National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Monocacy National Battlefield Natural Resource Condition Assessment

National Capital Region

Natural Resource Report NPS/NCRN/NRR—2011/415

ON THE COVER

Gambrill Mill Trail near Bush Creek, Monocacy National Battlefield.
Jane Thomas.

Monocacy National Battlefield
Natural Resource Condition Assessment

National Capital Region

Natural Resource Report NPS/NCRN/NRR—2011/415

Jane Thomas, Tim Carruthers, Bill Dennison
Integration & Application Network
University of Maryland Center for Environmental Science
PO Box 775
Cambridge, MD 21613

Mark Lehman, Megan Nortrup, Patrick Campbell
National Capital Region Inventory & Monitoring
National Park Service
4598 MacArthur Blvd NW, Washington, DC 20007

Andrew Banasik
Monocacy National Battlefield
National Park Service
4801 Urbana Pike
Frederick, MD 21704

June 2011

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

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

The Natural Resource Report Series is used to disseminate high-priority, current natural resource management information with managerial application. The series targets a general, diverse audience, and may contain NPS policy considerations or address sensitive issues of management applicability.

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

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

This report is available from the National Capital Region Network website (*http://science.nature.nps.gov/im/units/ncrn/index.cfm*) and the Natural Resource Publications Management website (*http://www.nature.nps.gov/publications/nrpm*) on the Internet.

Please cite this publication as:

Thomas, J. E., A. Banasik, J. P. Campbell, T. J. B. Carruthers, W. C. Dennison, M. Lehman, and M. Nortrup. 2011. Monocacy National Battlefield natural resource condition assessment: National Capital Region. Natural Resource Report NPS/NCRN/NRR—2011/415. National Park Service, Fort Collins, Colorado.

NPS 894/108048, June 2011

Contents

Executive Summary .... **ix**

Acknowledgements .... **xiii**

Chapter 1: NRCA background information **1**

1.1 NCRA background information 1

Chapter 2: Park resource setting/resource stewardship context **3**

2.1 Park resource setting 3

2.1.1 Park resources 4

2.1.2 Resource management issues overview 8

2.2 Resource stewardship context 14

2.2.1 Park enabling legislation 14

2.2.2 Resource stewardship planning 18

2.2.3 Resource stewardship science 21

2.3 Literature cited (Chapter 2) 22

Chapter 3: Study approach **25**

3.1 Preliminary scoping 25

3.1.1 Park involvement 25

3.1.2 Other NPS involvement 25

3.2 Reporting areas 26

3.2.1 Ecological reporting units 26

3.3 Study resources and indicators 26

3.3.1 Assessment frameworks used in this study 26

3.3.2 Candidate study resources and indicators 29

3.3.3 Priority study resources and indicators 34

3.4 Forms of reference conditions/reference values used in the study 34

3.4.1 Air & Climate 34

3.4.2 Water Resources 37

3.4.3 Biological Integrity 39

3.4.4 Landscape Dynamics 41

3.5 Study methods 42

3.5.1 Ecological monitoring framework 42

3.5.2 Habitat framework 51

3.6 Literature cited (Chapter 3) 56

Chapter 4: Natural resource conditions **61**

4.1 Regional/landscape context 61

4.2 Condition summaries by reporting areas....61

4.2.1 Habitat framework....61

4.3 Park-wide conditions....76

4.3.1 Ecological monitoring framework....76

4.4 Literature cited (Chapter 4)....77

Chapter 5: Discussion....79

5.1 Assessing natural resource condition in a battlefield park....79

5.2 Key findings and management implications....79

5.2.1 Forests....79

5.2.2 Wetlands and waterways....81

5.2.3 Grasslands (warm-season)....82

5.2.4 Croplands....82

5.2.5 Pastures....82

5.3 Data gaps and subsequent research needs....82

5.3.1 Air & Climate....82

5.3.2 Water Resources....83

5.3.3 Biological Integrity....83

5.3.4. Landscape Dynamics....83

5.4 Literature cited (Chapter 5)....86

Appendix A: Raw data used in Monocacy National Battlefield Natural Resource Condition Assessment....87

Appendix B: Information used in Monocacy National Battlefield Natural Resource Condition Assessment....123

Figures

Figure 2.1. GIS data layer showing the administrative/legislative and fee boundaries of Monocacy National Battlefield, which encompass 667 ha (1,647 acres) and 548 ha (1,355 acres), respectively. 4

Figure 2.2. Location of Monocacy National Battlefield in western Maryland. 5

Figure 2.3. Monocacy River and its watershed. 7

Figure 2.4. GIS data layer depicting the stream network for Monocacy National Battlefield. 8

Figure 2.5. GIS data layer of topographic elevation for Monocacy National Battlefield. 9

Figure 2.6. GIS data layer of surficial and bedrock geology in Monocacy National Battlefield. 10

Figure 2.7. GIS data layer of soil types found in Monocacy National Battlefield. 11

Figure 2.8. GIS data layer showing the trail system of Monocacy National Battlefield. 12

Figure 2.9. GIS data layer showing general location and types of habitats in Monocacy National Battlefield. 13

Figure 2.10. Conceptual diagram illustrating the major resource values and stressors in Monocacy National Battlefield. 15

Figure 2.11. GIS data layer showing population density surrounding the park in 1990 and 2000. 16

Figure 2.12. GIS data layer showing population density surrounding the park in 1990 and 2000. 17

Figure 2.13. GIS data layer showing road density surrounding the park in 2003. 18

Figure 2.14. GIS data layer showing protected areas surrounding the park in 2000. 19

Figure 2.15. GIS data layer showing percent impervious surface in and around Monocacy National Battlefield in 2000. 20

Figure 3.1. GIS data layer of major habitat types in Monocacy National Battlefield, as defined by aggregation of other GIS data layers. 27

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). 29

Figure 3.3. Conceptual framework for desired and degraded condition of habitats managed for natural resource values present within Monocacy National Battlefield, indicating metrics to track status of condition. 33

Figure 3.4. Conceptual framework for desired and degraded condition of habitats managed for agricultural values present within Monocacy National Battlefield, indicating metrics to track status of condition. 34

Figure 3.5. Summary of the two frameworks used in this assessment, including metrics. 36

Figure 3.6. Map of sampling stations PA00/ARE118 and MD99/BEL116 used for measuring mercury concentrations near Monocacy National Battlefield. 47

Figure 3.7. Stream sampling locations used for long-term water quality monitoring at Monocacy National Battlefield. 48

Figure 3.8. Stream sampling locations monitored for BIBI, FIBI, and PHI. 49

Figure 3.9. Forest monitoring sites and deer counting routes in Monocacy National Battlefield. 50

Figure 4.1. Total wet deposition of nitrate (NO_3^-) and ammonium (NH_4^+) (kg ha^{-1}) for the continental United States in 2009. 62

Figure 4.2. Total wet mercury (Hg) deposition (µg m^{-2}) for the continental United States in 2009. 62

Figure 4.3. Mean monthly mercury deposition (ng Hg L^{-1}) from 2004 to 2007 at sites PA00 and MD99 (see Figure 3.6). Acceptable range (Hg ≤ 2 ng L^{-1}) is shown in gray. 63

Figure 4.4. Summary results of habitat-based resource condition assessment of Monocacy National Battlefield. 66

Figure 4.5. GIS data layer showing percent impervious surface in 2000 within and around Monocacy National Battlefield. 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. 67

Figure 4.6. Extent of forest and non-forest landcover (Landsat 30-m) within and around Monocacy National Battlefield in 2000. 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. 68

Figure 4.7. Forest area and forest interior area in Monocacy National Battlefield. Forest interior area is defined as forested land cover ≥ 100 m from non-forest land cover or from primary, secondary, or county roads. 69

Figure 4.8. Acid neutralizing capacity (ANC; µeq L^{-1}) from 2005 to 2008 for three stream sampling location (see Figure 3.7) in Monocacy National Battlefield. Acceptable range (ANC ≥ 200 µeq L^{-1}) is shown in gray. 70

Figure 4.9. Median, 1st quartile, and 3rd quartile water temperature (°C) from 2004 to 2008 for 16 stream sampling locations (see Figure 3.7) in Monocacy National Battlefield. Acceptable range (temp. ≤ 32.0°C) is shown in gray. 70

Figure 4.10. Median, 1st quartile, and 3rd quartile dissolved oxygen concentration (mg DO L^{-1}) from 2004 to 2008 for 16 stream sampling locations in Monocacy National Battlefield (see Figure 3.7). Acceptable range (DO ≥ 5.0 mg L^{-1}) is shown in gray. 71

Figure 4.11. Median, 1st quartile, and 3rd quartile monthly salinity concentration from 2004 to 2008 for 16 stream sampling locations (see Figure 3.7) in Monocacy National Battlefield.[43] Acceptable range (salinity ≤ 0.25) is shown in gray. 72

Figure 4.12. Median, 1st quartile, and 3rd quartile pH values from 2004 to 2008 for 16 stream sampling locations (see Figure 3.7) in Monocacy National Battlefield. Acceptable ranges (6.5 ≥ pH ≤ 8.5) are shown in gray. 73

Figure 4.13. Median, 1st quartile, and 3rd quartile nitrate concentration (mg NO_3 L^{-1}) from 2004 to 2008 for 16 stream sampling locations (see Figure 3.7) in Monocacy National Battlefield. Acceptable range (NO_3 ≤ 2.0 mg L^{-1}) is shown in gray. 74

Figure 4.14. Median, 1st quartile, and 3rd quartile phosphate concentrations (mg PO_4 L^{-1}) from 2004 to 2008 for 16 stream sampling locations (see Figure 3.7) for Monocacy National Battlefield. Acceptable range (PO_4 < 0.1133 mg L^{-1}) is also shown in gray. 75

Figure 4.15. Grassland area and grassland interior area in Monocacy National Battlefield. Grassland interior area is defined as grassland ≥60 m from other land uses. 76

Tables

Table 3.1. Thresholds for Air & Climate metrics. 29

Table 3.2. Thresholds for Water Resources metrics. 30

Table 3.3. Thresholds for Biological Integrity metrics. 31

Table 3.4. Thresholds for Landscape Dynamics metrics. 32

Table 3.5. Thresholds for Cropland and Pasture metrics. 44

Table 3.6. Sources of data used in Monocacy National Battlefield resource condition assessment. 45

Table 3.7. Summary of data used in Monocacy National Battlefield resource condition assessment. 46

Table 3.8. Categorical ranking of threshold attainment categories. 52

Table 3.9. Summary of IUCN major habitat classifications. 52

Table 3.10. Summary of data used in Monocacy National Battlefield habitat-based condition assessment of habitats managed for natural resource values. 53

Table 3.11. Summary of data used in Monocacy National Battlefield habitat-based condition assessment of habitats managed for agricultural values. 54

Table 3.12. Area of each habitat type assessed in Monocacy National Battlefield. Developed lands make up another 22 ha (55 acres) but were not assessed. 55

Table 4.1. Summary of habitat-based resource condition assessment of Monocacy 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). 64

Table 4.2. Summary of habitat-based resource condition assessment of Monocacy 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). 65

Table 4.3. Area-weighted results of habitat-based resource condition assessment of Monocacy National Battlefield. 65

Table 4.4. Summary resource condition assessment for Monocacy National Battlefield by metric categories. 78

Table 5.1. Key findings, management implications, and recommended next steps for forest habitat in Monocacy National Battlefield. 80

Table 5.2. Key findings, management implications, and recommended next steps for wetland and waterway habitat in Monocacy National Battlefield. 80

Table 5.3. Key findings, management implications, and recommended next steps for warm-season grassland habitat in Monocacy National Battlefield. 80

Table 5.4. Key findings, management implications, and recommended next steps for cropland habitat in Monocacy National Battlefield. 81

Table 5.5. Key findings, management implications, and recommended next steps for pasture habitat in Monocacy National Battlefield. 81

Table 5.6. Data gaps, justification, and research needs for Air & Climate in Monocacy National Battlefield. 84

Table 5.7. Data gaps, justification, and research needs for Water Resources in Monocacy National Battlefield. 84

Table 5.8. Data gaps, justification, and research needs for Biological Integrity in Monocacy National Battlefield. 85

Table 5.9. Data gaps, justification, and research needs for Landscape Dynamics in Monocacy National Battlefield. 85

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. 87

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. 88

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.... 98

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. 98

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. 99

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. 99

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.... 99

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. 100

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. 100

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. 101

Table A-11. Presence and functional diversity of grassland birds. 101

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. 102

Table A-13. List of plant species recorded in Monocacy National Battlefield. 103

Table A-14. List of fish species recorded in Monocacy National Battlefield. 117

Table A-15. List of amphibian species recorded in Monocacy National Battlefield.... 118

Table A-16. List of reptile species recorded in Monocacy National Battlefield. 118

Table A-17. List of bird species recorded in Monocacy National Battlefield. 119

Table A-18. List of mammal species recorded in Monocacy National Battlefield....122

Table B-1. I&M reports used in the natural resource condition assessment. 123

Table B-2. Listing of known literature pertaining to Monocacy 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.... 124

Table B-3. List of acronyms used in this document.... 126

Executive Summary

The lands within Monocacy 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 Monocacy 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 presence of exotic plant species and insect pests displaces and degrades 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 some signs of acidification, low oxygen, and high nutrients, indicating degraded habitat value which is reflected in the regionally low benthic index of biotic integrity and moderate fish diversity. 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 developing 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 moderately 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 Monocacy 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 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.

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.

Pasture habitat within Monocacy 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 Monocacy 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 and salt—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 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.

Monocacy National Battlefield
Natural Resource Condition Assessment Resource Brief

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

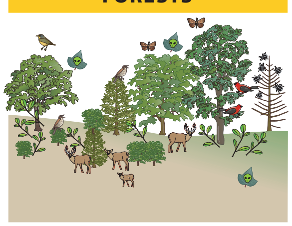
Habitats in Monocacy National Battlefield are in good condition overall. Habitats managed for natural resources are in fair condition. Forests were in fair condition, with low forest interior area and large deer populations balanced by good bird diversity and continuous forest cover. Wetlands and waterways were also in fair condition, with good pH and buffering capacity but high phosphate and degraded stream habitat. 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 MONOCACY NATIONAL BATTLEFIELD

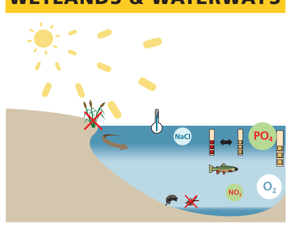
HABITATS MANAGED FOR NATURAL RESOURCES

FORESTS



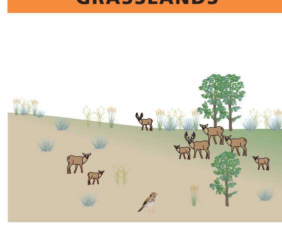
Forest habitat has low cover of exotic plants, low % of impervious surface, and high diversity of forest-dwelling bird species. Deer populations are large and forest interior area is low but continuous, with a fair presence of insect pests.

WETLANDS & WATERWAYS



Wetlands are not acidic and have high buffering capacity, resulting in high dissolved oxygen and cool water temperature. Salinity, nitrate, and fish diversity are good, but phosphate is high, benthic invertebrates are low and physical habitat is very degraded.

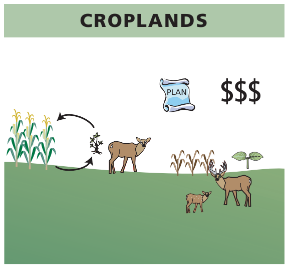
GRASSLANDS



Grassland habitat has very high deer populations and low bird diversity. Impervious surface cover is low but grasslands are patchy and have a small interior area.

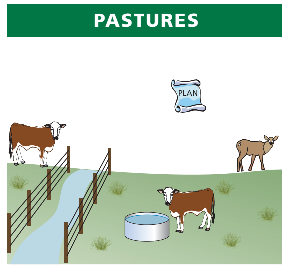
HABITATS MANAGED FOR CULTURAL RESOURCES

CROPLANDS



Croplands have high deer density, a high % of land undergoing crop rotation, conservation tillage, and cover crops, nutrient and soil & water conservation plans in place, and there are few crop yield concerns $$$.

