Native
<i>Anemone virginiana</i>	tall thimbleweed, Virginia anemone	Native
<i>Anemonella thalictroides</i>		Native
<i>Antennaria neglecta</i>	field pussytoes	Native
<i>Antennaria plantaginifolia</i>	plantainleaf pussytoes, woman's tobacco	Native
<i>Anthemis arvensis</i>	corn chamomile, mayweed, scentless chamomile	Non-Native
<i>Anthemis cotula</i>	chamomile, dog fennel, dogfennel, mayweed, mayweed chamomile, mayweed dogfennel, stinking chamomile, stinkweed	Non-Native
<i>Anthoxanthum odoratum</i>	sweet vernalgrass	Non-Native
<i>Aplectrum hyemale</i>	Adam and Eve, puttyroot	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 laevigata</i>	smooth rock-cress, smooth rockcress	Native
<i>Arabis lyrata</i>	lyrate rockcress	Native
<i>Aralia nudicaulis</i>	Wild sarsaparilla	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 triphyllum</i>	Indian jack in the pulpit, Jack in the pulpit, Jack-in-the-pulpit	Native
<i>Aristolochia serpentaria</i>	Virginia dutchmanspipe, Virginia snakeroot	Native
<i>Arnoglossum atriplicifolium</i>	pale Indian pliantain	Native
<i>Artemisia biennis</i>	biennial sagewort, biennial wormwood	Non-Native
<i>Artemisia vulgaris</i>	common wormwood, mugwort	Non-Native
<i>Asarum canadense</i>	Canadian wild ginger, Canadian wildginger	Native
<i>Asclepias quadrifolia</i>	fourleaf milkweed	Native
<i>Asclepias syriaca</i>	broadleaf milkweed, common milkweed	Native
<i>Asclepias tuberosa</i>	butterfly milkweed, butterflyweed	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 lateriflorus</i>	calico aster	Native
<i>Aster shortii</i>	Short's aster	Native
<i>Aster simplex</i>		Native
<i>Athyrium filix-femina</i>	common ladyfern, lady fern, ladyfern, subarctic lady fern	Native

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Scientific name	Common name/s	Status
Vascular plants		
<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>Berteroa incana</i>	hoary alyssum, hoary false alyssum, hoary false madwort	Non-Native
<i>Betula alleghaniensis</i>	yellow birch	Native
<i>Betula nigra</i>	river birch	Native
<i>Betula pendula</i>	European white birch	Non-Native
<i>Betula pendula laciniata</i>		Non-Native
<i>Bidens bipinnata</i>	Spanish needles, spanish-needles	Native
<i>Bidens connata</i>	purple-stem beggarticks, purplestem beggarticks	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>Boehmeria cylindrica</i>	small-spike false nettle, smallspike false nettle, smallspike falsenettle	Native
<i>Botrychium biternatum</i>	sparselobe grapefern	Native
<i>Botrychium dissectum</i>	cut-leaf grape fern, cutleaf grapefern	Native
<i>Botrychium dissectum var. obliquum</i>		Native
<i>Botrychium multifidum</i>	broadleaf grapefern, leathery grape fern, leathery grapefern	Native
<i>Botrychium virginianum</i>	rattlesnake fern	Native
<i>Brassica nigra</i>	black mustard, shortpod mustard	Non-Native
<i>Bromus ciliatus</i>	fringed brome	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 pubescens</i>	hairy wood brome grass, hairy woodland brome	Native
<i>Bromus sterilis</i>	barren bromegrass, poverty brome, sterile brome	Non-Native
<i>Bromus tectorum</i>	cheat grass, cheatgrass, downy brome, early chess, military grass, wild oats	Non-Native
<i>Buglossoides arvensis</i>	corn gromwell, corn-gromwell, field gromwell	Non-Native
<i>Buxus sempervirens</i>	common box	Non-Native
<i>Calystegia sepium ssp. sepium</i>	hedge false bindweed	Non-Native
<i>Campanula americana</i>		Native
<i>Campanulastrum americanum</i>	American bellflower	Native
<i>Campsis radicans</i>	common trumpetcreeper, cow-itch, trumpet creeper	Native
<i>Capsella bursa-pastoris</i>	shepardspurse, shepherd's purse, shepherd's-purse, shepherdspurse	Non-Native
<i>Capsella rubella</i>		Non-Native
<i>Cardamine angustata</i>	slender toothwort	Native
<i>Cardamine concatenata</i>	cutleaf toothwort	Native
<i>Cardamine parviflora</i>	sand bittercress, smallflowered bittercress	Native
<i>Cardamine pratensis</i>	cuckoo flower	Native
<i>Carduus acanthoides</i>	plumeless thistle, spiny plumeless thistle, spiny plumeless-thistle	Non-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

Scientific name	Common name/s	Status
Vascular plants		
<i>Carex albicans</i>	whitetinge sedge	Native
<i>Carex amphibola</i>	amphibious sedge, eastern narrowleaf sedge	Native
<i>Carex blanda</i>	bland sedge, eastern woodland sedge, woodland 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 flaccosperma</i>	thinfruit sedge	Native
<i>Carex glaucoidea</i>	blue sedge	Native
<i>Carex grisea</i>		Native
<i>Carex hirsutella</i>	fuzzy wuzzy sedge, hirsute sedge	Native
<i>Carex hitchcockiana</i>	Hitchcock's sedge, hitchcock's sedge	Native
<i>Carex jamesii</i>	James' sedge	Native
<i>Carex laxiflora</i>	broad looseflower sedge	Native
<i>Carex molesta</i>	troublesome sedge	Native
<i>Carex muehlenbergii</i>	Muhlenberg's sedge, muhlenberg's sedge	Native
<i>Carex normalis</i>	greater straw sedge	Native
<i>Carex oligocarpa</i>	eastern few-fruit sedge, richwoods 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 sparganioides</i>	burr reed sedge	Native
<i>Carex spicata</i>	prickly sedge	Non-Native
<i>Carex stipata</i>	owlfruit sedge, sawbeak sedge, stalk-grain sedge	Native
<i>Carex swanii</i>	swan sedge, Swan's sedge	Native
<i>Carex tribuloides</i>	blunt broom sedge	Native
<i>Carex umbellata</i>	parasol sedge	Native
<i>Carex willdenowii</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 ovata</i>	carya ovata australis, shag-bark hickory, shagbark hickory	Native
<i>Castanea dentata</i>	American chestnut	Native
<i>Catalpa speciosa</i>	northern catalpa	Native
<i>Caulophyllum thalictroides</i>	blue cohosh	Native
<i>Celastrus orbiculatus</i>	Asian bittersweet, Asiatic bittersweet, oriental bittersweet	Non-Native
<i>Celastrus scandens</i>	American bittersweet, staffvine, waxwork	Native
<i>Celtis occidentalis</i>	common hackberry, hackberry, western hackberry	Native
<i>Centaurea cyanus</i>	bachelor's button, cornflower, garden cornflower	Non-Native
<i>Cerastium arvense</i>	starry chickweed, field chickweed	Native