PASTURES

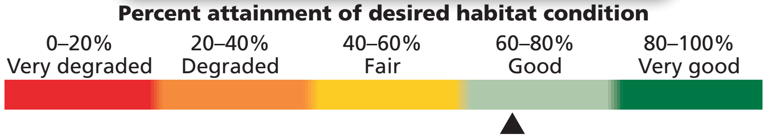


Pasture has a low stocking rate, alternative water sources, fenced streams, active nutrient and soil & water conservation plans, but very high deer density.

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

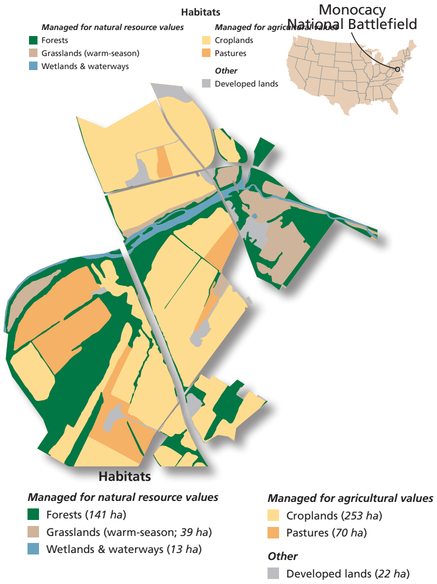
Forests: 141 ha
Wetlands & waterways: 13 ha
Warm-season grasslands: 39 ha
Croplands: 253 ha
Pastures: 70 ha

Percent attainment of desired habitat condition



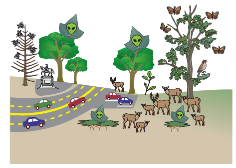
Habitat framework

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.



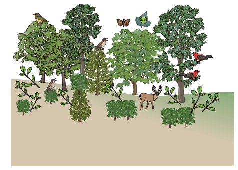
FORESTS

DEGRADED — DESIRED



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

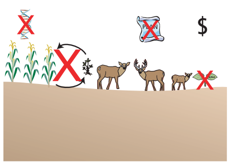
Degraded	INDICATORS	Desired
high	Cover of exotic plants	low
high	Presence of insect pests	low
low	Native tree seedling regeneration	high
low	Forest dwelling bird diversity	high
high	Deer density	low
low	Forest connectivity	high
high	Impervious surface	low
high	Forest interior area	low



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

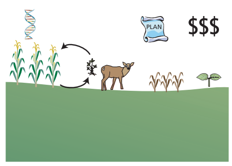
CROPLANDS

DEGRADED — DESIRED



Degraded croplands have high deer density and low % of land under best management practices: no crop rotation, no integrated pest management, no conservation tillage, no cover crops, absence of nutrient and soil & water conservation plans, and crop yield concerns $.

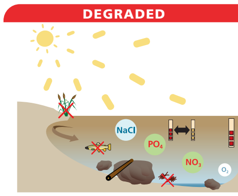
Degraded	INDICATORS	Desired
absent	Crop rotation	present
absent	Crop varieties for IPM	present
absent	Conservation tillage	present
absent	Cover crops	present
absent	Nutrient Management Plan	present
absent	Soil & Water Conservation Plan	present
present	Crop yield concerns ($ / $$$)	absent
high	Deer density	low



Desired croplands have low deer density and high % of land under best management practices: crop rotation, integrated pest management, conservation tillage, cover crops, existence of nutrient and soil & water conservation plans, and no crop yield concerns $$$.

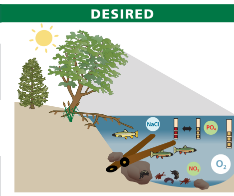
WETLANDS & WATERWAYS

DEGRADED — DESIRED



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

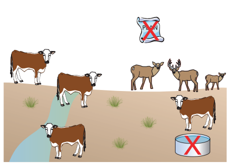
Degraded	INDICATORS	Desired
low	pH	high
low	Dissolved oxygen	high
high	Water temperature	low
low	Acid neutralizing capacity	high
high	Salinity	low
high	Nitrate	low
high	Phosphate	low
low	Benthos	high
low	Fish	high
low	Physical habitat	high



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

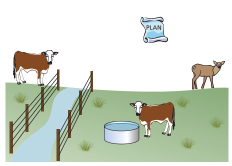
PASTURES

DEGRADED — DESIRED



Degraded pasture has a high stocking rate, no alternative water source, no fenced streams, no nutrient or soil & water conservation plan, and high deer density.

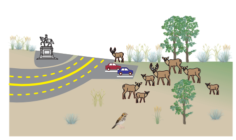
Degraded	INDICATORS	Desired
high	Stocking rate	low
stream	Water source	tank
absent	Fenced streams	present
absent	Nutrient Management Plan	present
absent	Soil & Water Conservation Plan	present
high	Deer density	low



Desired pasture has a low stocking rate, alternative water sources, fenced streams, active nutrient and soil & water conservation plans, and low deer density.

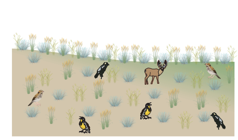
WARM-SEASON GRASSLANDS

DEGRADED — DESIRED



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

Degraded	INDICATORS	Desired
high	Deer density	low
high	Impervious surface	low
low	Grassland bird diversity	high
high	Grassland interior area	low
high	Contiguous grassland area	low



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

For more information, please visit the Park's Visitor Center or call 301-662-3515.

Monocacy National Battlefield
National Park Service
www.nps.gov/mono

Developed in collaboration with:

National Capital Region Network
Inventory & Monitoring Program
National Park Service

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

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

Acknowledgements

Marian Norris, Geoff Sanders, John Paul Schmit, and NPS National Capital Region Inventory & Monitoring, who provided data support. Susan Trail, Superintendent at Monocacy National Battlefield. Holly Salazer, Air Resources Coordinator, Northeast Region for advice on air quality metrics. Jeff Runde, Crater Lake National Park, for assistance with spatial metrics. Staff at the Center for Urban Ecology who assisted with data sourcing, scoping, and proofing.

Chapter 1: NRCA background information

1.1 NCRA BACKGROUND INFORMATION

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

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

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

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

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

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

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

Important NRCA success factors

Obtaining good input from park and other NPS subjective matter experts at critical points in the project timeline.

Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures → indicators → broader resource topics and park areas).

Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings.

1. However, the breadth of natural resources and number/type of indicators evaluated will vary by park.
2. Frameworks help guide a multi-disciplinary selection of indicators and subsequent 'roll up' and reporting of data for measures → conditions for indicators → condition summaries by broader topics and park areas.
3. NRCAs must consider ecologically based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions.
4. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management 'triggers').
5. As possible and appropriate, NRCAs describe condition gradients or differences across the park for important natural resources and study indicators through a set of GIS coverages and map products.
6. In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds and 2) for other park areas as requested.

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

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

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

Due to their modest funding, relatively quick timeframe for completion and reliance on existing data and information, NRCAs are not intended to be exhaustive. Study methods typically involve an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in our present data and knowledge bases across these varied study components.

NRCAs can yield new insights about current park resource conditions but in many cases their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Over the next several years, the NPS plans to fund a NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring Program. Additional NRCA[9] Program information is posted at: *http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm*

NRCA reporting products *provide a credible snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:*

- *Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations (near-term operational planning and management)*
- *Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values*

7. NRCAs are an especially useful lead-in to working on a park Resource Stewardship Strategy (RSS) but study scope can be tailored to also work well as a post-RSS project.
8. While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of 'resource condition status' reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.
9. Acronyms are defined in Table B-3 in Appendix B.

Chapter 2: Park resource setting/ resource stewardship context

2.1 PARK RESOURCE SETTING

Monocacy National Battlefield was created by Congress on June 21, 1934 to commemorate the Battle of Monocacy fought on July 9, 1864. Here, a small Union army successfully delayed a larger Confederate force advancing on Washington, DC. This delay provided Union General Ulysses S. Grant sufficient time to reinforce defenses at the nation's capital and prevent its capture. Because of this, Monocacy came to be known as the 'Battle that Saved Washington, DC.'

When the park was created by Congress in 1934, no funds were set aside to purchase land for the park. Unfortunately, anticipated land donations did not materialize (MONO 2009). It was not until February 4, 1975, after a campaign by concerned citizens and local elected officials, that Monocacy National Battlefield was placed on the National Register of Historic Places and finally in the 1980s, that the National Park Service began acquiring and protecting the lands comprising the national battlefield. A visitor contact station was opened in 1991, and a new visitor center was opened to the public in 2007. Initially, while land was acquired and visitor services developed, Monocacy was administered as part of nearby Antietam National Battlefield. The Antietam Assistant Superintendant was the primary administrator for the new park, and in 2003/2004, moved on-site to Monocacy, becoming the park's first superintendant.

Monocacy National Battlefield is comprised of 667 ha (1,647 acres) in Frederick County, Maryland. Within this administrative/legislative boundary, 548 ha (1,355 acres) are owned in fee by the federal government and managed by the National Park Service to maintain the historic setting and provide for visitor use (Figure 2.1), with the remaining area under private ownership, public rights-of-way, or other public ownership (Frederick County), with some having scenic easements on the land. The six properties that make up the battlefield (the Baker, Best, Lewis, Thomas, and Worthington Farms, and the Gambrill Mill Tract) essentially retain their Civil War-era character. The park encompasses more than 50 18th- and 19th-century historic structures and a number of field boundaries, fencelines, road traces, earthworks, and other landscape features that were in use at the time the Battle of Monocacy was fought. Most park land is used for agriculture, with a small portion left for forest cover of the mixed-oak deciduous variety common to the eastern United States.

The Thomas Farm.

The park is predominantly bordered by residential and commercial properties and is divided by Interstate 270. Nearby development and increasing road traffic threaten air and water quality as well as the soundscape and historic views within the park. The Monocacy River, a tributary of the Potomac River, flows in through the north end of the park, angling west to become the western park boundary.

In March of 2009, the Civil War Preservation Trust (CWPT) identified Monocacy as one of the country's most threatened Civil War sites, pointing to a proposed 'waste-to-energy facility' along the banks of the Monocacy River near the Worthington farm (CWPT 2009).

In summary, Monocacy National Battlefield is a relatively 'young' park amongst the nation's battlefield parks. Yet despite this, and

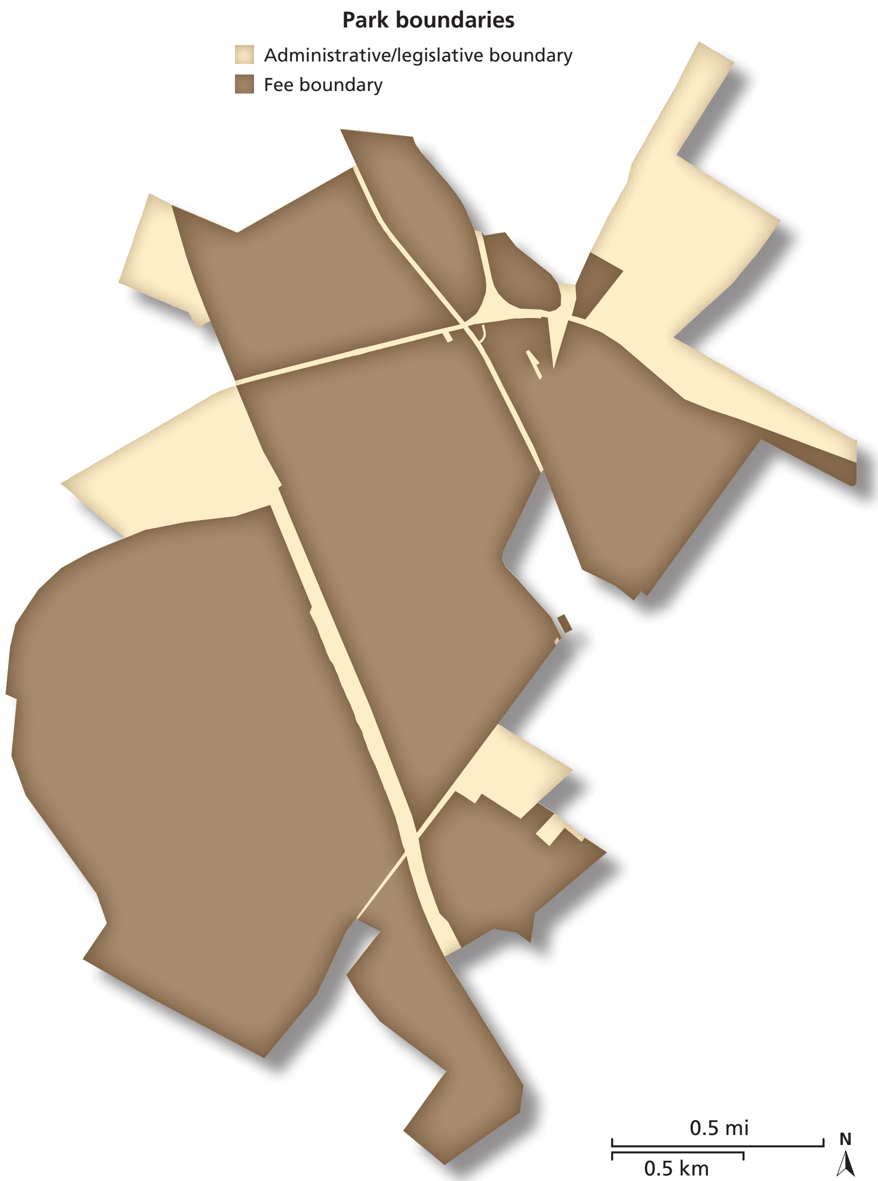


Figure 2.1. GIS data layer[11] showing the administrative/legislative and fee boundaries of Monocacy National Battlefield, which encompass 667 ha (1,647 acres) and 548 ha (1,355 acres), respectively.

the pressures of nearby development and pre-existing roadways, the park retains and preserves much of its rural character, serving the region as a reservoir of agrarian and natural resources in addition to interpreting a pivotal episode of the nation's history. Visitation to Monocacy has doubled over the past decade, with 15,000 visitors in 1999 increasing to 31,000 visitors in 2008 (NPS Public Use Statistics Office).[10]

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

Monocacy National Battlefield covers 667 ha (1,647 acres) and is located in Frederick County in western Maryland (Figure 2.2). The park is located the Lower Monocacy River watershed, which extends north into Pennsylvania (Figure 2.3). Approximately 4 km (2.5 mi) of the 93-km (58-mi) Monocacy River—a tributary of the Potomac River and ultimately Chesa-

10. *http://www.nature.nps.gov/stats*
11. MONO.

Figure 2.2. Location of Monocacy National Battlefield in western Maryland.[12]

peake Bay—run through the park (Figure 2.4; MONO 2009).

Geology

Monocacy National Battlefield is located in the Piedmont physiographic province, a landscape characterized by gently rolling hills that become gradually steeper towards the western edge of the province (Thorneberry–Ehrlich 2008). The park itself consists of rolling hills and river valleys, and ranges from 65–150 m (210–490 ft) above sea level (Figure 2.5). The geology of the park affected the 1864 Battle of Monocacy Junction on both regional and local levels. The Monocacy and Potomac

12. NPS.

Rivers shaped the course of military movements in the area before the battles, and the smaller streams within the park played a significant role in the actual fighting by creating important topographic differences and tactical targets such as railroad bridges, crossings, gaps, gulleys, and protective cover (Thorneberry–Ehrlich 2008).

The park is located in the Frederick Valley, a lowland region of the Piedmont province that stretches north from the Potomac River to northern Frederick County (Brezinski and Reger 2002). The most extensive underlying bedrock of the park is the Frederick Formation (limestone and dolostone intermixed with shale and sandstone), with the Araby Formation (metasiltstone and metashale) and the Ijamsville Phyllite Formation (phyllite, slate, and quartz) underlying the remainder of the park. These bedrock units are overlain by alluvial sediments on the Monocacy River floodplain (mostly clay, silt, sand, gravel, and cobbles) and colluvium on the lower slopes of ridges (primarily chips and cobbles derived from the erosion of the Araby Formation bedrock; Figure 2.6; Southworth and Denenny 2006). The carbonate rocks of the Frederick Formation are associated with the local karst features (sinkholes, springs; Weeks et al. 2007). Floodplain soils in Monocacy National Battlefield are generally of the Codorus and Lindside series while soils in the higher elevations are mainly of the Cardiff and Whiteford series (Figure 2.7). Many of the flatter areas in the park are classified as prime farmland, a designation identifying land that has a favorable combination of physical and chemical characteristics to promote greater production of crops, pasture, or hay (MONO 2009).

Trails

There are several trails in the national battlefield (Figure 2.8). One trail about 0.8 km (0.5 mi) long runs from the Gambrill Mill along the Monocacy River, where one can see key battlefield features. Another trail system on the Worthington Farm gives access to the battlefield and natural areas. It consists of two loops—the Brooks Hill Loop, a nature trail traversing Brooks Hill, and the Ford Loop along the Monocacy River, which interprets key events in the Battle of Monocacy. There are two walking trails on the Thomas Farm—the Thomas Farm Loop Trail which traces the key events in the Battle of Monocacy and the Middle Ford Ferry Loop Trail which explores the early settlement of the Monocacy region.

Forests

Approximately 33% of Monocacy National Battlefield is forested, with the largest forested areas found along the Monocacy River, on and around Brooks Hill near Hardings Run, along Bush Creek on the Gambrill Farm, and on the Lewis Farm (MONO 2009; Figure 2.9). Primary canopy species found are typical of Eastern deciduous forests—oaks (*Quercus* spp.), hickories (*Carya* spp.), maples (*Acer* spp.), American beech (*Fagus grandifolia*), tulip poplar (*Liriodendron tulipifera*), and American sycamore (*Platanus occidentalis*).

Wetlands and waterways

According to the U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI) database, there are approximately 46 ha (113 acres) of wetland area within the park boundary (MONO 2009, Figure 2.9). These areas are mostly comprised of 'freshwater forested/shrub wetland' (i.e., floodplain and riparian areas along Monocacy River) and the waterways themselves—Monocacy River, Bush Creek, and Harding's Run. 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).

Grasslands

Managed to maintain historic landscapes and land use patterns that existed at the time of the battle, Monocacy National Battlefield contains approximately 39 ha (96 acres) of managed warm-season grasslands, as well as 70 ha (172 acres) of cool-season grasslands (Figure 2.9).[13] Warm-season grassland species are those that initiate

13. 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.

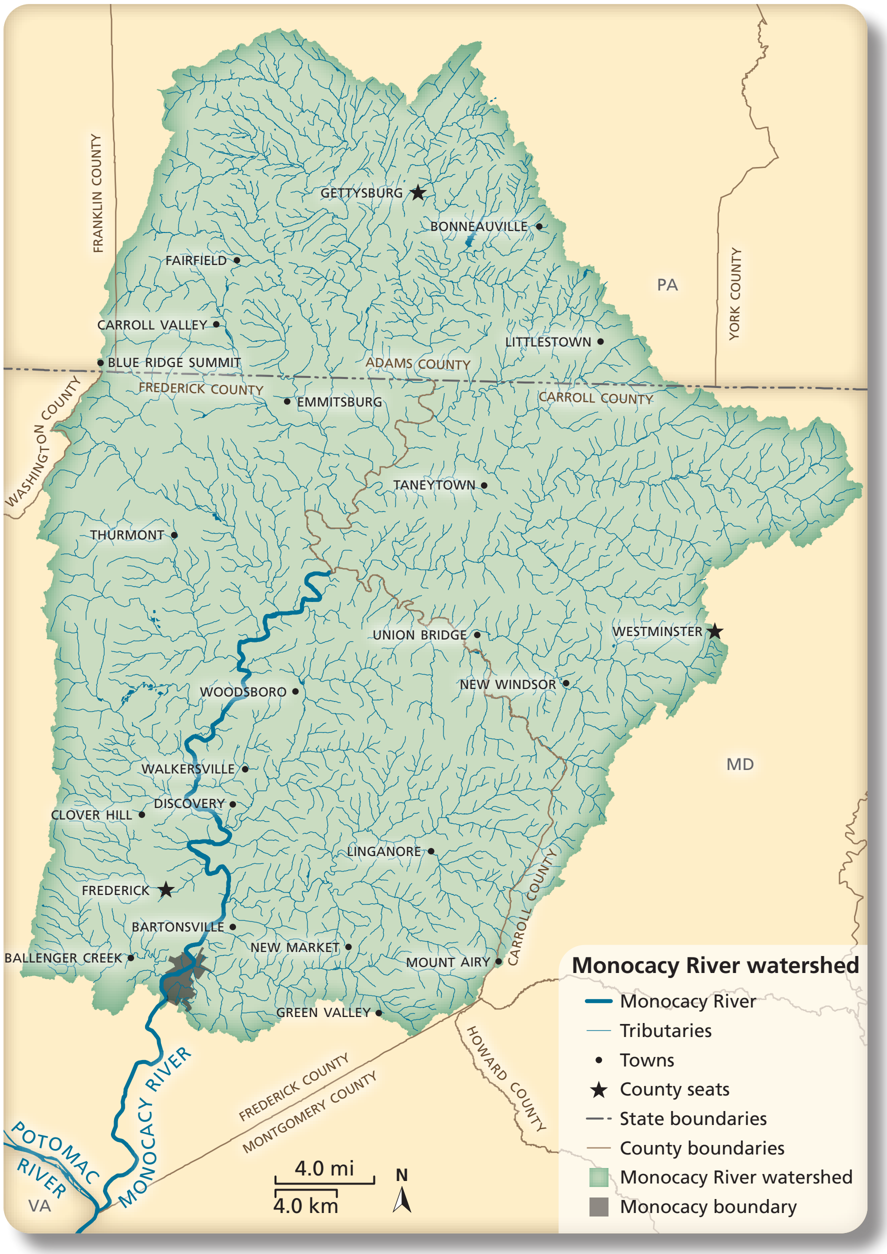


Figure 2.3. Monocacy River and its watershed.[14]

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 (April) and flower in June. Storage in rhizomes controls winter hardiness. Most cool-season grasses are non-native to the Mid-Atlantic region, including bluegrass (*Poa* spp.), brome (*Bromus* spp.), fescue (*Festuca* spp.), timothy (*Phleum pratense*), and orchard grass (*Dactylis glomerata*; Peterjohn 2006).

Rare, threatened, and endangered species

Monocacy National Battlefield provides habitat for several plants that are state-ranked as rare or highly rare—crowned beggarticks (*Bidens coronata*), troublesome

14. USGS EDNA watersheds, ESRI, MONO.

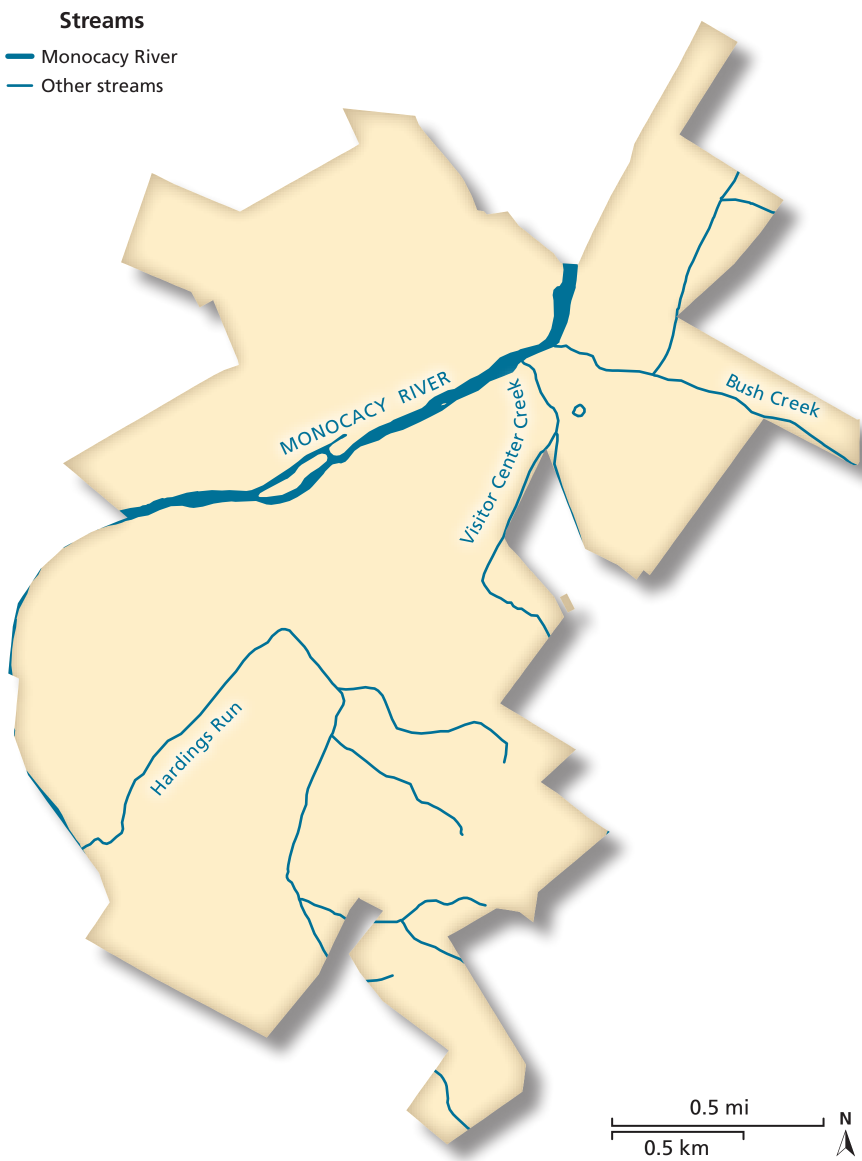


Figure 2.4. GIS data layer[15] depicting the stream network for Monocacy National Battlefield.

sedge (*Carex molesta*), Kentucky coffeetree (*Gymnocladus dioicus*), Engelmann's dock (*Rumex hastatulus*), veined skullcap (*Scutellaria nervosa*), and leather grape-fern (*Botrychium multifidum*). This latter species is historically known but ranked as 'extirpated' in Maryland, and investigation is underway to verify the identification of this species (Engelhardt 2005, MONO 2009).

In addition to these plants, there are several state-listed species of fish (mottled sculpin [*Coittus bairdii*], pearl dace [*Margariscus margarita*]), birds (spotted sandpiper [*Actitis macularius*], northern harrier [*Circus cyaneus*], magnolia warbler [*Dendroica magnolia*], dark-eyed junco [*Junco hyemalis*], loggerhead shrike [*Lanius ludovicianus*], hooded merganser [*Lophodytes cucullatus*], vesper sparrow [*Pooecetes gramineus*], golden-crowned kinglet [*Regulus satrapa*], yellow-bellied sapsucker [*Sphyrapicus varius*], Nashville warbler [*Vermivora ruficapilla*]), and mammals (Indiana bat [*Myotis sodalist*], southern bog lemming [*Synaptomys cooperi*], black bear [*Ursus americanus*]) found in the park.

2.1.2 Resource management issues overview

Monocacy National Battlefield has seen considerable change along its borders since land acquisition began in the 1980s, and the

15. ESRI, MONO.

Figure 2.5. GIS data layer[16] of topographic elevation for Monocacy National Battlefield.

park faces a number of resource management issues, many of which are related to the surrounding land use (NCRN 2006; Figure 2.10). Encroaching development reduces the habitat available for native flora and fauna. Between 1990 and 2000, population density in the vicinity of the park has continued to increase, with development of the city of Frederick spreading to the park's northern boundary and other housing developments are rapidly approaching the southern boundary (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 highest around Frederick and also around Gaithersburg to the southeast (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 Monocacy 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 (Andrén 1994,

16. National Elevation Database: Gesch et al 2002, Gesch 2007, MONO.

Figure 2.6. GIS data layer[17] of surficial and bedrock geology in Monocacy National Battlefield.

Environmental Law Institute 2003). The park increasingly represents a sanctuary for native flora and fauna within this rapidly urbanizing environment and significant habitat fragmentation has occurred because of this development and proliferation of utility corridors and roads (MONO 2009). 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 Monocacy River watershed (Figure 2.3), it is susceptible to degradation of landscape and water quality that occurs outside the

17. Thorneberry–Ehrlich 2008, MONO.

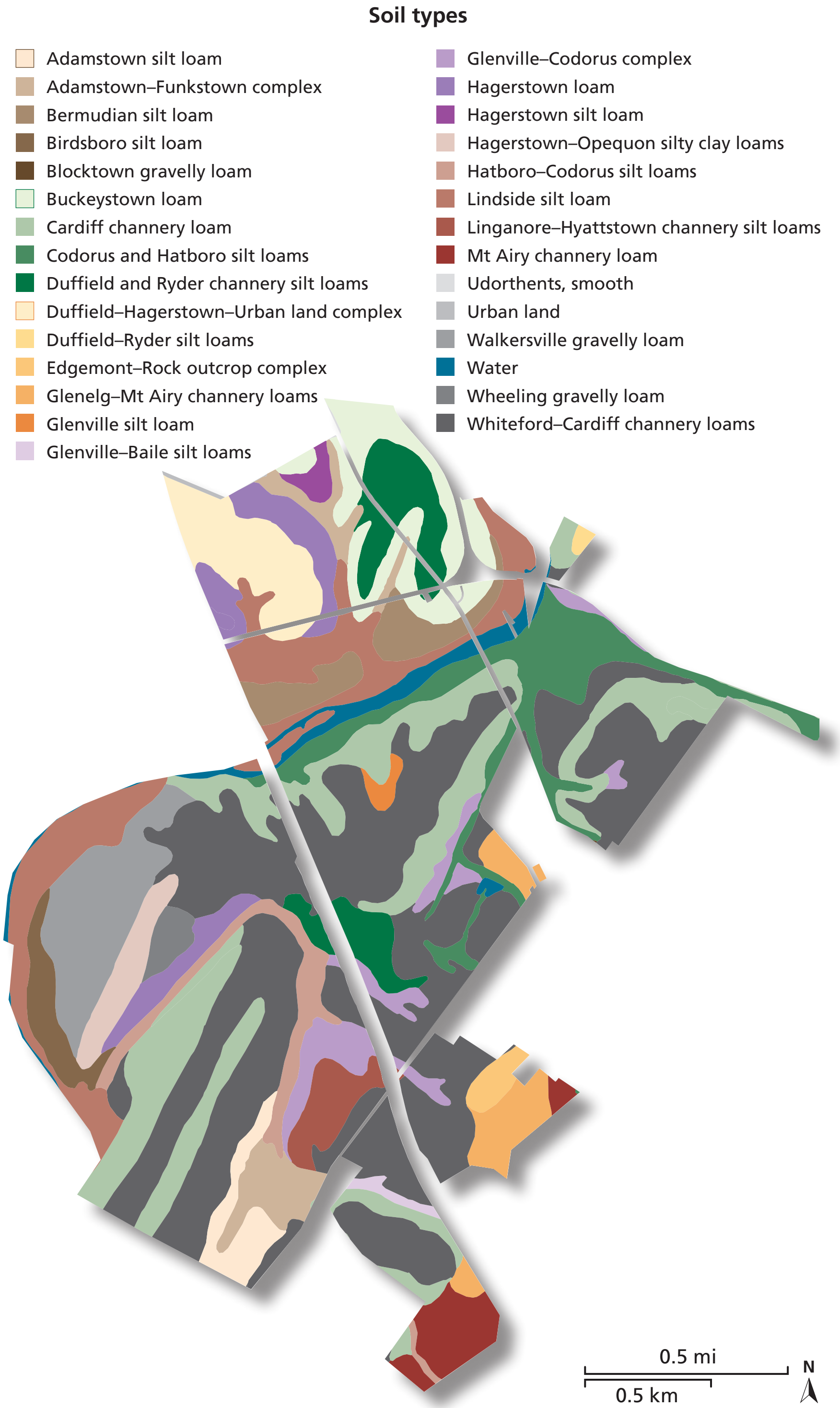
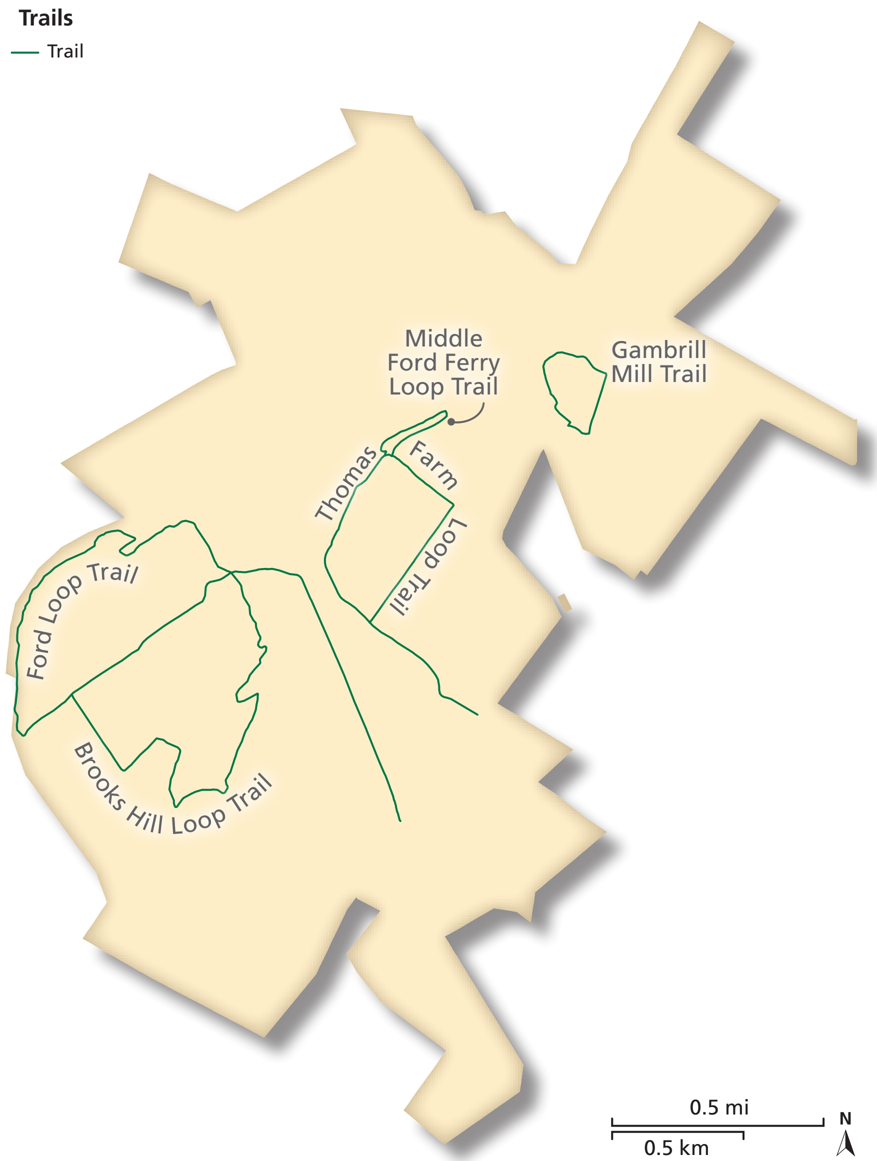