Scientific name	Common name/s	Status
Vascular plants		
<i>Cerastium fontanum ssp. vulgare</i>	big chickweed, common mouse-ear chickweed	Non-Native
<i>Cerastium viscosum</i>		Non-Native
<i>Cerastium vulgatum</i>	big chickweed, mouseear chickweed	Non-Native
<i>Cercis canadensis</i>	eastern redbud, Redbud	Native
<i>Chaerophyllum procumbens</i>	spreading chervil	Native
<i>Chamaesyce nutans</i>	eyebane, nodding spurge, spotted sandmat, spotted spurge	Native
<i>Cheilanthes lanosa</i>	hairy lipfern	Native
<i>Chelidonium majus</i>	celandine	Non-Native
<i>Chenopodium album</i>	common lambsquarters, lambsquarters, lambsquarters goosefoot, white goosefoot	Non-Native
<i>Chenopodium ambrosioides</i>	Mexican tea, Mexican-tea	Non-Native
<i>Chimaphila maculata</i>	striped prince's pine, striped prince's-pine	Native
<i>Chondrilla juncea</i>	hogbite, rush skeletonweed, skeletonweed	Non-Native
<i>Chrysanthemum leucanthemum</i>	ox-eye daisy, oxeye daisy	Non-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>Circaea canadensis</i>		Non-Native
<i>Circaea lutetiana ssp. canadensis</i>	broad-leaf enchanter's-nightshade, broadleaf enchanter's nightshade	Native
<i>Circaea quadrisulcata</i>		Native
<i>Cirsium arvense</i>	Californian thistle, Canada thistle, Canadian thistle, creeping thistle, field thistle	Non-Native
<i>Cirsium vulgare</i>	bull thistle, common thistle, spear thistle	Non-Native
<i>Claytonia virginica</i>	narrow-leaved spring beauty, Spring beauty, Virginia springbeauty	Native
<i>Clematis viorna</i>	vasevine	Native
<i>Clematis virginiana</i>	devil's darning needles, devil's-darning-needles, virgin's bower, Virginia bower	Native
<i>Clinopodium vulgare</i>	wild basil	Native
<i>Collinsonia canadensis</i>	richweed	Native
<i>Commelina communis</i>	Asiatic dayflower, common dayflower	Non-Native
<i>Conium maculatum</i>	cigue maculee, cigue tachetee, deadly hemlock, poison hemlock, poison parsley, poison-hemlock	Non-Native
<i>Conoclinium coelestinum</i>	blue mistflower	Native
<i>Conopholis americana</i>	American squawroot, squaw-root	Native
<i>Convolvulus arvensis</i>	creeping jenny, European bindweed, field bindweed, morningglory, perennial morningglory, smallflowered morning glory	Non-Native
<i>Convolvulus sepium</i>	hedge false bindweed	Native
<i>Convolvulus sepium var. repens</i>		Native
<i>Conyza canadensis</i>	Canada horseweed, Canadian horseweed, horseweed, horseweed flea-bane, mares tail, marestail	Native
<i>Cornus alternifolia</i>	alternate-leaf dogwood, alternateteleaf dogwood	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

Scientific name	Common name/s	Status
Vascular plants		
<i>Corydalis flavula</i>	pale corydalis, yellow fumewort	Native
<i>Corylus americana</i>	hazelnut, American hazelnut	Native
<i>Cryptotaenia canadensis</i>	Canadian honewort, honewort	Native
<i>Cuscuta gronovii</i>	scaldweed	Native
<i>Cynodon dactylon</i>	Bermudagrass, chiendent pied-de-poule, common bermudagrass, devil-grass, grama-seda, manienie, motie molulu	Non-Native
<i>Cynoglossum officinale</i>	common houndstongue, gypsy-flower, gypsyflower, hound's tongue, houndstongue	Non-Native
<i>Cyperus echinatus</i>	globe flatsedge	Native
<i>Cyperus esculentus</i>	chufa, chufa flatsedge, yellow nutgrass, yellow nutsedge	Native
<i>Cyperus strigosus</i>	stawcolored flatsedge, strawcolor flatsedge, strawcolor nutgrass, straw-colored flatsedge, strawcolored nutgrass	Native
<i>Cystopteris bulbifera</i>	bulb bladderfern, bulblet bladderfern	Native
<i>Cystopteris fragilis</i>	brittle bladder fern, brittle bladderfern, fragile fern	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>Datura stramonium var. stramonium</i>	jimsonweed	Non-Native
<i>Daucus carota</i>	bird's nest, Queen Anne's lace, wild carrot	Non-Native
<i>Delphinium tricornis</i>	dwarf larkspur, rock larkspur	Native
<i>Dentaria heterophylla</i>		Native
<i>Dentaria laciniata</i>		Native
<i>Desmodium canescens</i>	hoary tickclover, hoary ticktrefoil	Native
<i>Desmodium paniculatum</i>	narrow-leaf tick-trefoil, paniced tickclover, panicedleaf ticktrefoil	Native
<i>Desmodium perplexum</i>	perplexed ticktrefoil	Native
<i>Dianthus armeria</i>	Deptford pink, Deptford's pink	Non-Native
<i>Dicentra canadensis</i>	squirrel corn	Native
<i>Dicentra cucullaria</i>	dutchman's breeches, Dutchman's-breeches, Dutchmans breeches, dutchmans britches	Native
<i>Dichanthelium boscii</i>	Bosc's panicgrass	Native
<i>Dichanthelium scabriusculum</i>	woolly rosette grass	Native
<i>Dichanthelium villosissimum var. villosissimum</i>	white-hair rosette grass, whitehair rosette grass	Native
<i>Digitaria filiformis</i>	slender crabgrass	Native
<i>Dioscorea quaternata</i>	fourleaf yam	Native
<i>Dioscorea villosa</i>	wild yam	Native
<i>Diospyros virginiana</i>	common persimmon, eastern persimmon, Persimmon	Native
<i>Dipsacus fullonum ssp. sylvestris</i>	common teasel, Fuller's teasel, teasel	Non-Native
<i>Dodecatheon meadia</i>	common shooting star, pride of Ohio	Native
<i>Draba verna</i>	spring draba, spring Whitlowgrass	Non-Native
<i>Dryopteris carthusiana</i>	spinulose wood fern, spinulose woodfern	Native
<i>Dryopteris marginalis</i>	marginal woodfern, woodfern	Native
<i>Duchesnea indica</i>	India mockstrawberry, Indian strawberry	Non-Native

Scientific name	Common name/s	Status
Vascular plants		
<i>Echinochloa muricata</i>	rough barnyard grass, rough barnyardgrass	Non-Native
<i>Echinochloa muricata</i> var. <i>muricata</i>	rough barnyardgrass	Native
<i>Echium vulgare</i>	blueweed, common echium, common vipersbugloss	Non-Native
<i>Eclipta alba</i>		Native
<i>Elaeagnus multiflora</i>	cherry silverberry	Non-Native
<i>Elaeagnus umbellata</i>	autumn olive, oleaster	Non-Native
<i>Eleusine indica</i>	crowsfoot grass, goose grass, goosegrass, Indian goose grass, Indian goosegrass, manienie ali'l, silver crabgrass, wiregrass	Non-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 villosus</i>	hairy wild rye, hairy wildrye, slender wild-rye	Native
<i>Elymus virginicus</i>	Virginia wild rye, Virginia wildrye	Native
<i>Epifagus virginiana</i>	beechnuts	Native
<i>Epilobium coloratum</i>	purple-leaf willowherb, purpleleaf willowherb, willowweed	Native
<i>Equisetum arvense</i>	field horsetail, scouring rush, western horsetail	Native
<i>Equisetum hyemale</i>	horsetail, scouring horsetail, scouringrush, scouringrush horsetail, tall scouring-rush, western scouringrush	Native
<i>Eragrostis spectabilis</i>	petticoat-climber, purple lovegrass	Native
<i>Erigenia bulbosa</i>	harbinger of spring	Native
<i>Erigeron annuus</i>	annual fleabane, eastern daisy fleabane	Native
<i>Erigeron philadelphicus</i>	Philadelphia daisy, Philadelphia fleabane	Native
<i>Erigeron pulchellus</i>	poor robin fleabane, robin's plantain	Native
<i>Erigeron strigosus</i>	Daisy Fleabane, prairie fleabane, rough fleabane	Native
<i>Erodium cicutarium</i>	alfilaree, alfilaria, California filaree, cutleaf filaree, filaree, red-stem stork's-bill, redstem, redstem filaree, redstem stork's bill, stork's bill, storksbill	Non-Native
<i>Erythronium albidum</i>	small white fawnlily, white fawnlily	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 atropurpurea</i>	eastern wahoo, wahoo	Native
<i>Eupatorium coelestinum</i>	blue mistflower	Native
<i>Eupatorium dubium</i>	coastalplain joepyeweed	Native
<i>Eupatorium fistulosum</i>	Joe Pye weed, trumpetweed	Native
<i>Eupatorium purpureum</i>	sweetscented joepyeweed	Native
<i>Eupatorium rugosum</i>	richweed, snakeroot, white snakeroot	Native
<i>Euphorbia corollata</i>	flowering spurge, floweringspurge euphorbia	Native
<i>Euphorbia dentata</i>	toothed euphorbia, toothed spurge, toothedleaf poinsettia	Native
<i>Euphorbia esula</i>	leafy spurge, spurge, wolf's milk, wolf's-milk	Non-Native
<i>Euphorbia supina</i>		Native
<i>Fagus grandifolia</i>	American beech	Native
<i>Festuca pratensis</i>		Non-Native