Figure 2.7. GIS data layer[18] of soil types found in Monocacy National Battlefield.

park and therefore beyond park management's control. Like other battlefield parks, it has the legislated challenge of combining the preservation of a historic landscape with natural resource management. Potential threats to the park's natural resources include the release of pollutants from agriculture, industrial complexes located southwest of the park, and heavy traffic on Interstate 270, which bisects the park (NCRN 2006; Figure 2.2). Suburban sprawl increasingly makes the park an important refuge for native flora and fauna, but the spread of exotic plants and an increase in deer population have already been documented and pose a threat to the park's

18. SSURGO, MONO.

Figure 2.8. GIS data layer[19] showing the trail system of Monocacy National Battlefield.



natural resources (Figure 2.15; MONO 2009).

In 2009, a Total Maximum Daily Load (TMDL) was approved for the Lower Monocacy River for sediment (MDE 2008). This was based on 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 the Monocacy River in the vicinity of the park, it is designated as a Use I-P waterbody (Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply; MDE 2010).

The waters of the Lower Monocacy River have also been identified by MDE as impaired by bacteria and nutrients. A TMDL for bacteria has been submitted to the U.S. EPA to address that impairment (MDE 2007), and a TMDL to address the listing for nutrients is currently under development, and the listing for impacts to biological communities will be addressed at a later date (MDE 2008).

19. MONO.

Figure 2.9. GIS data layer[20] showing general location and types of habitats in Monocacy National Battlefield.

Grasslands

Management of grasslands is high on the list of Monocacy'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).

Forests

The mosaic of forest, grassland, and agricultural lands at Monocacy 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). Re-

20. National Wetlands Inventory, MONO.

search 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).

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 Monocacy National Battlefield showed that of the six most abundant species in the park, two were non-native (Engelhardt 2005). Those two species were garlic mustard (*Alliaria petiolata*) and tufted knotweed (*Polygonum caespitosum*).

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 *Ceratocycstis ulmi* (Dutch elm disease), and the exotic emerald ash borer (*Agrilus planipennis*; USDA 2009a, b, 2010a, b, c).

Agriculture

Much of the land in Monocacy National Battlefield is managed as a historic agricultural landscape through permits for crops and pasture. Farm activities outside and inside the park threaten the health of the Monocacy River through high inputs of nutrients, sediments, and pesticides. To combat these threats, the park encourages best management practices within its boundaries including the preservation of large forested buffers between agricultural fields and waterways, reducing erosion along river banks and absorbing runoff from neighboring fields (MONO 2009).

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). Monocacy National Battlefield is one of several historical parks that have issued agricultural special use permits to local farmers 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 important documents broadly guide the management of Monocacy National Battlefield's natural resources: the National Park Service Organic Act of 1916 ("Organic Act", Ch. 1, 39 Stat. 535), the 1934 founding legislation for the park, the battlefield's 2008 Draft General Management Plan/Environmental Impact Statement (NPS 2008), 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 Monocacy National Battlefield Park's chief environmental

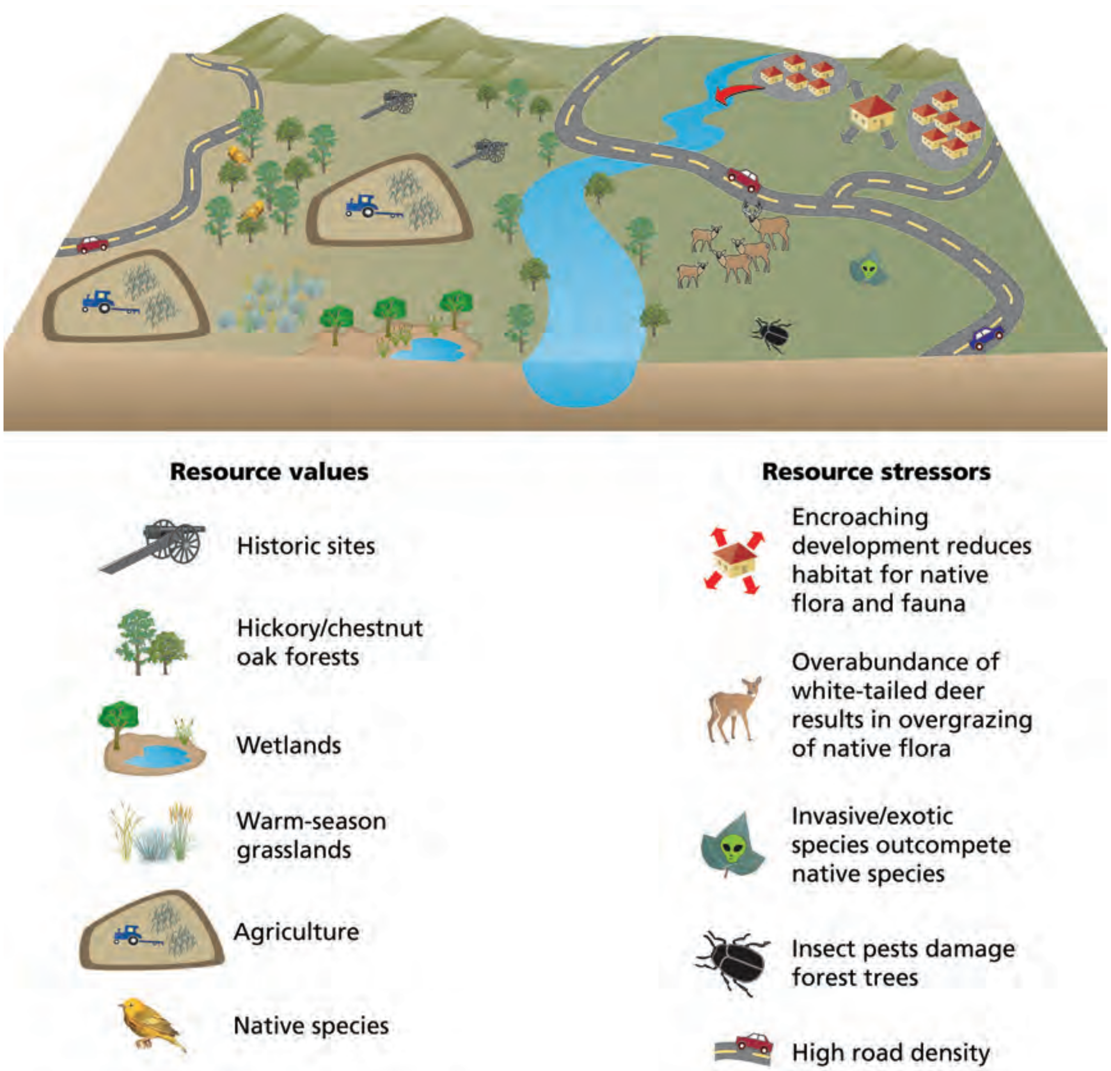


Figure 2.10. Conceptual diagram illustrating the major resource values and stressors in Monocacy National Battlefield.

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.

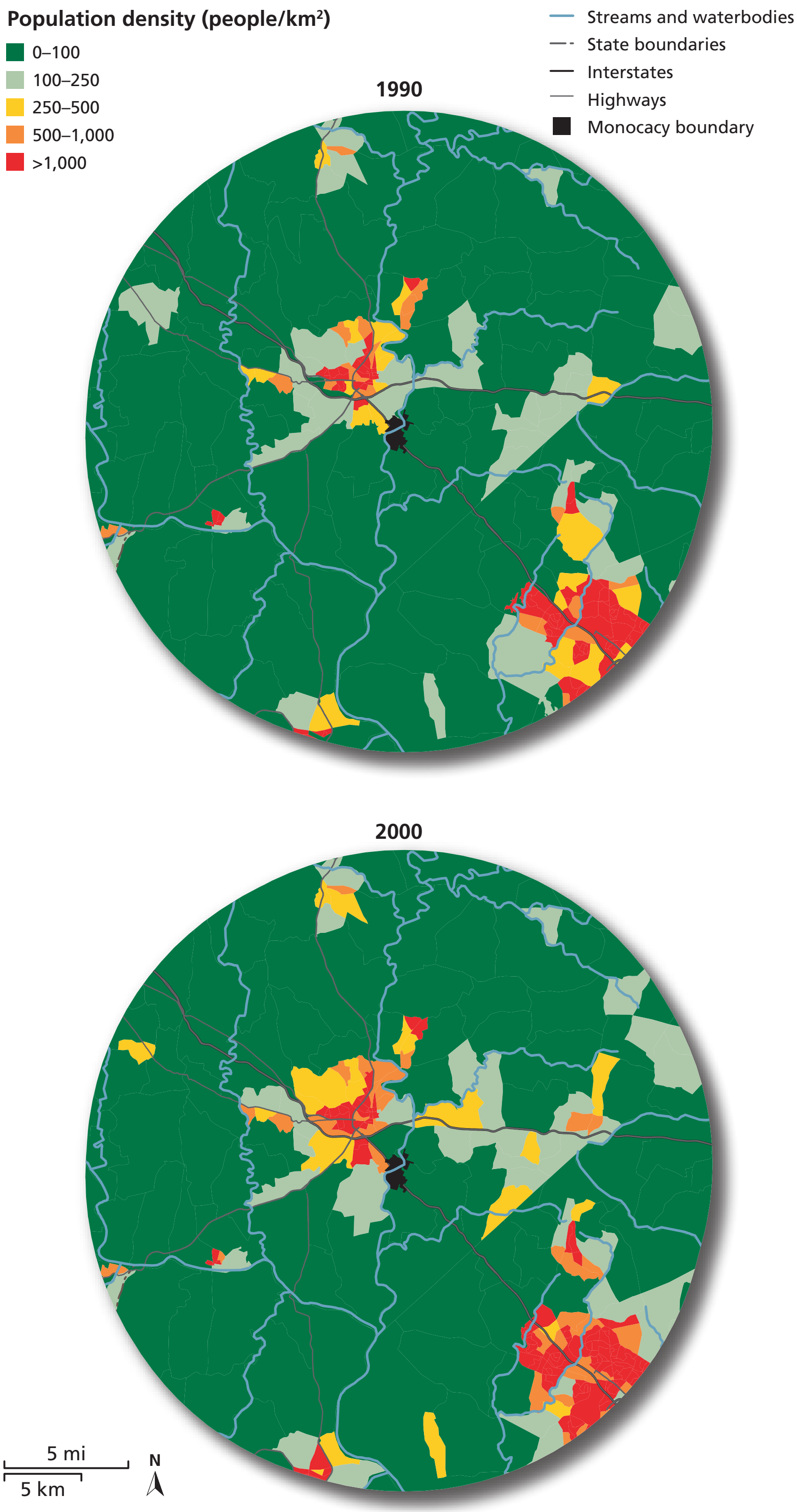
However, as a battlefield park, natural resource management at the park is set within a cultural and historic context. The 1934 congressional authorization for Monocacy National Military Park (later changed to Monocacy National Battlefield; Act of June 21, 1934, 48 Stat. 1198) includes in its statement of purpose,

> *"Preserving the breastworks, earthworks, walls, and other defenses and shelters used by the Confederate and Union armies on July 9, 1864, as well as the buildings, roads and outlines of the battlefield."*

Thus, as a battlefield park, natural resource management at Monocacy 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."*

Figure 2.11. GIS data layer[21] showing population density surrounding the park in 1990 and 2000.



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

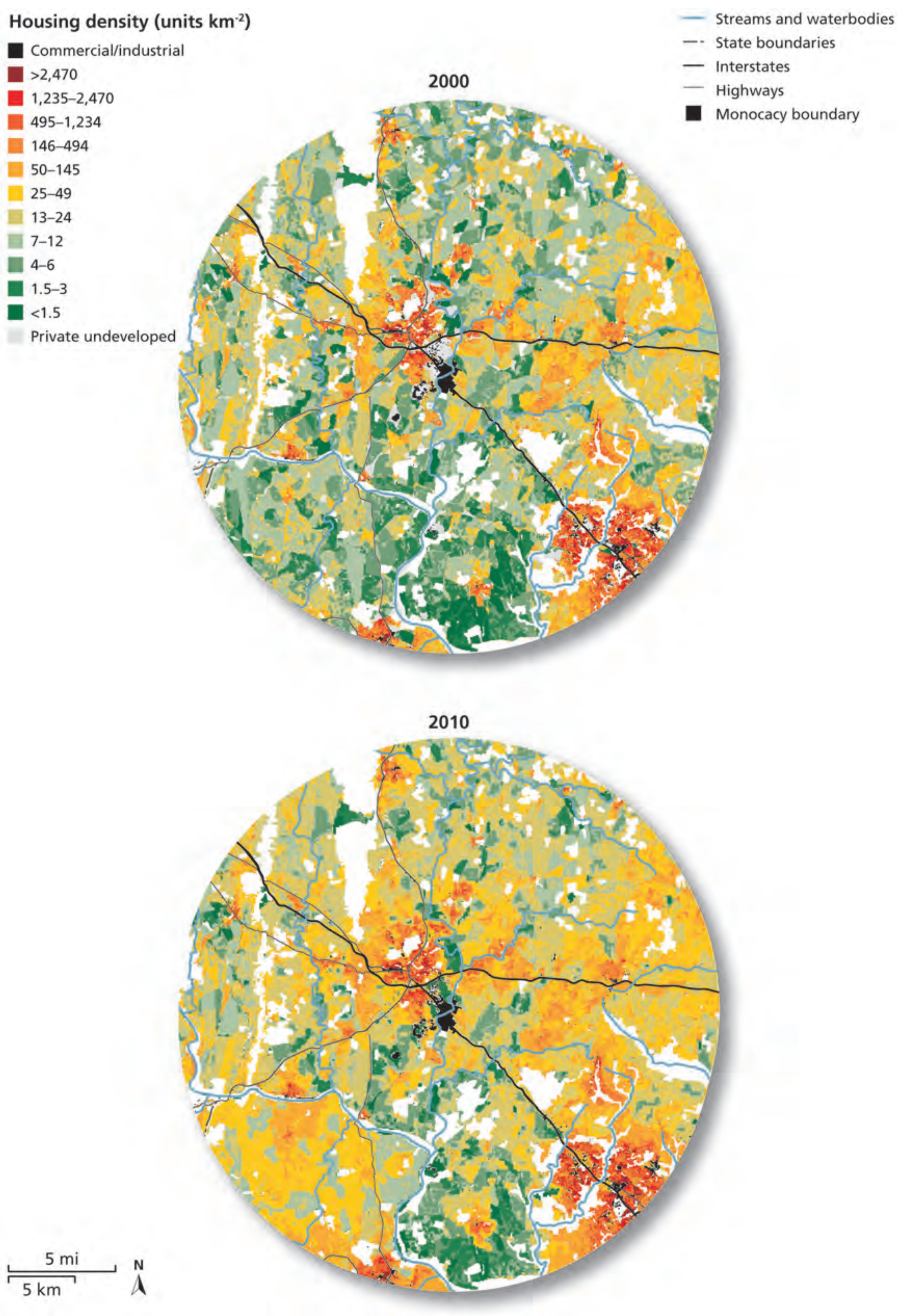


Figure 2.12. GIS data layer[22] showing population density surrounding the park in 1990 and 2000.

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

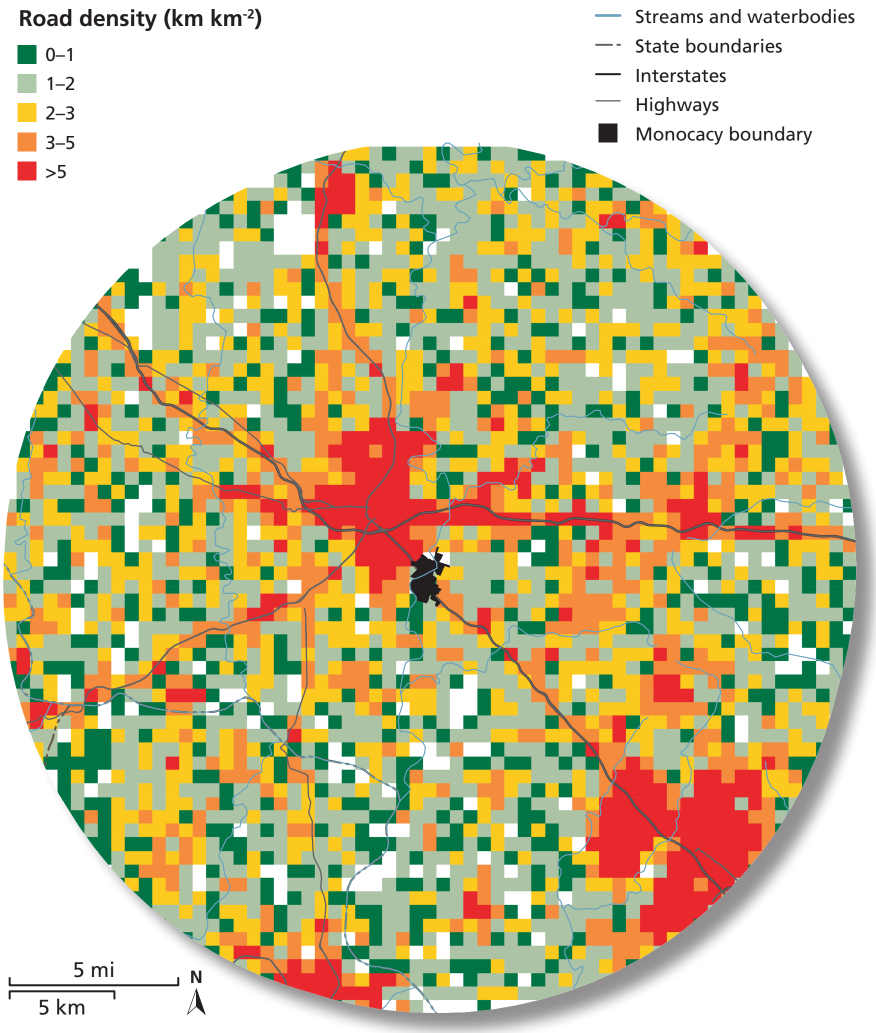


Figure 2.13. GIS data layer[23] showing road density surrounding the park in 2003.

Monocacy National Battlefield 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 managed for agricultural values (croplands and pastures).

2.2.2 Resource stewardship planning

The 2008 Draft General Management Plan (GMP)/Environmental Impact Statement for Monocacy, when approved and finalized, will establish a direction to guide the management of the battlefield's resources and the visitor experience for the next 15 to 20 years. Saving the rural historical qualities of the landscape is one of the major issues addressed in the draft GMP.

The recently completed Resource Stewardship Strategy (RSS) will provide guidance for the research, resource management, and resource education programs of the NPS at Monocacy National Battlefield (MONO 2009). The RSS identifies the fundamental and other important resources and values (natural and cultural resources, soundscape, and viewshed) which are significant to the park's purpose, significance, and mangement. Fundamental park resources and other important resources

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

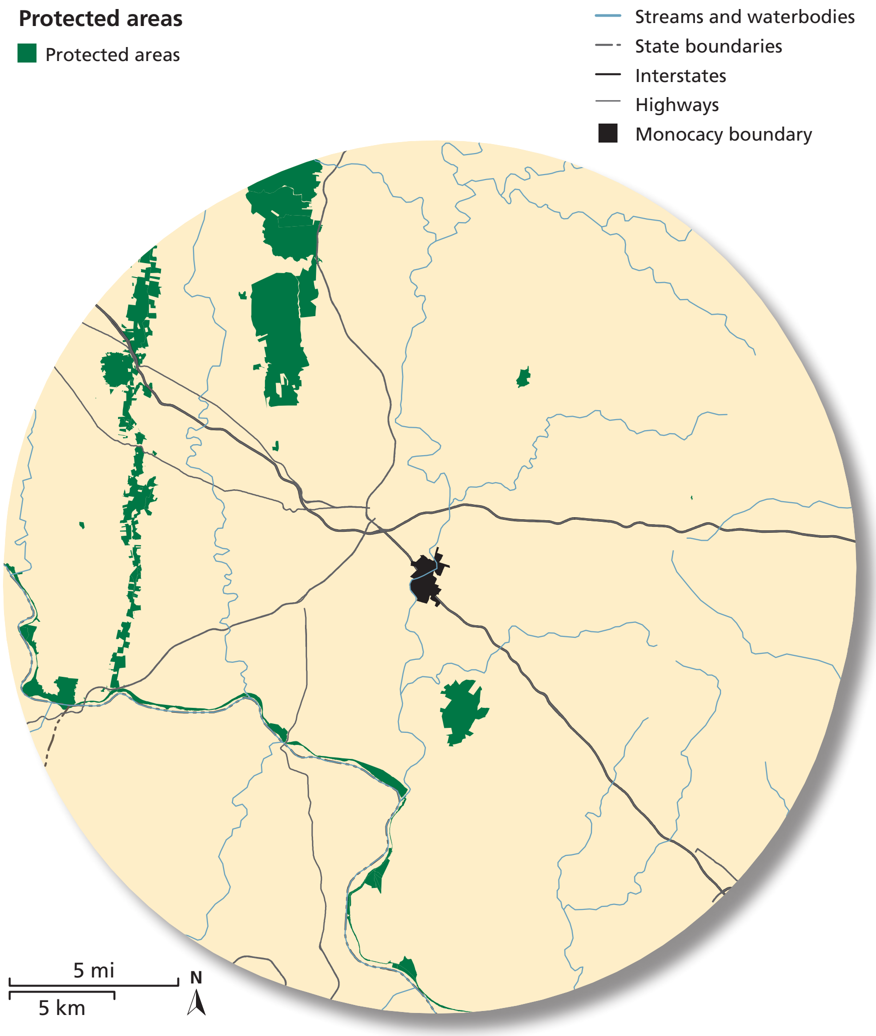


Figure 2.14. GIS data layer[24] showing protected areas surrounding the park in 2000.

and values as well as their statements of desired conditions were identified as follows:

1. Natural resources related to the Battle of Monocacy

1.1. Waterways. Waterways will be improved or maintained in as natural a state as possible, given cultural resource preservation needs, to support aquatic life and natural hydrogeomorphic processes.

1.2. Agrarian landscape. The agrarian landscape will be maintained and enhanced to preserve the battlefield's historic appearance, using sustainable and non-polluting agricultural practices to the greatest extent practicable.

1.3. Forested areas. Forests that are documented as historic to the battle period will be maintained as sustainable, regenerating, native forests.

1.4. Witness trees. Large diameter trees that were probably in existence at the time of the battle will be managed to ensure their long-term health and longevity.

2. Cultural resources related to the Battle of Monocacy

2.1. Archeological sites. Archeological sites that contribute to the significance of the battlefield will be maintained in good condition per the Archeological Sites Management Information System (ASMIS).

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

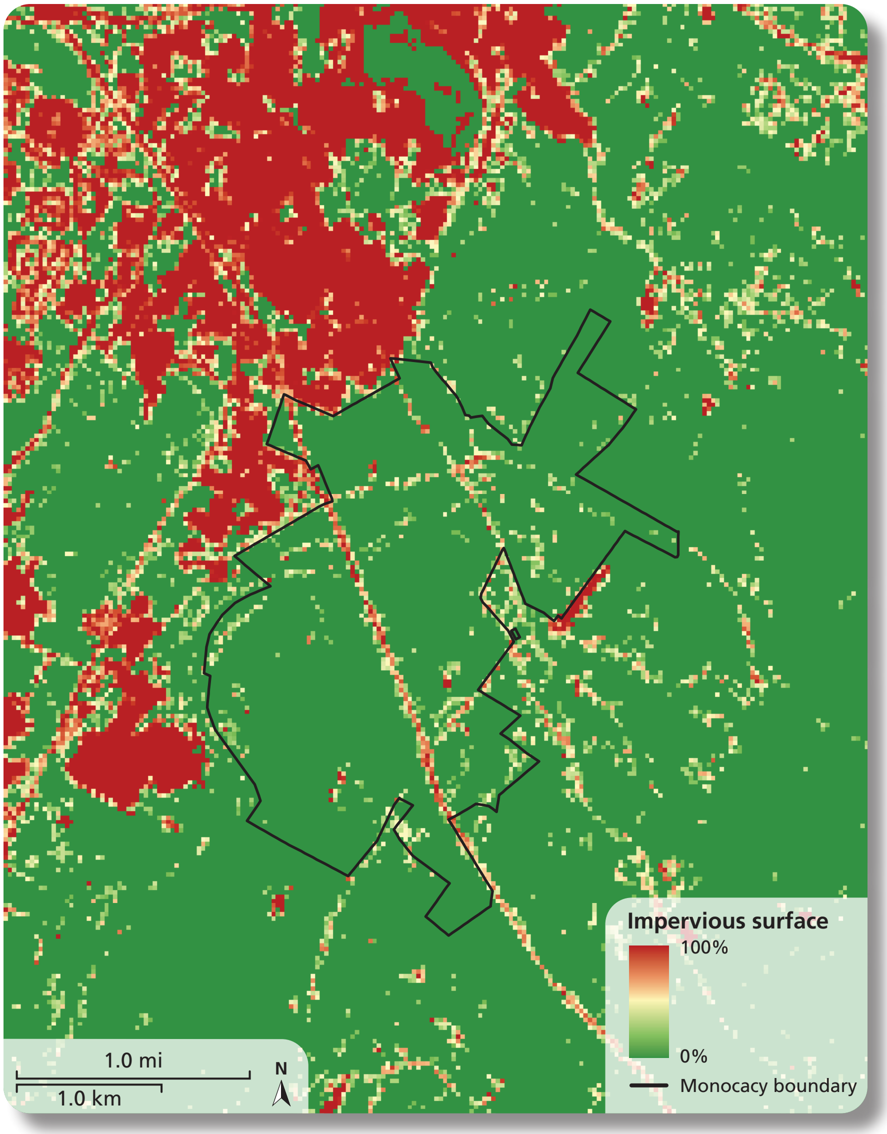


Figure 2.15. GIS data layer[25] showing percent impervious surface in and around Monocacy National Battlefield in 2000.

2.2. Historic structures. Historic structures that contribute to the significance of the battlefield will be stabilized, preserved, and maintained in good condition per the List of Classified Structures (LCS).

2.3. Cultural landscape elements. Cultural landscape elements that contribute to the significance of the battlefield will be stabilized, preserved, and maintained in good condition per the Cultural Landscape Inventory (CLI).

2.4. Museum collections and artifact assemblages. Museum collections and artifact assemblages will be preserved and managed according to accepted curatorial practices and maintained in proper environmental conditions.

3. Soundscape and viewshed: Visitor experience of personal immersion into the battlefield setting

3.1. Soundscape. Natural sounds and pastoral values of the battlefield will be preserved and intrusions minimized.

3.2. Viewshed. Scenic values of the battlefield will be preserved by maintaining historic views and minimizing modern intrusions.

25. RESAC Impervious Surface Area Time Series, MONO.

4. Natural resources other than battle-related

4.1. Water resources. Water resources will be improved or maintained in as natural a state as possible, given cultural resource preservation needs, to support aquatic life and natural hydrogeomorphic processes.

4.2. Native/exotic plant species. In natural areas, native species and communities will be preserved, protected, and encouraged and exotic species will be reduced, prevented, and controlled. In domestic landscapes, exotic species may be maintained or replaced with representative native species in accordance with management goals.

4.3. Species of management concern. Populations of species of management concern will be maintained at appropriate levels to ensure population viability or to prevent adverse impacts to other park resources.

4.4. Natural history collections. Natural history collections will be preserved and managed according to accepted curatorial practices and maintained in proper environmental conditions.

5. Cultural resources other than battle-related

5.1. Archeological sites. Significant archeological sites that are not battle-related will be maintained in good condition per ASMIS.

5.2. Historic structures. Historic structures that contribute to the significance of the cultural landscape, but which are not battle-related, will be stabilized, preserved, and maintained in good condition per the CLI.

5.3. Artifact assemblages. Artifact assemblages will be preserved and managed according to accepted curatorial practices and maintained in proper environmental conditions.

2.2.3 Resource stewardship science

The Resource Stewardship Strategy (RSS) for Monocacy National Battlefield details the park's resources and desired conditions (as outlined above), and carries that forward with assessing the status of the resource knowledge, identifying current and potential indicators and reference conditions for each indicator, and developing comprehensive strategies and associated activities/projects to ensure the National Park Service is attaining and maintaining the desired conditions for all fundamental and other important resources and values (MONO 2009). This will be achieved through filling data gaps necessary to define and evaluate indicators and targets for park resources, monitoring park resources and visitor activity and managing these resources to ensure that targets for each indicator are achieved, and managing cultural and natural resources to preserve, protect, and maintain their condition and enhance the visitor experience.

This natural resource condition assessment builds on the RSS by synthesizing monitoring data into a habitat-assessed framework, putting management goals in a landscape context, and addressing some of the data gaps identified in the RSS.

2.3 LITERATURE CITED (CHAPTER 2)

Andrén, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. Oikos 71: 355–366.

Askins, R.A. 1999. History of grassland birds in eastern North America. Studies in Avian Biology 19: 60–71.

Askins, R.A. 2000. Restoring North America's birds: lessons from landscape ecology. Yale University Press, New Haven, CT.

Augustine, D.J., L.E. Frelich, and P.A. Jordon. 1998. Evidence for two alternate stable states in an ungulate grazing system. Ecological Applications 8: 1260–1269.

Bates, S. 2009. National Capital Region Network 2008 deer monitoring report. Natural Resources Technical Report NPS/NCRN/NRTR-2009/275. National Park Service, Fort Collins, CO.

Brennan, L.A. and W.P. Kuvlesky Jr. 2005. North American grassland birds: an unfolding conservation crisis? Journal of Wildlife Management 69: 1–13.

Brezinski, D.K. and J.P. Reger. 2002. Stratigraphy–karst relationships in the Frederick Valley of Maryland. In: Kuniansky, E.L. (ed). U.S. Geological Survey Karst Interest Group Proceedings, Shepherdstown, West Virginia. August 20–22, 2002. U.S. Geological Survey Water-Resources Investigation Report 02-4174.

Civil War Preservation Trust (CWPT). 2009. History under siege: 2009 guide to America's most endangered battlefields.