Scientific name	Common name/s	Status
Vascular plants		
<i>Festuca rubra</i>	ravine fescue, red fescue	Native
<i>Festuca subverticillata</i>	nodding fescue	Native
<i>Floerkea proserpinacoides</i>	false mermaid-weed, false mermaidweed, falsemermaid	Native
<i>Fraxinus americana</i>	white ash	Native
<i>Fraxinus americana</i> var. <i>biltmoreana</i>		Native
<i>Fraxinus pennsylvanica</i>	green ash	Native
<i>Galactia regularis</i>	eastern milkpea	Native
<i>Galactia volubilis</i>	downy milkpea	Native
<i>Galearis spectabilis</i>	showy orchid, showy orchis	Native
<i>Galinsoga ciliata</i>	shaggy soldier	Non-Native
<i>Galinsoga parviflora</i>	gallant soldier, gallant-soldier, gallantsoldier, littleflower quickweed	Non-Native
<i>Galinsoga quadriradiata</i>	fringed quickweed, hairy galinsoga, shaggy soldier, shaggy-soldier	Non-Native
<i>Galium aparine</i>	bedstraw, catchweed bedstraw, cleavers, cleaverwort, goose grass, scarthgrass, sticky-willy, stickywilly, white hedge	Native
<i>Galium asprellum</i>	rough bedstraw	Native
<i>Galium circaezans</i>	licorice bedstraw, wild licorice, woods bedstraw	Native
<i>Galium concinnum</i>	shining bedstraw	Native
<i>Galium lanceolatum</i>	lanceleaf wild licorice	Native
<i>Galium parisiense</i>	wall bedstraw	Non-Native
<i>Galium triflorum</i>	fragrant bedstraw, sweet bedstraw, sweetscented bedstraw	Native
<i>Geranium bicknellii</i>	Bicknell's cranesbill, northern crane's-bill	Native
<i>Geranium columbinum</i>	longstalk cranesbill	Non-Native
<i>Geranium maculatum</i>	spotted crane's-bill, spotted geranium, wild crane's-bill	Native
<i>Geranium molle</i>	awnless geranium, dovefoot geranium	Non-Native
<i>Geranium pusillum</i>	small geranium, small-flower crane's-bill	Non-Native
<i>Geum canadense</i>	white 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>Gleditsia triacanthus inermis</i>		Native
<i>Glyceria fluitans</i>	water mannagrass	Non-Native
<i>Glyceria striata</i>	fowl manna grass, fowl mannagrass	Native
<i>Gnaphalium obtusifolium</i> var. <i>obtusifolium</i>	rabbit tobacco	Native
<i>Gymnocladus dioicus</i>	Kentucky coffeetree, Kentucky coffeetree	Native
<i>Hackelia virginiana</i>	beggar's-lice, beggarslice, sticktight, virginia stickseed	Native
<i>Hamamelis virginiana</i>	American witchhazel, witch-hazel, witchhazel	Native
<i>Hedera helix</i>	English ivy	Non-Native
<i>Hemerocallis fulva</i>	orange day lily, orange daylily, tawny daylily	Non-Native
<i>Hepatica americana</i>		Native
<i>Hepatica nobilis</i> var. <i>acuta</i>	sharplobe hepatica	Native
<i>Hepatica nobilis</i> var. <i>obtusata</i>	roundlobe hepatica	Native
<i>Heracleum maximum</i>	common cowparsnip, cow parsnip, cowparsnip	Native

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Scientific name	Common name/s	Status
Vascular plants		
<i>Hesperis matronalis</i>	dame rocket, dame's rocket, dames rocket, dames violet, mother-of-the-evening	Non-Native
<i>Heuchera americana</i>	alumroot, American alumroot	Native
<i>Hibiscus syriacus</i>	althea, rose of Sharon, rose-of-sharon, shrub althea, shrub-althea	Non-Native
<i>Hieracium caespitosum</i>	meadow hawkweed, yellow hawkweed	Non-Native
<i>Hieracium venosum</i>	rattlesnakeweed	Native
<i>Hosta ventricosa</i>	blue plantain lily	Non-Native
<i>Houstonia caerulea</i>	azure bluet	Native
<i>Houstonia purpurea</i>	purple bluets, Venus' pride	Native
<i>Humulus japonicus</i>	Japanese hop	Non-Native
<i>Hybanthus concolor</i>	eastern greenviolet, nodding violet	Native
<i>Hydrangea arborescens</i>	smooth hydrangea, wild hydrangea	Native
<i>Hydrastis canadensis</i>	goldenseal	Native
<i>Hydrophyllum canadense</i>	blunt-leaf waterleaf, bluntleaf waterleaf	Native
<i>Hydrophyllum virginianum</i>	Shawnee salad, Shawnee-salad	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 punctatum</i>	spotted St. Johnswort	Native
<i>Hystrix patula</i>		Native
<i>Ilex crenata</i>	Japanese holly	Non-Native
<i>Ilex opaca</i>	American holly	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 morningglory, man of the earth, man-of-the-earth	Native
<i>Jeffersonia diphylla</i>	twinleaf	Native
<i>Juglans cinerea</i>	butternut	Native
<i>Juglans nigra</i>	black walnut	Native
<i>Juncus compressus</i>	roundfruit rush	Native
<i>Juncus tenuis</i>	field rush, path rush, poverty rush, slender rush, slender yard rush, wire-grass	Native
<i>Juniperus horizontalis plumosa</i>		Non-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>Lactuca biennis</i>	tall blue lettuce, wild blue lettuce	Native
<i>Lactuca canadensis</i>	Canada lettuce, Florida blue lettuce, wild lettuce	Native
<i>Lactuca floridana</i>	Florida lettuce, woodland lettuce	Native
<i>Lactuca scariola</i>		Non-Native
<i>Lactuca serriola</i>	China lettuce, prickly lettuce, wild lettuce	Non-Native
<i>Lamium album</i>	white deadnettle	Non-Native
<i>Lamium amplexicaule</i>	common henbit, giraffehead, henbit, henbit deadnettle	Non-Native
<i>Lamium maculatum</i>	spotted henbit	Non-Native
<i>Lamium purpureum</i>	purple deadnettle, red deadnettle	Non-Native

Scientific name	Common name/s	Status
Vascular plants		
<i>Laportea canadensis</i>	Canada lettuce, Canada woodnettle, Canadian wood-nettle, Canadian woodnettle	Native
<i>Larix decidua</i>	European larch	Non-Native
<i>Lechea intermedia</i>	largepod 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 cardiaca</i>	common motherwort, motherwort	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>Leucanthemum vulgare</i>	ox-eye daisy, oxeye daisy, oxeye-daisy, oxeyedaisy	Non-Native
<i>Ligustrum vulgare</i>	European privet, wild privet	Non-Native
<i>Linaria vulgaris</i>	butter and eggs, butterandeggs, flaxweed, greater butter-and-eggs, Jacob's ladder, ramsted, wild snapdragon, yellow toadflax	Non-Native
<i>Lindera benzoin</i>	northern spicebush, spicebush	Native
<i>Lindernia dubia</i>	moistbank pimpernel, shortstalk lindernia, yellow-seed false pimpernel, yellowseed false pimpernel	Native
<i>Liparis liliifolia</i>	brown widelip orchid	Native
<i>Liparis loeselii</i>	yellow wide-lip orchid, yellow widelip orchid	Native
<i>Lippia lanceolata</i>		Native
<i>Liquidambar styraciflua</i>	sweetgum	Native
<i>Liriodendron tulipifera</i>	tulip poplar, tuliptree, yellow poplar, yellow-poplar	Native
<i>Lobelia cardinalis</i>	cardinal flower	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>Lolium arundinaceum</i>	Lolium arundinaceum, tall fescue	Non-Native
<i>Lolium perenne ssp. perenne</i>	perennial rye grass, perennial 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
<i>Lonicera tatarica</i>	bush honeysuckle, Tartarian honeysuckle, Tartarian honeysuckle	Non-Native
<i>Ludwigia alternifolia</i>	bushy seedbox, seedbox	Native
<i>Ludwigia palustris</i>	marsh primrose-willow, marsh seedbox	Native
<i>Luzula echinata</i>	hedgheg woodrush	Native
<i>Lychnis alba</i>	white cockle	Native
<i>Lycopsis arvensis</i>		Non-Native
<i>Lycopus americanus</i>	American bugleweed, American water horehound, American waterhorehound, cut-leaf water-horehound, water horehound, waterhorehound	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 nummularia</i>	creeping jenny, moneywort	Non-Native
<i>Maclura pomifera</i>	bois d'arc, osage orange, osage-orange, osageorange	Native

Scientific name	Common name/s	Status
Vascular plants		
<i>Maianthemum racemosum</i> ssp. <i>racemosum</i>	false Solomon's-seal, feather Solomons seal, feathery false lily of the vally, feathery false Solomon's-seal	Native
<i>Malus floribunda</i>	Japanese flowering crabapple	Non-Native
<i>Matricaria discoidea</i>	disc mayweed, pineapple weed, pineappleweed	Non-Native
<i>Mellilotus officinalis</i>	yellow sweet-clover, yellow sweetclover	Non-Native
<i>Melissa officinalis</i>	common balm	Non-Native
<i>Menispermum canadense</i>	Canadian moonseed, common moonseed	Native
<i>Mentha arvensis</i>	field mint, wild mint	Native
<i>Mentha spicata</i>	bush mint (spearmint), spearmint	Native
<i>Mertensia virginica</i>	Virginia bluebells	Native
<i>Microstegium vimineum</i>	Japanese stiltgrass, Nepalese browntop	Non-Native
<i>Mikania scandens</i>	climbing hempvine, climbing hempweed	Native
<i>Mimulus alatus</i>	sharpwing monkeyflower	Native
<i>Mirabilis nyctaginea</i>	heart-leaf four-o'clock, heart-leaved four o'clock, heartleaf four o'clock, heartleaf four-o'clock, prairie four o clock, wild four-o'clock	Native
<i>Mitchella repens</i>	partridgeberry	Native
<i>Mitella diphylla</i>	twoleaf miterwort	Native
<i>Monarda clinopodia</i>	white bergamot	Native
<i>Monarda fistulosa</i>	mintleaf beebalm, Oswego-tea, wild bergamot, wildbergamot beebalm, wildbergamot horsemint	Native
<i>Monotropa uniflora</i>	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>Muhlenbergia tenuiflora</i>	slender muhly	Native
<i>Muscari botryoides</i>	common grape hyacinth	Non-Native
<i>Myrica pensylvanica</i>	northern bayberry	Native
<i>Narcissus pseudonarcissus</i>	common daffodil, daffodil	Non-Native
<i>Nasturtium officinale</i>	no common name (local name: watercress)	Non-Native
<i>Nepeta cataria</i>	catmint, catnip, catwort, field balm	Non-Native
<i>Nyssa sylvatica</i>	black gum, black tupelo, blackgum	Native
<i>Oenothera biennis</i>	common evening primrose, common evening-primrose, common eveningprimrose, evening primrose (common), hoary eveningprimrose, king's-cureall	Native
<i>Onoclea sensibilis</i>	sensitive fern	Native
<i>Ophioglossum vulgatum</i>	Southern adder's-tongue, southern adderstongue	Native
<i>Ornithogalum nutans</i>	drooping star of Bethlehem	Non-Native
<i>Ornithogalum umbellatum</i>	Pyrenees Star of Bethlehem, sleepydick, Star-of-Bethlehem	Non-Native
<i>Orobanche uniflora</i>	naked broom-rape, naked broomrape, oneflowered broomrape	Native
<i>Osmorhiza claytonii</i>	Clayton's sweetroot, hairy sweet-cicely	Native
<i>Osmorhiza longistylis</i>	aniseroor, longstyle sweetroot	Native
<i>Osmunda cinnamomea</i>	cinnamon fern	Native
<i>Ostrya virginiana</i>	eastern hophornbeam, hophornbeam	Native

Scientific name	Common name/s	Status
Vascular plants		
<i>Oxalis corniculata</i>	'ihi, creeping oxalis, creeping woods, creeping woodsorrel, oxalis, yellow oxalis, yellow wood sorrel	Native
<i>Oxalis europaea</i>		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>Panax quinquefolius</i>	American ginseng, american ginseng	Native
<i>Panicum boscii</i>		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 villosissimum</i>		Native
<i>Parietaria pensylvanica</i>	Pennsylvania pellitory	Native
<i>Paronychia canadensis</i>	smooth forked nailwort	Native
<i>Parthenocissus quinquefolia</i>	American ivy, fiveleaved ivy, Virginia creeper, woodbine	Native
<i>Paspalum ciliatifolium</i>		Native
<i>Paspalum dissectum</i>	mudbank crowngrass	Native
<i>Paspalum laeve</i>	field paspalum	Native
<i>Paspalum setaceum</i>	fringeleaf paspalum, sand paspalum, slender crown grass, thin paspalum	Native
<i>Paulownia tomentosa</i>	princess tree, princesstree, royal paulownia	Non-Native
<i>Pellaea atropurpurea</i>	purple cliffbrake, purple-stem cliff-brake, purple-stem cliffbrake	Native
<i>Perilla frutescens</i>	beefsteak, beefsteak mint, beefsteakplant, Purple mint	Non-Native
<i>Phacelia dubia</i>	smallflower phacelia	Native
<i>Phalaris arundinacea</i>	reed canary grass, reed canarygrass	Native
<i>Phleum pratense</i>	common timothy, timothy	Non-Native
<i>Phlox divaricata</i>	wild blue phlox	Native
<i>Phragmites australis</i>	common reed	Native
<i>Phryma leptostachya</i>	American lopseed, lopseed	Native
<i>Physalis heterophylla</i>	clammy ground-cherry, clammy groundcherry	Native
<i>Physalis heterophylla</i> var. <i>heterophylla</i>	clammy groundcherry	Native
<i>Physalis longifolia</i> var. <i>subglabrata</i>	longleaf groundcherry	Native
<i>Physalis virginiana</i>	ground cherry (Virginia), lanceleaf groundcherry, Virginia ground-cherry, Virginia groundcherry	Native
<i>Phytolacca americana</i>	American pokeweed, common pokeweed, inkberry, pigeonberry, poke, pokeberry, pokeweed	Native
<i>Picea abies</i>	Norway spruce	Non-Native
<i>Pilea pumila</i>	Canada clearweed, Canadian clearweed	Native
<i>Pinus resinosa</i>	norway pine, red pine	Non-Native
<i>Pinus rigida</i>	pitch pine	Native
<i>Pinus strobus</i>	easter white pine, eastern white pine, northern white pine, soft pine, weymouth pine, white pine	Native
<i>Pinus virginiana</i>	jersey pine, scrub pine, Virginia pine	Native
<i>Plantago aristata</i>	bottlebrush Indianwheat, largebracted plantain	Native