Engelhardt, K.A.M. 2005. A vascular plant inventory for four parks of the National Capital Network. UMCES Contribution #TS-489-05. UMCES, Frostburg, MD.

Environmental Law Institute. 2003. Conservation thresholds for land use planners. Environmental Law Institute. Washington, DC.

Gesch, D., M. Oimoen, S. Greenlee, C. Nelson, M. Steuck, and D. Tyler, D. 2002. The National Elevation Dataset: photogrammetric engineering and remote sensing, v. 68, no. 1.

Gesch, D.B. 2007. The National Elevation Dataset. In: Maune, D. (ed.) Digital Elevation Model Technologies and Applications: the DEM users manual, 2nd edition. Bethesda, Maryland, American Society for Photogrammetry and Remote Sensing.

Gibbs, J.P. and W.G. Shriver. 2002. Estimating the effects of road mortality on turtle populations. Conservation Biology 16: 1647–1652.

Hansen, L.P., C.M. Nixon, and J. Beringer. 1997. Role of refuges in the dynamics of outlying deer populations. In: McShea, W.J., H.B. Underwood, and J.H. Rappole (eds). The science of overabundance: deer population ecology and management. Smithsonian Institution Press, Washington, DC.

Mack, R.N., D. Simberloff, W.M. Lonsdale, H. Evans, M. Clout, and F.A. Bazzaz. 2000. Biotic invasions: causes, epidemiology, global consequences, and control. Ecological Applications 10: 689–710.

McShea, W.J. and J.H. Rappole. 1997. Herbivores and the ecology of forest understory birds. In: McShea, W.J., H.B. Underwood, and J.H. Rappole (eds). The science of overabundance: deer ecology and population management. Smithsonian Institution Press, Washington, DC.

MDE. 2007. Total Maximum Daily Loads of fecal bacteria for the Lower Monocacy River Basin in Carroll, Frederick, and Montgomery Counties, Maryland. Draft. Baltimore, MD.

MDE. 2008. Total Maximum Daily Load of sediment in the Lower Monocacy River Watershed, Frederick, Carroll, and Montgomery Counties, Maryland. Baltimore, MD.

MDE. 2010. Stream segment use designations in Frederick County. *http://www.mde.state.md.us/assets/document/Frederick_Cnty_DUs.pdf*

MONO. 2009. Review Draft, Resource Stewardship Strategy, Monocacy National Battlefield. Frederick, MD.

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

NPS. July 2008. Draft General Management Plan/Environmental Impact Statement, Monocacy National Battlefield.

Peterjohn, B. 2006. Conceptual ecological model for management of breeding grassland birds in the Mid-Atlantic region. Technical Report NPS/NER/NRR—2006/005. National Park Service, Philadelphia, PA.

RESAC Impervious Surface Area Time Series version 1.3. University of Maryland and the Woods Hole Research Center.

Russell, L.F., D.B. Zippin, and N.L. Fowler. 2001. Effects of white-tailed deer (*Odocoileus virginianus*) on plants, plant populations ,and communities: a review. American Midland Naturalis 146: 1–26.

Southworth, S. and D. Denenny. 2006. Geologic map of the National Parks in the National Capital Region, Washington DC., Virginia, Maryland and West Virginia. Scale 1:24,000. Open-File Report OF 2005-1331. U.S. Geological Survey, Reston, VA.

SSURGO. Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database for Frederick County, Maryland. Available online at *http://soildatamart.nrcs.usda.gov*

Steen, D.A. and J.P. Gibbs. 2004. Effects of roads on the structure of freshwater turtle populations. Conservation Biology 18: 1143–1148.

Stromayer, K.A.K. and R.J. Warren. 1997. Are overabundant deer herds in the eastern United States creating alternate stable states in forest plant communities? Wildlife Society Bulletin 25: 227–234.

Thorneberry–Ehrlich, T. 2008. Monocacy National Battlefield geologic resource evaluation report. Natural Resource Report NPS/NRPC/GRD/NRR—2008/051. National Park Service, Denver, CO.

U.S. Congress. Ch. 1, 39 Stat 535. Act to establish a National Park Service (Organic Act), 1916. 16 USC 1, 2, 3, and 4. August 25, 1916.

U.S. Congress. Act of June 21, 1934 (48 Stat. 1198; 16 U.S.C. 430j) Monocacy National Military Park.

U.S. Department of Interior. National Park Service. 2006. Management policies 2006.

USDA (United States Department of Agriculture) Forest Service. 2009a. Gypsy moth in North America. *http://www.fs.fed.us/ne/morgantown/4557/gmoth/*

USDA (United States Department of Agriculture) Forest Service. 2009b. Hemlock woolly adelgid, Forest Health Protection, USDA Forest Service. *http://na.fs.fed.us/fhp/hwa/*

USDA (United States Department of Agriculture) Forest Service. 2010a. How to identify and control dogwood anthracnose. *http://www.na.fs.fed.us/spfo/pubs/howtos/ht_dogwd/ht_dog.htm*

USDA (United States Department of Agriculture) Forest Service. 2010b. Dutch elm disease, Forest Health Protection, USDA Forest Service. *http://na.fs.fed.us/fhp/ded/*

USDA (United States Department of Agriculture) Forest Service. 2010c. Emerald ash borer. *http://www.na.fs.fed.us/fhp/eab/*

Weeks D, Norris M, & A. Banasik. 2007. Water resources stewardship report: Monocacy National Battlefield. Natural Resource Technical Report NPS/NRPC/WRD/NRTR—2007/048. National Park Service, Fort Collins, CO.

Chapter 3: Study approach

3.1 PRELIMINARY SCOPING

3.1.1 Park involvement

Monocacy park staff, including Superintendent Susan Trail and natural resource manager Andrew Banasik, 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 Antietam 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 Antietam 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.

3.1.2 Other NPS involvement

The NCRN I&M was the primary coordinator and leader for the production of this NRCA for Monocacy National Battlefield. NCRN staff established a cooperative agreement with University of Maryland

The Monocacy River.

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 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 shown in the figures in Chapter 2 in that the fee boundary encompasses only the lands that are currently owned by NPS (Figure 2.1). NPS jurisdiction limitations generally prohibit the park from managing resources outside of the fee boundary, so the habitat assessment is limited to those lands. The administrative/legislative boundary equals 667 ha (1,647 acres), while the fee boundary is 548 ha (1,355 acres). Six predominant ecological habitat types were identified within Monocacy 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 condition within Monocacy 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 Monocacy 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 and pastures). Developed areas, although defined as a third habitat managed for agricultural values, were not assessed for natural resource condition.

Utility of thresholds

A natural resource condition assessment requires the establishment of criteria for defining ecological condition and the current assessment was based upon explicitly defined threshold values. Even though increasing scientific research has been focused upon defining ecological thresholds, uncertainty in definition as well as spatial and temporal variability has often led to disagreement on specific values (Groffman et al. 2006,

Figure 3.1. GIS data layer[26] of major habitat types in Monocacy National Battlefield, as defined by aggregation of other GIS data layers.

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

26. NCRN I&M, MONO.

resulting in significant—and perhaps irreversible—damage (Hendricks and Little 2003). Three types of thresholds are used for different aspects of natural resources management and all can provide useful information for the assessment of natural resource condition. These thresholds are management, ecological, or regulatory and while in some cases they overlap (or are the same), these thresholds often provide different information as a result of being established for very different purposes (Figure 3.2; Bennetts et al. 2007).

Management thresholds are intended to instigate changes in management activity 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. 2007) 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 Monocacy 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).

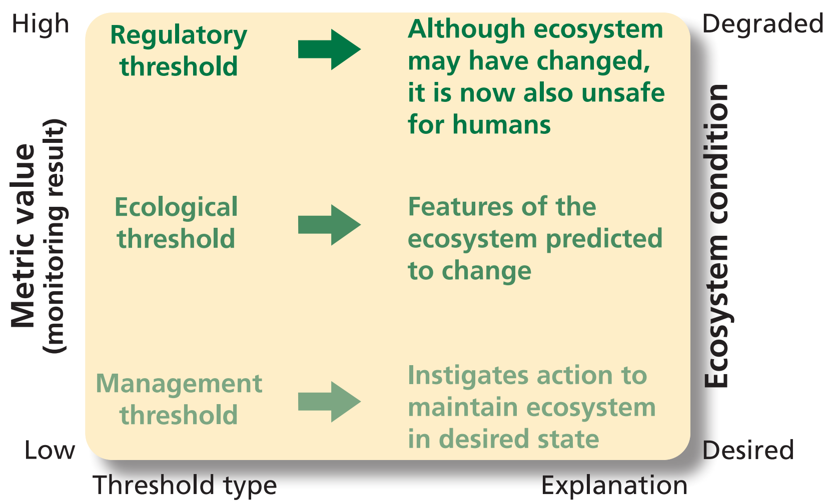


Figure 3.2. Conceptual relationship between ecosystem condition and the different types of thresholds. In all cases, it is presumed that the metric is well-studied with a reliable measurement protocol and well-understood responses (e.g., available large spatio-temporal data sets).

3.3.2 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 Monocacy: bird monitoring (grassland, wetland, forest, birds of prey, etc.), macrofungi, regular small mammal monitoring, grasses, groundwater levels,

Table 3.1. Thresholds for Air & Climate metrics.

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

Table 3.2. Thresholds for Water Resources metrics.

Metric	Threshold	Justification	Threshold source
pH	6.5 ≤ 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	< 32.0°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)	Threshold based on relationship to benthic invertebrate index.	Southerland et al. 2007
Phosphate (PO_4)	0.1133 mg PO_4 L^{-1} (monthly instantaneous measurements)	Threshold based on U.S. EPA nutrient ecoregional criteria, to maintain baseline conditions with minimal impact from anthropogenic eutrophication.	U.S. EPA 2000 U.S. EPA nutrient criteria inland waters
Benthic index of biotic integrity (IBI)	Benthic IBI > 3 (one sample per site)	Threshold based on statewide assessment of benthic communities; resulting in the scale: 1.0–1.9 (very poor), 2.0–2.9 (poor), 3.0–3.9 (fair), 4.0–5.0 (good).	Southerland et al. 2007 Norris and Sanders 2009
Physical habitat index (PHI)	PHI > 81 (one sample per site)	Threshold based on Maryland Biological Stream Survey data on the condition of MD streams: 0–50 (severely degraded), 51–65 (partially degraded), 66–80 (degraded), and 81–100 (minimally degraded).	Paul et al. 2003 Southerland et al. 2005

Table 3.3. Thresholds for Biological Integrity metrics.

Metric	Threshold	Justification	Threshold source
Cover of herbaceous species, woody vines, and target exotic trees and shrubs	< 5% cover. Measured as area of ground covered by herbs and vines, and percent of total basal area for shrubs and trees (one sample per site)	This threshold is more than a simple presence of these species, but an indication that they have the potential to increase in abundance, displacing native species.	This threshold is a guideline to commence active management of an area by removal of these species.
Presence of pest species	>1% of trees infested (one sample per site)	The emerald ash borer threshold is based upon any observed presence of this pest species being unacceptable. The gypsy moth threshold is based on documented forest response.	Montgomery 1990 Liebhold et al. 1994
Native tree seedling regeneration	35,000 seedlings ha^{-1} (one sample per site)	Based on natural densities of native tree seedlings in a healthy and self-sustaining forest. This threshold may vary depending on deer population.	McWilliams et al. 1995 Carter and Fredericksen 2007 Marquis et al. 1992
Fish index of biotic integrity (IBI)	Fish IBI > 3 (one sample per site)	Based on 1994–1997 data from a total of 1,098 sites. Sites were classified based on physical and chemical data and compared to a range of stream fish related metrics: 1.0–1.9 (very poor), 2.0–2.9 (poor), 3.0–3.9 (fair), 4.0–5.0 (good).	Southerland et al. 2007
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} (two assessments 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

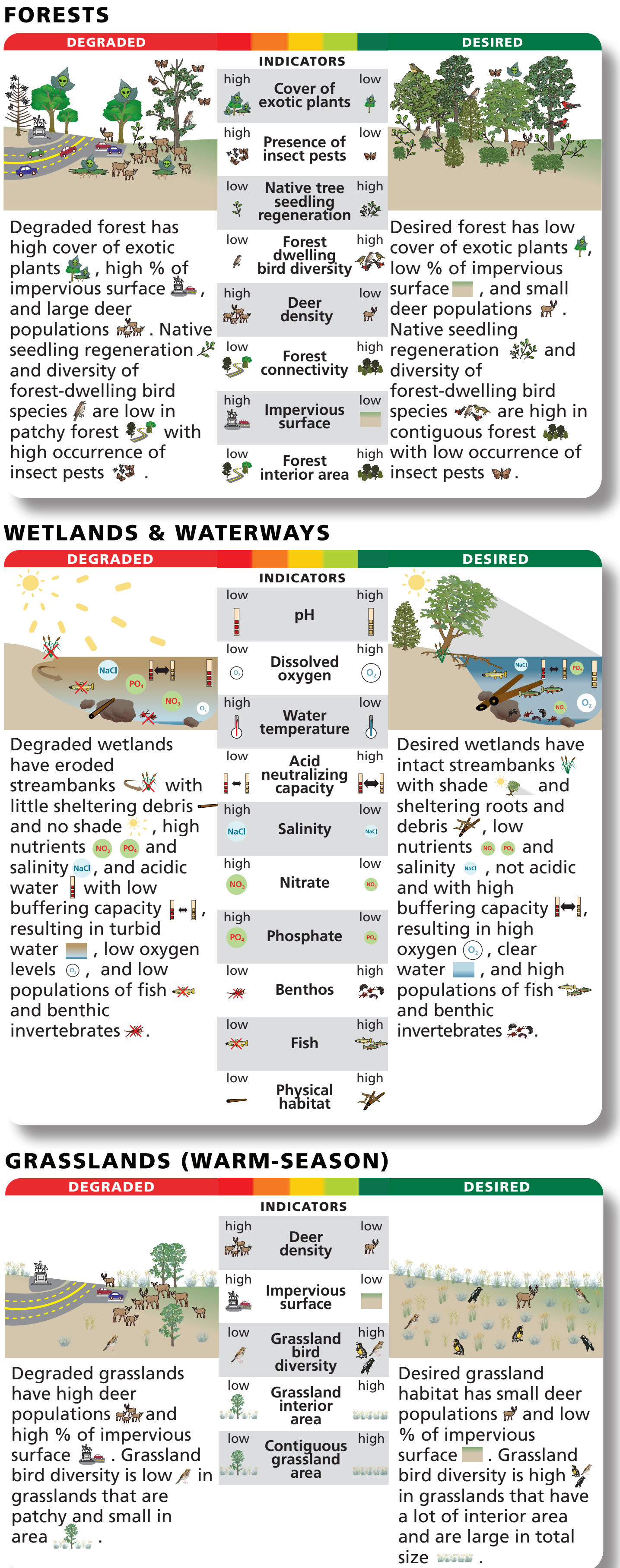


Figure 3.3. Conceptual framework for desired and degraded condition of habitats managed for natural resource values present within Monocacy National Battlefield, indicating metrics to track status of condition.

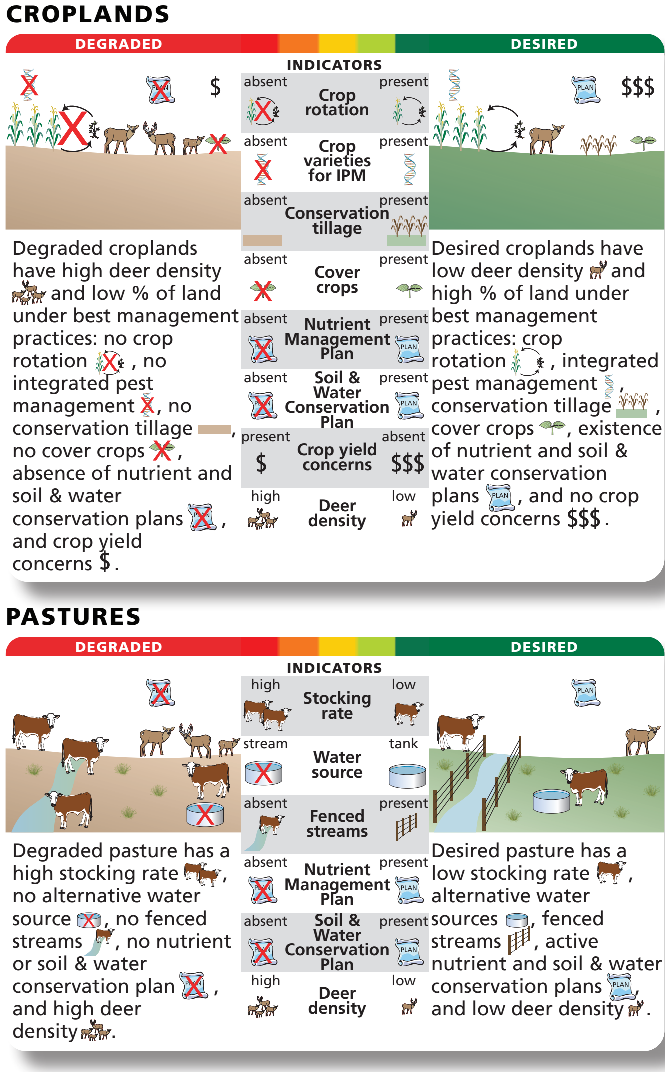


Figure 3.4. Conceptual framework for desired and degraded condition of habitats managed for agricultural values present within Monocacy National Battlefield, indicating metrics to track status of condition.