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Vascular plants		
<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	Native
<i>Plantago rugelii</i>	black-seed plantain, blackseed plantain, Rugel's plantain	Native
<i>Platanus occidentalis</i>	American sycamore, sycamore	Native
<i>Poa annua</i>	annual blue grass, annual bluegrass, walkgrass	Non-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>Polygonatum biflorum</i>	king Solomon's seal, King Solomon's-seal, smooth Solomon's seal, Solomon's seal	Native
<i>Polygonum aviculare</i>	prostrate knotweed, yard knotweed	Non-Native
<i>Polygonum caespitosum</i>	bristled knotweed, bunchy knotweed, oriental ladysthumb	Non-Native
<i>Polygonum cespitosum</i>	oriental ladysthumb	Native
<i>Polygonum convolvulus</i>	black bindweed, black-bindweed, climbing buckwheat, climbing knotweed, cornbind, dullseed cornbind, pink smartweed, wild buckwheat	Non-Native
<i>Polygonum hydropiper</i>	annual smartweed, marshpepper knotweed, mild water-pepper	Non-Native
<i>Polygonum hydropiperoides</i>	swamp smartweed	Native
<i>Polygonum lapathifolium</i>	curltop ladysthumb, curlytop knotweed, curlytop smartweed, dock-leaf smartweed, nodding smartweed, pale smartweed, smartweed	Native
<i>Polygonum pensylvanicum</i>	Pennsylvania knotweed, Pennsylvania smartweed, pinkweed, pinweed	Native
<i>Polygonum persicaria</i>	lady's-thumb, ladysthumb, ladysthumb smartweed, smartweed, spotted knotweed, spotted ladysthumb, spotted smartweed	Non-Native
<i>Polygonum virginianum</i>	jumpseed, Virginia smartweed	Native
<i>Polymnia canadensis</i>	rayless leafcup, whiteflower leafcup	Native
<i>Polymnia uvedalia</i>		Native
<i>Polypodium virginianum</i>	rock polypody	Native
<i>Polystichum acrostichoides</i>	Christmas fern	Native
<i>Populus deltoides</i>	common cottonwood, cottonwood, eastern cottonwood, plains cottonwood	Native
<i>Portulaca oleracea</i>	akulikuli-kula, common purslane, duckweed, garden purslane, little hogweed, little-hogweed, purslane, pursley, pusley, wild portulaca	Native
<i>Potentilla canadensis</i>	dwarf cinquefoil	Native
<i>Potentilla intermedia</i>	downy cinquefoil	Non-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 trifoliolata</i>	gall of the earth	Native
<i>Prunella vulgaris</i>	common selfheal, heal all, healall, selfheal	Native
<i>Prunus avium</i>	sweet cherry	Non-Native
<i>Prunus cerasus</i>	sour cherry	Non-Native
<i>Prunus pensylvanica</i>	fire cherry, pin cherry	Native
<i>Prunus serotina</i>	black cherry, black chokecherry	Native
<i>Prunus serrulata</i>	Japanese flowering cherry	Non-Native

Scientific name	Common name/s	Status
Vascular plants		
<i>Prunus virginiana</i>	chokecherry, chokecherry (common), common chokecherry, Virginia chokecherry	Native
<i>Pseudotsuga menziesii</i> var. <i>menziesii</i>	coast douglas fir, Douglas-fir	Non-Native
<i>Pseudotsuga taxifolia</i>	no common name (local name: Douglas fir)	Non-Native
<i>Pteridium aquilinum</i>	bracken, bracken fern, brackenfern, northern bracken fern, western brackenfern	Native
<i>Pyracantha coccinea</i>	scarlet firethorn	Non-Native
<i>Pyrola americana</i>	American wintergreen	Native
<i>Pyrola rotundifolia</i>		Native
<i>Pyrus comunis</i>	common pear	Non-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 michauxii</i>	swamp chestnut oak	Native
<i>Quercus muehlenbergii</i>	chinkapin oak	Native
<i>Quercus palustris</i>	pin oak	Native
<i>Quercus prinus</i>	chestnut oak	Native
<i>Quercus rubra</i>	northern red 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 acris</i>	meadow buttercup, tall buttercup	Non-Native
<i>Ranunculus bulbosus</i>	blister flower, bulbous buttercup, bulbous crowfoot, gowan, St. Anthony's turnip, yellow weed	Non-Native
<i>Ranunculus hispidus</i>	bristly buttercup	Native
<i>Ranunculus recurvatus</i>	blisterwort, littleleaf buttercup	Native
<i>Ranunculus sardous</i>	hairy buttercup	Non-Native
<i>Ranunculus sceleratus</i>	celeryleaf buttercup, cursed buttercup	Native
<i>Rhododendron carolinianum</i>	Carolina azalea	Non-Native
<i>Rhus aromatica</i>	fragrant sumac	Native
<i>Rhus glabra</i>	smooth sumac	Native
<i>Rhus hirta</i>	staghorn sumac	Native
<i>Rhus typhina</i>	staghorn sumac	Native
<i>Ribes cynosbati</i>	eastern prickly gooseberry, pasture currant	Native
<i>Robinia pseudoacacia</i>	black locust, false acacia, yellow locust	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 occidentalis</i>	black raspberry	Native
<i>Rubus pensilvanicus</i>	Pennsylvania blackberry	Native
<i>Rubus phoenicolasius</i>	Japanese wineberry, wine raspberry, wineberry	Non-Native
<i>Rudbeckia hirta</i>	blackeyed Susan, blackeyedsusan	Native
<i>Rudbeckia laciniata</i>	cutleaf coneflower, green-head coneflower	Native

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Scientific name	Common name/s	Status
Vascular plants		
<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 hastatulus</i>	heartwing dock, heartwing sorrel	Native
<i>Rumex obtusifolius</i>	bitter dock, bluntleaf dock	Non-Native
<i>Rumex pulcher</i>	fiddle dock	Non-Native
<i>Rumex verticillatus</i>	swamp dock	Native
<i>Salix exigua</i>	sandbar willow	Native
<i>Salix nigra</i>	black willow	Native
<i>Salvia lyrata</i>	lyreleaf sage	Native
<i>Sambucus nigra ssp. canadensis</i>	blue elder, common elderberry, elder, elderberry, Mexican elderberry	Native
<i>Sanguinaria canadensis</i>	bloodroot	Native
<i>Sanicula canadensis</i>	Canada sanicle, Canadian blacksnakeroot	Native
<i>Sanicula odorata</i>	cluster sanicle, clustered blacksnakeroot	Native
<i>Saponaria officinalis</i>	bouncing bet, bouncing-bett, bouncingbet, bouncingbet soapweed, soapwort, sweet Betty	Non-Native
<i>Sassafras albidum</i>	sassafras	Native
<i>Satureja vulgaris</i>		Native
<i>Saxifraga virginiana</i>	early saxifrage	Native
<i>Scrophularia marilandica</i>	carpenter's square, maryland figwort	Native
<i>Scutellaria incana</i>	hoary skullcap	Native
<i>Scutellaria incana var. incana</i>	hoary skullcap	Native
<i>Scutellaria lateriflora</i>	blue skullcap, mad dog skullcap	Native
<i>Scutellaria nervosa</i>	veiny skullcap	Native
<i>Sedum ternatum</i>	woodland stonecrop	Native
<i>Senecio aureus</i>	golden ragwort	Native
<i>Setaria faberi</i>	Chinese foxtail, Chinese millet, giant bristlegrass, giant foxtail, Japanese bristlegrass, nodding foxtail, tall green bristlegrass	Non-Native
<i>Setaria geniculata</i>	marsh bristlegrass	Native
<i>Setaria glauca</i>	pearl millet, pigeongrass, wild millet, yellow bristlegrass, yellow foxtail	Non-Native
<i>Setaria pumila</i>	cattail grass, yellow bristle grass, yellow bristlegrass	Non-Native
<i>Setaria viridis</i>	bottle grass, green bristle grass, green bristlegrass, green foxtail, pigeon-grass, wild millet	Non-Native
<i>Sicyos angulatus</i>	blueeyedgrass, bur cucumber, burcucumber, oneseed burr cucumber, wall bur cucumber	Native
<i>Sida spinosa</i>	prickly fanpetals, prickly sida	Native
<i>Silene cucubalus</i>		Non-Native
<i>Silene odora</i>		Native
<i>Silene stellata</i>	whorled catchfly, widowsfrill	Native
<i>Silene vulgaris</i>	bladder campion, bladder silene, cowbell, maiden's tears, maiden's-tears, maidenstears, rattleweed	Non-Native
<i>Sisymbrium altissimum</i>	Jim Hill mustard, tall hedge-mustard, tall mustard, tall tumbledustard, tumble mustard, tumbledustard, tumbleweed mustard	Non-Native
<i>Sisymbrium officinale</i>	hairypod hedgemustard, hedge mustard, hedge tumbledustard, hedge-mustard, hedgemustard, hedgeweed, wild mustard	Non-Native

Scientific name	Common name/s	Status
Vascular plants		
<i>Sisyrinchium angustifolium</i>	blue eyegrass, blue-eyed grass, common blue eyedgrass, common blue-eyedgrass, narrowleaf blue-eyed grass	Native
<i>Smilanthus uvedalius</i>	hairy leafcup	Native
<i>Smilacina racemosa</i>		Native
<i>Smilax herbacea</i>	herbaceous greenbrier, smooth carrionflower	Native
<i>Smilax hispida</i>	no common name (local name: bristly greenbrier)	Native
<i>Smilax rotundifolia</i>	bullbrier, common catbrier, common greenbrier, greenbrier, horsebrier, roundleaf greenbrier, roundleaf 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>Solanum nigrum</i>	black nightshade, deadly nightshade, garden 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 canadensis var. canadensis</i>	Canada goldenrod, Canadian goldenrod	Native
<i>Solidago canadensis var. hargerii</i>	Canadian goldenrod, Harger's goldenrod	Native
<i>Solidago canadensis var. scabra</i>	Canada goldenrod, Canadian goldenrod	Native
<i>Solidago flexicaulis</i>	zigzag goldenrod	Native
<i>Solidago juncea</i>	early goldenrod	Native
<i>Solidago nemoralis</i>	dyersweed goldenrod, gray goldenrod	Native
<i>Solidago odora</i>	anisescented goldenrod, fragrant goldenrod	Native
<i>Solidago ulmifolia</i>	elmleaf goldenrod	Native
<i>Sonchus asper</i>	perennial sowthistle, prickly sowthistle, spiny sowthistle, spiny-leaf sowthistle	Non-Native
<i>Sorbus americana</i>	American mountain ash	Native
<i>Sorghastrum nutans</i>	Indiangrass, yellow indian-grass	Native
<i>Sorghum halepense</i>	aleppo milletgrass, herbe de Cuba, Johnson grass, Johnsongrass, sorgho d'Alep, sorgo de alepo, zacate Johnson	Non-Native
<i>Sphenopholis nitida</i>	shiny wedgescale	Native
<i>Sphenopholis obtusata</i>	prairie wedgegrass, prairie wedgescale	Native
<i>Spiranthes cernua</i>	nodding ladies'-tresses, nodding ladiestresses, white nodding ladies'-tresses	Native
<i>Spiranthes lacera var. lacera</i>	northern slender ladies'-tresses	Native
<i>Staphylea trifolia</i>	American bladdernut, american bladdernut	Native
<i>Stellaria aquatica</i>		Non-Native
<i>Stellaria graminea</i>	grass-leaf starwort, grassleaved stichwort, grasslike starwort, grassy starwort, lesser starwort, little starwort	Non-Native
<i>Stellaria media</i>	chickweed, common chickweed, nodding chickweed	Non-Native
<i>Stellaria pubera</i>	star chickweed	Native
<i>Stuckenia pectinatus</i>	sago pondweed	Native
<i>Stylophorum diphyllum</i>	celandine poppy	Native
<i>Symphoricarpos orbiculatus</i>	coralberry, coralberry (buck brush), Indiancurrant coralberry	Native
<i>Symphyotrichum cordifolium</i>	common blue wood aster	Native

Scientific name	Common name/s	Status
Vascular plants		
<i>Symphotrichum divaricatum</i>	southern annual saltmarsh aster	Native
<i>Symphotrichum ericoides</i> var. <i>ericoides</i>	white heath aster	Native
<i>Symphotrichum shortii</i>	Short's aster	Native
<i>Synosma suaveolens</i>		Native
<i>Tanacetum vulgare</i>	common tansy, garden tansy, tansy	Non-Native
<i>Taraxacum officinale</i>	blowball, common dandelion, dandelion, faceclock	Non-Native
<i>Taxodium distichum</i>	bald cypress, baldcypress	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 polygamum</i>		Native
<i>Thalictrum thalictroides</i>	rue anemone	Native
<i>Thlaspi arvense</i>	fanweed, field pennycress, Frenchweed, pennycress, stinkweed	Non-Native
<i>Thuja occidentalis</i>	arborvitae, eastern white cedar, northern white cedar, northern white-cedar, swamp cedar	Non-Native
<i>Tilia americana</i>	American basswood	Native
<i>Tovara virginiana</i>		Native
<i>Toxicodendron radicans</i>	eastern poison ivy, poison ivy, poisonivy	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>Tragopogon pratensis</i>	Jack-go-to-bed-at-noon, meadow salsify	Non-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 aureum</i>	golden 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 dubium</i>	hop clover, smallhop clover, suckling clover	Non-Native
<i>Trifolium hybridum</i>	alsike clover	Non-Native
<i>Trifolium pratense</i>	red clover	Non-Native
<i>Trifolium repens</i>	Dutch clover, ladino clover, white clover	Non-Native
<i>Trillium sessile</i>	toadshade	Native
<i>Triticum aestivum</i>	common wheat, wheat	Non-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>Urtica dioica</i>	California nettle, slender nettle, stinging nettle, tall nettle	Non-Native
<i>Uvularia perfoliata</i>	perfoliate bellwort	Native
<i>Uvularia puberula</i>	mountain bellwort	Native
<i>Valerianella locusta</i>	Lewiston 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