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

Visibility condition—management

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

Mercury deposition—regulatory

The threshold value of 2 ng Hg L^{-1} (2 ppt; annual mean) in rain, used in this assessment, is an indirect modeled estimate of rainfall concentrations that result in tissue concentrations within inland fish species of 0.5 mg methylmercury kg^{-1} (0.5 ppm) wet weight (Meili et al. 2003, Hammerschmidt and Fitzgerald 2006). The authors do concede that this value is for low organic soils, as highly humic soils are known to potentially store large amounts of mercury which can slowly leach into inland waters, in some cases contributing much more to mercury concentrations

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

Ecological monitoring framework

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

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

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

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

Habitat framework

—Habitats managed for natural resource values—

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

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

Warm-season grasslands
- Deer density ($deer\ km^{-2}$)
- Impervious surface (% cover)
- Grassland bird diversity
- Grassland interior area (ha)
- Contiguous grassland area (ha)

—Habitats managed for agricultural values—

Croplands
- Crop rotation (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 ($deer\ km^{-2}$)

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 ($deer\ km^{-2}$)

than current atmospheric deposition (Meili et al. 2003). Currently, the U.S. EPA also has a lower recommended fish tissue regulatory maximum threshold of 0.3 mg methylmercury kg^{-1} (0.3 ppm) wet weight, which would result in reducing the modeled atmospheric deposition threshold (U.S. EPA 2001). Human and mammalian regulatory thresholds are based on the effects of exposure. In vitro exposure can cause mental retardation, cerebral palsy, deafness, blindness, and dysarthria (speech disorder), and adult exposure can cause motor dysfunction and other neurological and mental impacts (U.S. EPA 2001). Avian species are particularly susceptible as mercury reduces reproductive potential (Wolfe et al. 1998). Measured atmospheric wet and dry mercury deposition trends from west to east across North America can also be measured in the common loon (*Gavia immer*) and throughout North America in mosquitoes (Evers et al. 1998, Hammerschmidt and Fitzgerald 2002). Mercury is also recognized to have a toxic effect on soil microflora, although no ecological depositional threshold is currently available (Meili et al. 2003). Mercury deposition data from 2004–2008 from the two sites closest to the park were obtained from the Maryland Deposition Network website (*http://nadp.sws.uiuc.edu/mdn*). The annual mean was calculated and compared to the threshold.

3.4.2 Water Resources

pH, dissolved oxygen, temperature—regulatory

The State of Maryland has classified its waterbodies on the basis of their designated uses. Minimum water quality critera have been established that will maintain these designated uses. The Lower Monocacy River is designated as a Use I-P waterbody (Water Contact Recreation, Protection of Aquatic Life, 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. Note that the Monocacy Resource Stewardship Strategy used more stringent thresholds for reference condition with respect to water temperature and pH (COMAR 2007b, MONO 2009).

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 32°C (87°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 (Norris and Sanders 2009). 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, U.S. EPA 2009 where 1 mg L^{-1} [1 ppm] $CaCO_3$ = 20 μeq L^{-1}). A less conservative threshold of 50 μeq L^{-1} has also been suggested by some authors (Hendricks and Little 2003, Schindler 1988). ANC is reported monthly as an instantaneous measure. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

Salinity—regulatory

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

Nitrate—ecological

The nitrate concentration threshold was developed by the MBSS program after their first round of sampling as described for the ANC threshold. The MBSS determined that a nitrate concentration of 2 mg NO_3 L^{-1} (2 ppm) indicated stream degradation (Southerland et al. 2007, Norris and Sanders 2009). Instantaneous measurements were taken monthly. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment. If a measurement was listed as "not detected," it was assigned a pass result because the detection limit for nitrate is lower than the assessment threshold (M. Norris, pers. comm.).

Phosphate—ecological

The phosphate threshold is based on the U.S. EPA Ecoregional Nutrient Criteria. These criteria were developed to prevent eutrophication nationwide and are not regulatory (U.S. EPA 2000). The criteria are developed as baselines for specific geographic regions. Monocacy National Battlefield is located in Ecoregion IX or the Southeastern Temperate Forested Plains and Hills region (U.S. EPA 2000). The ecoregional reference condition value for total phosphorus is 0.3656 mg PO_4 L^{-1} (0.3656 ppm), which equates to a phosphate threshold of 0.1133 mg PO_4 L^{-1} (0.1133 ppm; U.S. EPA 2000). Measurements were taken monthly as instantaneous measurements. Each measurement was assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment. If a measurement was listed as "not detected," it was assigned a pass result because the detection limit for phosphate is lower than the assessment threshold (M. Norris, pers. comm.).

Benthic IBI—ecological

The aquatic macroinvertebrates threshold is based on the MBSS interpretation of the benthic index of biotic integrity (IBI). The IBI scores range from 1 to 5 and are calculated by comparing the site's benthic assemblage to the assemblage found at minimally impacted sites (Norris and Sanders 2009). An IBI score of 3 indicates that a site is considered to be comparable to (i.e., not significantly different from) reference sites. A score greater than 3 indicates that a site is in better condition than the reference sites. Any sites with IBIs less than 3 are in worse condition than reference sites (Southerland et al. 2007, Norris and Sanders 2009), and the entire scale is 1.0–1.9 (very degraded), 2.0–2.9 (degraded), 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), instream 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 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. Both the Organic Act that established the National Park Service in 1916 and the Resource Stewardship Strategy mandate the conservation of both natural and cultural resources (see Section *2.2.1—Park enabling legislation*). This threshold is a guide to commence active management of an area by removal of these species. Reported data was from permanent plots monitored annually and reported as the percent of plots that attained the threshold. The cover of exotic herbaceous species in a plot was calculated from the percent cover of the single exotic species with the greatest cover. The cover of exotic trees and shrubs in a plot was calculated as the percentage of total tree or shrub basal area. Tree saplings and seedlings were not included in this calculation. Results from each plot were assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

Presence of pest species—management, ecological

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

Native tree seedling regeneration—ecological

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

Fish Index of Biotic Integrity—ecological

A threshold value of 3 was used as an ecological threshold indicating attainment of overall reference ecosystem condition. The fish index of biotic integrity (IBI) was 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 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 two sites in 2007 and three sites in 2008 (Goodwin and Shriver 2009). These data were compared against the list of FIDS (MD DNR undated) and the number of FIDS was compared to the threshold. The park was given a rating of either 100% or 0% attainment.

Grassland bird diversity—ecological

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

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

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

3.4.4 Landscape Dynamics

Impervious surface—ecological

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

Forest interior area

Interior forest area is essential for the breeding success of many birds. There are 26 species of birds that breed in the Piedmont 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 (Dcrit) is a measure of the distance at which 75% of forest patches are connected, therefore allowing landscape-level dispersal (Townsend et al. 2009). From 13 tree species, an effective dispersal distance of 65 ± 15 m (210 ± 50 ft; mean ± standard error) has been calculated, indicating on average a 95% probability of effective dispersal over that distance. The maximum dispersal distance for these same species was 997 ± 442 m (3,271 ± 1,450 ft), indicating almost zero probability (<0.1%) of a seed dispersing that distance (He and Mladenoff 1999). Other studies have shown similar dispersal ranges for small mammals (Bowman et al. 2002). For this assessment, Dcrit was calculated and compared to a threshold of <360 m (1,180 ft) based on the distance that many small mammals and tree seeds can disperse (He and Mladenoff 1999, Bowman et al. 2002).

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

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

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

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 of 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 Monocacy 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 some Water Resources metrics within Monocacy 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 Monocacy 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 nitrogen and sulfur deposition, and visibility (2003–2007) were taken from interpolated results from the NPS Assessment of Current Air Quality Conditions (NPS 2009), while mercury deposition data (2004–2008) came from two nearby monitoring sites (Figure 3.6). A total of 16 sites were monitored for water quality from 2004–2008 (pH, dissolved oxygen, temperature, salinity, nitrate, and phosphate) in Monocacy National Battlefield—three sites monitored by NCRN I&M and 13 sites monitored by park staff (Figure 3.7). ANC was only measured at the three NCRN I&M sites during 2005–2008. Eight sites were monitored in 2004 by NCRN I&M for the Benthic Index of Biotic Integrity, Physical Habitat Index (both Water Resources metrics), and the Fish Index of Biotic Integrity (a Biological Integrity metric; Figure 3.8).

Forest data (exotic species cover and density, presence of pest species, and native tree seedling regeneration) were collected at two sites from 2006–2008 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 (impervious 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 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 432 measurements (water temperature) during the nine-year period (Table 3.7; Appendix A). These data were compared to threshold values (Tables 3.1, 3.2, 3.3, 3.4), as a percentage of measurements attaining the threshold value for each metric, where a value of 100% indicated that all sites and times met the threshold to maintain natural resources, and 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 Monocacy National Battlefield. An assessment was made of the whole park by calculating an un-

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 CO2 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 staff at the nearby Antietam National Battlefield 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 Monocacy 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, MONO	Norris et al. 2007, Norris and Pieper 2010
Dissolved oxygen	NCRN I&M, MONO	Norris et al. 2007, Norris and Pieper 2010
Water temperature	NCRN I&M, MONO	Norris et al. 2007, Norris and Pieper 2010
Acid neutralizing capacity	NCRN I&M	Norris et al. 2007, Norris and Pieper 2010
Salinity	NCRN I&M, MONO	Norris et al. 2007, Norris and Pieper 2010
Nitrate	NCRN I&M, MONO	Norris et al. 2007, Norris and Pieper 2010
Phosphate	NCRN I&M, MONO	Norris et al. 2007, Norris and Pieper 2010
Benthic index biological integrity (BIBI)	NCRN I&M, MBSS	Norris and Sanders 2009, MBSS
Physical habitat index (PHI)	NCRN I&M, MBSS	Norris and Sanders 2009, MBSS
Biological Integrity		
Cover of exotic herbaceous species	NCRN I&M	Schmit and Campbell 2007, 2008
Cover of exotic trees and shrubs	NCRN I&M	Schmit and Campbell 2007, 2008
Presence of forest pest species	NCRN I&M	Schmit and Campbell 2007, 2008
Native tree seedling regeneration	NCRN I&M	Schmit and Campbell 2007, 2008
Fish index biological integrity (FIBI)	NCRN I&M, MBSS	Norris and Sanders 2009
Presence of forest interior dwelling species (FIDS) of birds	NCRN I&M	Goodwin and Shriver 2009
Grassland bird diversity	NCRN I&M	Goodwin and Shriver 2009
Deer density	NCRN I&M	Bates 2007
Landscape Dynamics		
Impervious surface (within park)	UMCES, NCRN I&M	Townsend et al. 2006
Impervious surface (within park) + 5X buffer	UMCES, NCRN I&M	Townsend et al. 2006
Forest interior area	UMCES, NCRN I&M	NCRN I&M
Forest connectivity (Dcrit; within park)	UMCES, NCRN I&M	Townsend et al. 2006
Forest connectivity (within park) + 5X buffer	UMCES, NCRN I&M	Townsend et al. 2006
Grassland interior area	UMCES, NCRN I&M	NCRN I&M
Contiguous grassland area	UMCES, NCRN I&M	NCRN I&M

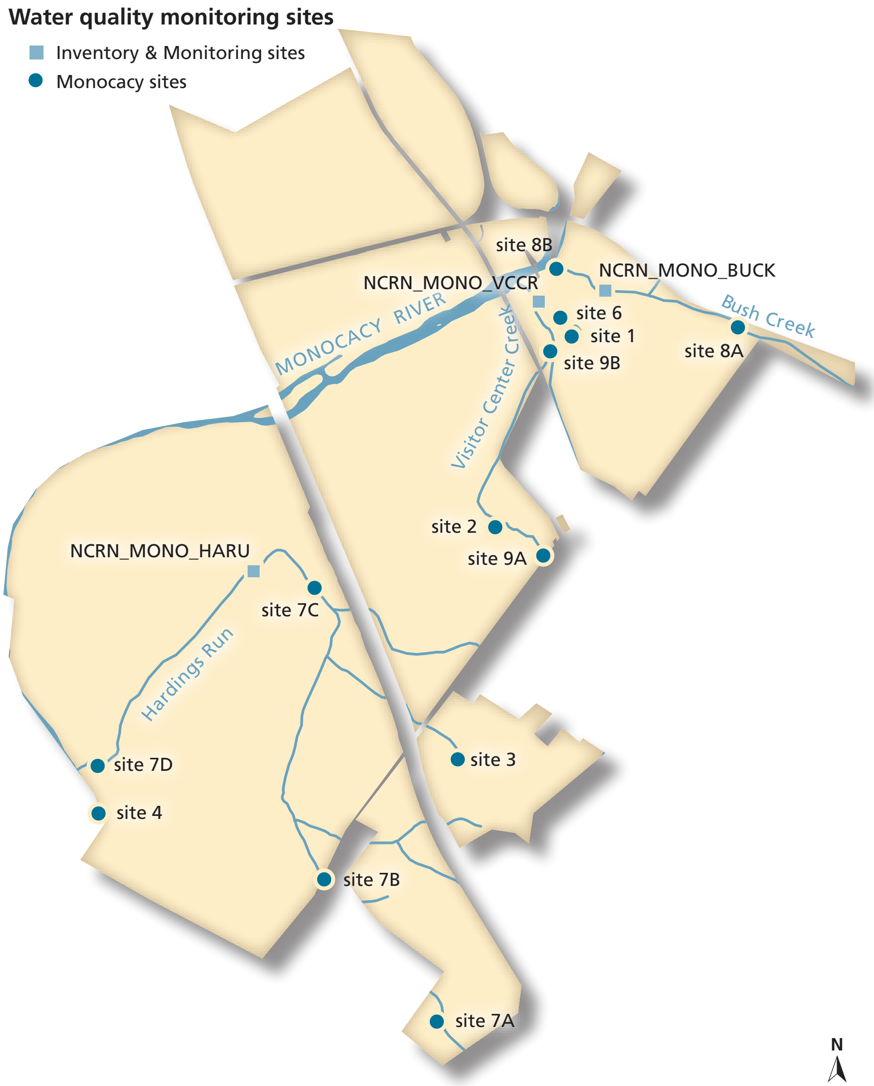
Table 3.7. Summary of data used in Monocacy National Battlefield resource condition assessment.

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	16	427	2004–2008
Dissolved oxygen (DO)	≥ 5.0 mg DO L^{-1}	16	420	2004–2008
Water temperature	≤ 32.0ºC	16	432	2004–2008
Acid neutralizing capacity	≥ 200 µeq L^{-1}	3	99	2005–2008
Salinity	< 0.25	16	408	2004–2008
Nitrate (NO_3)	< 2 mg NO_3 L^{-1}	16	385	2004–2008
Phosphate (PO_4)	< 0.1133 mg PO_4 L^{-1}	16	371	2004–2008
Benthic index biological integrity (BIBI)	> 3	8	8	2004
Physical habitat index (PHI)	> 81	8	8	2004
Biological Integrity				
Cover of exotic herbaceous species	< 5% (of area)	2	2	2006–2008
Cover of exotic trees and shrubs	< 5% (of total basal area)	2	2	2006–2008
Presence of forest pest species	< 1% of trees infested	2	2	2006–2008
Native tree seedling regeneration	> 35,000 seedlings ha^{-1}	2	2	2006–2008
Fish index biological integrity (FIBI)	> 3	8	8	2004
Presence of forest interior dwelling species (FIDS) of birds	> 1 highly sensitive FIDS > 4 sensitive FIDS	3	14	2007–2008
Grassland bird diversity	% functional groups found translates directly to % attainment	3	1	2007–2008
Deer density	< 8 deer km^{-2} (forest) < 20 deer km^{-2} (grassland)	Park	8	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/ARE118 and MD99/BEL116[27] used for measuring mercury concentrations near Monocacy National Battlefield.