Scientific name	Common name/s	Status
Vascular plants		
<i>Verbena urticifolia</i>	white verbena, white vervain	Native
<i>Verbesina alternifolia</i>	wingstem	Native
<i>Vernonia noveboracensis</i>	New York ironweed	Native
<i>Veronica agrestis</i>	field speedwell, green field speedwell	Non-Native
<i>Veronica anagallis-aquatica</i>	blue water speedwell, water speedwell	Native
<i>Veronica hederifolia</i>	ivyleaf speedwell	Non-Native
<i>Veronica officinalis</i>	common gypsyweed	Native
<i>Veronica peregrina</i>	neckweed, purslane speedwell	Native
<i>Veronica persica</i>	bird-eye speedwell, birdeye 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 prunifolium</i>	blackhaw	Native
<i>Vinca minor</i>	common periwinkle, lesser periwinkle, myrtle	Non-Native
<i>Viola bicolor</i>	field pansy	Native
<i>Viola blanda</i>	sweet white violet	Native
<i>Viola palmata</i>	early blue violet, trilobed violet	Native
<i>Viola papilionacea</i>	common blue violet, hooded blue violet, meadow violet	Native
<i>Viola pensylvanica</i>		Native
<i>Viola pubescens</i>	downy yellow violet	Native
<i>Viola sororia</i>	common blue violet, hooded blue violet	Native
<i>Viola striata</i>	striped cream violet	Native
<i>Viola triloba</i>		Native
<i>Vitis aestivalis</i>	summer grape	Native
<i>Vitis labrusca</i>	fox grape	Native
<i>Vitis riparia</i>	river-bank grape, riverbank grape	Native
<i>Vitis rotundifolia</i>	muscadine, muscadine grape	Native
<i>Vitis vulpina</i>	fox grape, frost grape, wild grape	Native
<i>Woodsia obtusa</i>	blunt-lobe woodsia, bluntlobe cliff fern	Native
<i>Xanthium strumarium</i>	cocklebur, cockleburr, common cocklebur, rough cocklebur, rough cockleburr	Native
<i>Zea mays</i>	corn	Non-Native
<i>Zizia aurea</i>	golden alexanders, golden zizia	Native

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

Scientific name	Common name/s	Status
Fish		
<i>Ambloplites rupestris</i>	rock bass	Non-Native
<i>Ameiurus natalis</i>	yellow bullhead	Native
<i>Ameiurus nebulosus</i>	brown bullhead	Native
<i>Anguilla rostrata</i>	American eel	Native
<i>Campostoma anomalum</i>	central stoneroller	Native
<i>Catostomus commersoni</i>	white sucker	Native
<i>Clinostomus funduloides</i>	rosyside dace	Native
<i>Cottus caeruleomentum</i>	Blue Ridge sculpin	Native
<i>Cottus girardi</i>	Potomac sculpin	Native
<i>Cottus sp. cf. cognatus</i>	checkered sculpin	
<i>Cyprinella analostana</i>	satinfin shiner	Native
<i>Cyprinella spiloptera</i>	spotfin shiner	Native
<i>Cyprinus carpio</i>	common carp, European carp	Non-Native
<i>Etheostoma blennioides</i>	greenside darter	Non-Native
<i>Etheostoma caeruleum</i>	rainbow darter	Native
<i>Etheostoma flabellare</i>	fantail darter	Native
<i>Etheostoma olmstedii</i>	tessellated darter	Native
<i>Exoglossum maxillingua</i>		Native
<i>Hypentelium nigricans</i>	northern hogsucker	Native
<i>Lepomis auritus</i>	redbreast sunfish	Native
<i>Lepomis cyanellus</i>	green sunfish	Non-Native
<i>Lepomis gibbosus</i>		Native
<i>Lepomis macrochirus</i>	bluegill	Non-Native
<i>Luxilus cornutus</i>	common shiner	Native
<i>Margariscus margarita</i>	pearl dace	Native
<i>Micropterus dolomieu</i>	smallmouth bass	Non-Native
<i>Micropterus salmoides</i>	largemouth bass	Non-Native
<i>Moxostoma erythrurum</i>	golden redhorse	Non-Native
<i>Moxostoma macrolepidotum</i>	shorthead redhorse	Native
<i>Nocomis micropogon</i>	river chub	Native
<i>Notropis hudsonius</i>	spottail shiner	Native
<i>Notropis rubellus</i>	rosyface shiner	Native
<i>Oncorhynchus mykiss</i>	rainbow trout	Non-Native
<i>Perca flavescens</i>	yellow perch	Native
<i>Percina peltata</i>	shield darter	Native
<i>Pimephales notatus</i>	bluntnose minnow	Non-Native
<i>Rhinichthys atratulus</i>	blacknose dace, eastern blacknose dace	Native
<i>Rhinichthys cataractae</i>	longnose dace	Native
<i>Salmo trutta</i>	brown trout	Non-Native
<i>Salvelinus fontinalis</i>	brook trout, charr, salter	Native
<i>Semotilus atromaculatus</i>	creek chub	Native
<i>Semotilus corporalis</i>	fallfish	Native

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

Scientific name	Common name/s	Status
Amphibians		
<i>Anaxyrus americanus americanus</i>	eastern American toad	Native
<i>Desmognathus fuscus fuscus</i>	northern dusky salamander	Native
<i>Eurycea bislineata</i>	northern two-lined salamander, two-lined salamander	Native
<i>Eurycea longicauda longicauda</i>	longtail salamander, long-tailed salamander	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>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 Antietam National Battlefield.

Scientific name	Common name/s	Status
Reptiles		
<i>Agkistrodon contortrix mokasen</i>	northern copperhead	Native
<i>Chelydra serpentina serpentina</i>	common snapping turtle	Native
<i>Chrysemys picta picta</i>	eastern painted turtle	Native
<i>Clemmys insculpta</i>	ornate box turtle, wood turtle	Native
<i>Diadophis punctatus edwardsii</i>	northern ringneck snake	Native
<i>Elaphe obsoleta obsoleta</i>	black rat snake	Native
<i>Lampropeltis triangulum triangulum</i>	eastern milk snake	Native
<i>Nerodia sipedon sipedon</i>	northern water snake	Native
<i>Pseudemys rubriventris</i>	redbelly turtle	Native
<i>Regina septemvittata</i>	queen snake, queensnake	Native
<i>Terrapene carolina carolina</i>	eastern box turtle	Native
<i>Thamnophis sirtalis sirtalis</i>	eastern garter snake	Native

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

Scientific name	Common name/s	Status
Birds		
<i>Accipiter cooperii</i>	Cooper's hawk	Native
<i>Accipiter gentilis</i>	northern goshawk	Native
<i>Accipiter striatus</i>	sharp-shinned hawk	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 discors</i>	blue-winged teal	Native
<i>Anas platyrhynchos</i>	mallard	Native
<i>Anas rubripes</i>	American black duck	Native
<i>Anthus rubescens</i>	American pipit	Native
<i>Archilochus colubris</i>	ruby-throated hummingbird	Native
<i>Ardea alba</i>	great egret	Native
<i>Ardea herodias</i>	great blue heron	Native
<i>Asio otus</i>	long-eared owl	NA
<i>Aythya americana</i>	redhead	NA
<i>Bartramia longicauda</i>	upland sandpiper	Native
<i>Bombycilla cedrorum</i>	cedar waxwing	Native
<i>Bonasa umbellus</i>		Native
<i>Branta canadensis</i>	Canada goose	Native
<i>Bubo virginianus</i>	great horned owl	Native
<i>Buteo jamaicensis</i>	red-tailed hawk	Native
<i>Buteo lagopus</i>		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>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	NA
<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
<i>Chordeiles minor</i>	Common Nighthawk	Native
<i>Circus cyaneus</i>	Northern Harrier	Native
<i>Coccothraustes vespertinus</i>	Evening Grosbeak	NA
<i>Coccyzus americanus</i>	Yellow-billed Cuckoo	Native

Scientific name	Common name/s	Status
Birds		
<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	NA
<i>Dendroica cerulea</i>	Cerulean Warbler	NA
<i>Dendroica coronata</i>	Yellow-rumped Warbler	Native
<i>Dendroica discolor</i>	Prairie Warbler	Native
<i>Dendroica dominica</i>	Yellow-throated Warbler	NA
<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	NA
<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	Native
<i>Dryocopus pileatus</i>	Pileated Woodpecker	Native
<i>Dumetella carolinensis</i>	Gray Catbird, Grey Catbird	Native
<i>Empidonax minimus</i>	Least Flycatcher	NA
<i>Empidonax traillii</i>	Willow Flycatcher	NA
<i>Empidonax virescens</i>	Acadian Flycatcher	Native
<i>Eremophila alpestris</i>	Horned Lark	Native
<i>Euphagus carolinus</i>	Rusty Blackbird	NA
<i>Falco sparverius</i>	American Kestrel	Native
<i>Gallinago gallinago</i>	common snipe	NA
<i>Geothlypis trichas</i>	Common Yellowthroat	Native
<i>Guiraca caerulea</i>	blue grosbeak	Native
<i>Haliaeetus leucocephalus</i>	Bald Eagle	Native
<i>Helmitheros vermivorus</i>	Worm-eating Warbler	NA
<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	Native
<i>Icterus spurius</i>	Orchard Oriole	Native
<i>Junco hyemalis</i>	Dark-eyed Junco	Native

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Scientific name	Common name/s	Status
Birds		
<i>Lanius ludovicianus</i>	Loggerhead Shrike	Native
<i>Larus argentatus</i>	Herring Gull	NA
<i>Larus delawarensis</i>	Ring-billed Gull	Native
<i>Lophodytes cucullatus</i>	Hooded Merganser	Native
<i>Megaceryle alcyon</i>	Belted kingfisher	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 melodia</i>	Song Sparrow	Native
<i>Mergus merganser</i>	Common Merganser	Native
<i>Mimus polyglottos</i>	Northern Mockingbird	Unknown
<i>Mniotilta varia</i>	Black-and-white Warbler	NA
<i>Molothrus ater</i>	Brown-headed Cowbird	Native
<i>Myiarchus crinitus</i>	Great Crested Flycatcher	Native
<i>Oporornis formosus</i>	Kentucky Warbler	Native
<i>Otus asio</i>	Eastern Screech-Owl	Native
<i>Pandion haliaetus</i>	Osprey	Native
<i>Parula americana</i>	Northern Parula	Native
<i>Parus atricapillus</i>	Black-capped Chickadee	NA
<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	Native
<i>Passerina cyanea</i>	Indigo Bunting	Native
<i>Petrochelidon pyrrhonota</i>	American Cliff Swallow, Cliff Swallow	NA
<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, Rufous-sided Towhee	Native
<i>Piranga olivacea</i>	Scarlet Tanager	Native
<i>Piranga rubra</i>	Summer Tanager	NA
<i>Podilymbus podiceps</i>	Pied-billed Grebe	Native
<i>Poecile carolinensis</i>	Carolina chickadee	
<i>Polioptila caerulea</i>	blue-gray gnatcatcher, Blue-grey Gnatcatcher	Native
<i>Pooecetes gramineus</i>	Vesper Sparrow	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	NA
<i>Sayornis phoebe</i>	Eastern Phoebe	Native

Scientific name	Common name/s	Status
	Birds	
<i>Seiurus aurocapillus</i>	Ovenbird	NA
<i>Seiurus motacilla</i>	Louisiana Waterthrush	Native
<i>Seiurus noveboracensis</i>	Northern Waterthrush	NA
<i>Setophaga ruticilla</i>	American Redstart	Native
<i>Sialia sialis</i>	Eastern Bluebird	Native
<i>Sitta canadensis</i>	Red-breasted Nuthatch	NA
<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 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 melanoleuca</i>	Greater Yellowlegs	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 forficatus</i>	Scissor-tailed Flycatcher	NA
<i>Tyrannus tyrannus</i>	Eastern Kingbird	Native
<i>Tyto alba</i>	Barn Owl, Common Barn-Owl	Native
<i>Vermivora chrysoptera</i>	Golden-winged Warbler	NA
<i>Vermivora peregrina</i>	Tennessee Warbler	NA
<i>Vermivora pinus</i>	Blue-winged Warbler	NA
<i>Vermivora ruficapilla</i>	Nashville Warbler	NA
<i>Vireo flavifrons</i>	Yellow-throated Vireo	NA
<i>Vireo gilvus</i>	Warbling Vireo	Native
<i>Vireo griseus</i>	White-eyed Vireo	Native
<i>Vireo olivaceus</i>	red-eyed vireo	Native
<i>Vireo solitarius</i>	Blueheaded vireo	Native
<i>Wilsonia canadensis</i>	Canada Warbler	Native
<i>Wilsonia citrina</i>	Hooded Warbler	Native
<i>Zenaidura 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 Antietam National Battlefield.

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	
<i>Castor canadensis</i>	american beaver, beaver	Native
<i>Cryptotis parva</i>	bee shrew, least shrew, little short-tailed shrew	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>Lasiurus cinereus</i>	hoary bat	Native
<i>Lutra canadensis</i>	River otter	
<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	Native
<i>Mustela vison</i>	American Mink, mink	Native
<i>Myotis keenii</i>	Keen's myotis	Native
<i>Myotis lucifugus</i>	little brown bat, little brown myotis	Native
<i>Ochrotomys nuttalli</i>	golden mouse	Non-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>Peromyscus maniculatus</i>	deer 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	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	
<i>Sorex cinereus</i>	Cinereus Shrew, common shrew, masked shrew	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>Vulpes vulpes</i>	Red Fox	Native
<i>Zapus hudsonius</i>	meadow jumping mouse	Native

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

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

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 Antietam National Battlefield, 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.

1986. Resource management. In: Snell, C.W. and S.A. Brown. Antietam National Battlefield and National Cemetery, Sharpsburg, Maryland: an administrative history. National Park Service, Washington, DC.

1991. Ground-water spring discharge: Maryland, Washington County. In: James, R.W. and M.J. Smigaj. Water resources data: Maryland and Delaware, water year 1991: volume 2 ground-water data. United States Geological Survey, Towson, MD.

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

Acronym	Description
ANC	Acid neutralizing capacity
ANTI	Antietam National Battlefield (NPS—NCRN)
BIBI	Benthic Index of Biotic Integrity
BMP	Best Management Practice
CATO	Catoctin Mountain Park (NPS—NCRN)
CBOD	Carbonaceous biochemical oxygen demand
CHOH	Chesapeake & Ohio Canal National Historical Park (NPS—NCRN)
COMAR	Code of Maryland Regulations
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
IPM	Integrated Pest Management
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
MDE	Maryland Department of the Environment
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
NBOD	Nitrogenous biochemical oxygen demand
NPS	National Park Service
NCRN	National Capital Region Network
NRCA	Natural Resource Condition Assessment
NSDWS	National Secondary Drinking Water Standards
NWI	National Wetlands Inventory
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
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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