27. National Atmospheric Deposition Program: *http://nadp.sws.uiuc.edu;* Mercury Deposition Network: *http://nadp.sws.uiuc.edu/mdn*

Figure 3.7. Stream sampling locations[28] used for long-term water quality monitoring at Monocacy National Battlefield.



28. Norris et al. 2007, MONO.

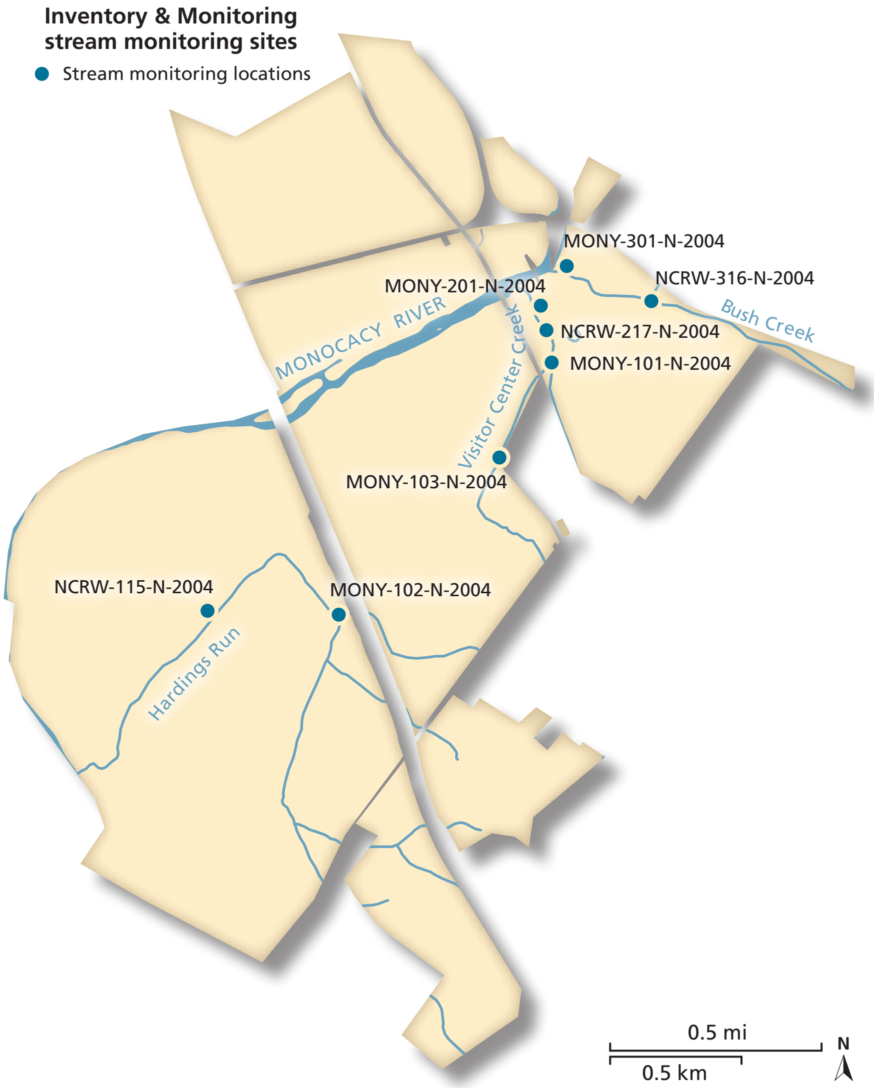


Figure 3.8. Stream sampling locations[29] monitored for BIBI, FIBI, and PHI.

29. NCRN I&M, MONO.

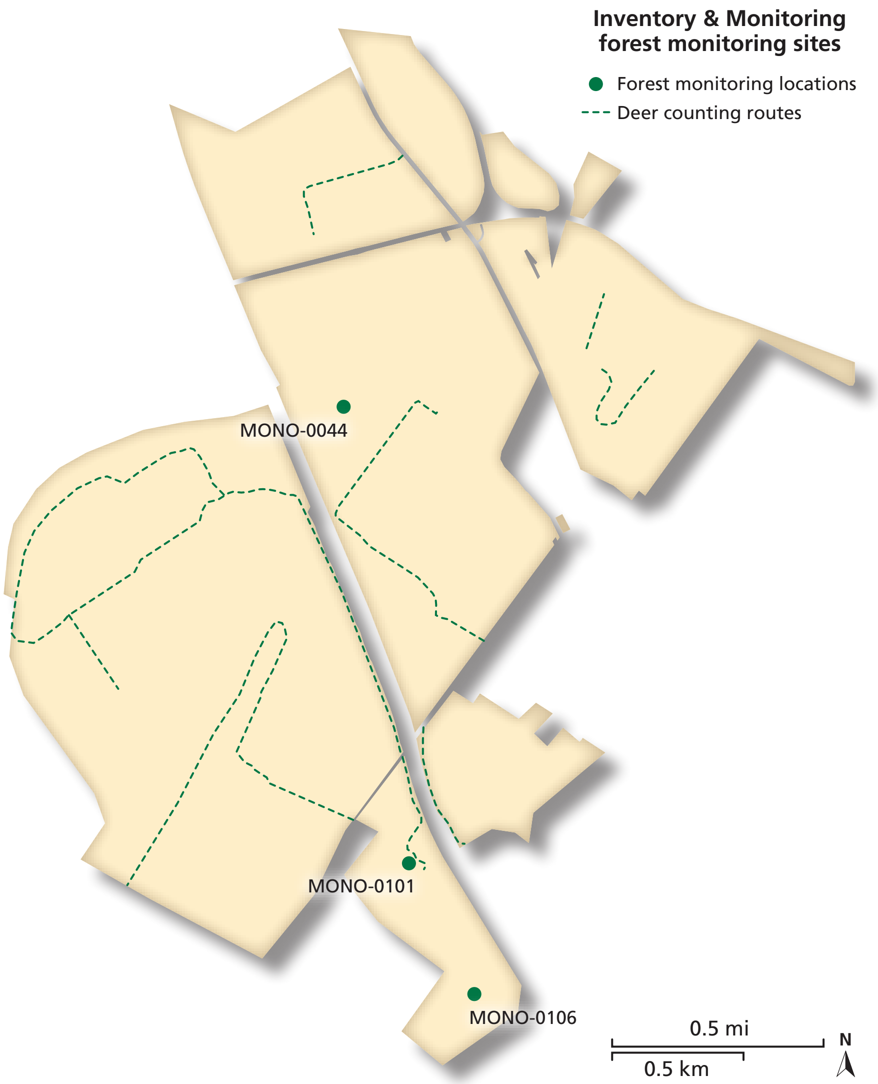


Figure 3.9. Forest monitoring sites and deer counting routes[30] in Monocacy National Battlefield.

30. NCRN I&M, MONO.

weighted mean of the four category percentage attainment values. For determination of status of metrics, vital sign categories, and the whole park assessment, percentage attainment scores were categorized on a scale from very good to very degraded (Table 3.8).

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 Monocacy National Battlefield and these were further defined as 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.

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 31 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 framework, so 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 Monocacy National Battlefield was calculated as an un-weighted mean of the attainment scores for the 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 538 ha (1,329 acres)[31] within the fee boundary of Monocacy National Battlefield used in this assessment, 193 ha (477 acres) were designated as habitats that are managed for natural resource values (forests: 141 ha [349 acres]; wetlands and waterways: 13 ha [32 acres]; and warm-season grasslands: 39 ha [96 acres]; Table 3.12). 323 ha (797 acres) were designated as habitats that are managed for agricultural values (croplands: 253 ha [625 acres]; and pastures: 70 ha [172 acres], bringing the total area assessed to 516 ha (1,274 acres). The remaining 22 ha (55 acres) were classified as developed lands and were not assessed.

31. Note: this area differs from the official fee area of 1,355 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 Monocacy 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)	2	2	2006–2008
Cover of exotic trees and shrubs	< 5% (of total basal area)	2	2	2006–2008
Presence of forest pest species	< 1% of trees infested	2	2	2006–2008
Native tree seedling regeneration	> 35,000 seedlings ha^{-1}	2	2	2006–2008
Presence of forest interior dwelling species (FIDS) of birds	> 1 highly sensitive FIDS > 4 sensitive FIDS	3	14	2007–2008
Deer density (forest)	< 8 deer km^{-2} (forest)	Park	8	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	16	427	2004–2008
Dissolved oxygen (DO)	≥ 5.0 mg DO L^{-1}	16	420	2004–2008
Water temperature	≤ 32.0ºC	16	432	2004–2008
Acid neutralizing capacity	≥ 200 µeq L^{-1}	3	99	2005–2008
Salinity	< 0.25	16	408	2004–2008
Nitrate (NO_3)	< 2 mg NO_3 L^{-1}	16	385	2004–2008
Phosphate (PO_4)	< 0.1133 mg PO_4 L^{-1}	16	371	2004–2008
Benthic index biological integrity (BIBI)	> 3	8	8	2004
Fish index biological integrity (FIBI)	> 3	8	8	2004
Physical habitat index (PHI)	> 81	8	8	2004
Grasslands (warm-season)				
Deer density (grassland)	< 20 deer km^{-2} (grassland)	Park	8	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 Monocacy 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
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

Table 3.12. Area of each habitat type assessed in Monocacy National Battlefield. Developed lands make up another 22 ha (55 acres) but were not assessed.

Habitat	Area (ha)	Area (acres)	% of area assessed
Habitats managed for natural resource values			
Forests	141	349	27%
Wetlands and waterways	13	32	3%
Warm-season grasslands	39	96	8%
Total	***193***	***477***	***37%***

Habitat	Area (ha)	Area (acres)	% of area assessed
Habitats managed for agricultural values			
Croplands	253	625	49%
Pastures	70	172	14%
Total	***323***	***797***	***63%***

TOTAL AREA ASSESSED 516 ha (1,274 acres)

3.6 LITERATURE CITED (CHAPTER 3)

Anderson, J.R., E.E. Hardy, J.T. Roach, and R.E. Witmer. 1976. A land use and land cover classification system for use with remote sensor data. U.S. Geological Survey Professional Paper 964, U.S. Geological Survey, Reston, VA.

Anderson, M., P. Bourgeron, M.T. Bryer, R. Crawford, L. Engelking, D. Faber–Langendoen, M. Gallyoun, K. Goodin, D.H. Grossman, S. Landaal, K. Metzler, K.D. Patterson, M. Pyne, M. Reid, L. Sneddon, and A.S. Weakley. 1998. International classification of ecological communities: terrestrial vegetation of the United States. Volume II. The National Vegetation Classification System: List of types. The Nature Conservancy, Arlington, VA.

Arnold Jr, C.L. and C.J. Gibbons. 1996. Impervious surface coverage. Journal of the American Planning Association 62: 243–269.

Bates, S. 2007. National Capital Region Network 2006 deer monitoring report. Natural Resources Technical Report NPS/NCRN/NRTR—2007/033. National Park Service, Fort Collins, CO.

Bennetts, R.E., J.E. Gross, K. Cahill, C. McIntyre, B.B. Bingham, A. Hubbard, L. Cameron, and S.L. Carter. 2007. Linking monitoring to management and planning: assessment points as a generalized approach. The George Wright Forum 24: 59–79.

Biggs, H.C. 2004. Promoting ecological research in national parks: a South African perspective. Ecological Applications 14: 21–24.

Bowman, J., A. Jochen, G. Jaeger, and L. Fahrig. 2002. Dispersal distance of mammals in proportion to home range size. Ecology 83: 2049–2055.

Burger, L.D., L.W. Burger, Jr., and J.R. Faaborg. 1994. Effects of prairie fragmentation on predation on artificial nests. Journal of Wildlife Management. 58: 249–254.

Carter, W.K. and T.S. Fredericksen. 2007. Tree seedling and sapling density and deer browsing incidence on recently logged and mature non-industrial private forestlands in Virginia, USA. Forest Ecology and Management 242: 671–677.

Chesapeake Bay Program. Undated. BMP handbook. *http://archive.chesapeakebay.net/pubs/waterqualitycriteria/BMPHandbook1-8f.pdf*

COMAR (Code of Maryland Regulations). 2007a. 26.08.02.02: Designated Uses. Title 26: Maryland Department of the Environment. Subtitle 08: Water Pollution. Chapter 02: Water Quality.

COMAR (Code of Maryland Regulations). 2007b. 26.08.02.03-3: Water Quality Criteria Specific to Designated Uses. Title 26: Maryland Department of the Environment. Subtitle 08: Water Pollution. Chapter 02: Water Quality.

COMAR (Code of Maryland Regulations). 2007c. 26.08.02.08: Stream Segment Designations. Title 26: Maryland Department of the Environment. Subtitle 08: Water Pollution. Chapter 02: Water Quality.

Cuffney, T.F., R.A. Brightbill, J.T. May, and I.R. Waite. 2010. Responses of benthic macroinvertebraes to environmental changes associated with urbanization in nine metropolitan areas. Ecological Applications 20: 1134–1401.

Decalesta, D.S. 1997. Deer ecosystem management. In: McShea, W.J., H.B. Underwood, and J.H. Rappole (eds). The science of overabundance: deer ecology and population management. Springer, Netherlands.

Dupont, J., T.A. Clair, C. Gagnon, D.S. Jeffries, J.S. Kahl, S.J. Nelson, and J.M. Peckenham. 2005. Estimation of critical loads of acidity for lakes in northeastern Unites States and eastern Canada. Environmental Monitoring and Assessment 109: 275–291.

Evers, D.C., J.D. Kaplan, M.W. Meyer, P.S. Reaman, W.E. Braselton, A. Major, N. Burgess, and A.M. Scheuhammer. 1998. Geographic trend in mercury measured in common loon feathers and blood. Environmental Toxicology and Chemisty 17: 173–183.

Fancy, S.G., J.E. Gross, and S.L. Carter. 2008. Monitoring the condition of natural resources in U.S. national parks. Environmental Monitoring and Assessment: Electronically published May 29, 2008.

Fenn, M.E., J.S. Baron, E.B. Allen, H.M. Rueth, K.R. Nydick, L. Geiser, W.D. Bowman, J.O. Sickman, T. Meixner, D.W. Johnson, & P. Neitlich. 2003. Ecological effects of nitrogen deposition in the western United States. BioScience 53: 404–420.

Franklin, J.F. 1993. Preserving biodiversity: species, ecosystems, or landscapes. Ecological Applications 3: 202–205.

Goodwin, S. and G. Shriver. 2009. Avian monitoring in the National Capital Region: 2007 and 2008 annual report. Draft. U.S. Department of the Interior.

Groffman, P.M. J.S. Baron, T. Blett, A.J. Gold, I. Goodman, L.H. Gunderson, B.M. Levinson, M.A. Palmer, H.W. Paerl, G.D. Peterson, N. L. Poff, D.W. Rejeski, J.F. Reynolds, M.G. Turner, K.C. Weathers, and J. Wiens. 2006. Ecological thresholds: the key to successful environmental management or an important concept with no practical application? Ecosystems 9: 1–13.

Grossman, D.H., D. Faber Langendoen, A.S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K.D. Patterson, M. Pyne, M. Reid, and L. Sneddon. 1998. International classification of ecological communities: terrestrial vegetation of the United States. Volume I. The National Vegetation Classification System: development, status, and applications. The Nature Conservancy, Arlington, VA.

Hammerschmidt, C.R. and W.F. Fitzgerald. 2002. Methylmercury in mosquitoes related to atmospheric mercury. Environmental Science and Technology 39: 3034–3039.

Hammerschmidt, C.R. and W.F. Fitzgerald. 2006. Methylmercury in freshwater fish linked to atmospheric mercury deposition. Environmental Science and Technology 40: 7764–7770.

He, H.S. and D.J. Mladenoff. 1999. The effects of seed dispersal on the simulation of long-term forest landscape change. Ecosystems 2: 308–319.

Healy, W.M. 1997. Influence of deer on the structure and composition of oak forests in central Massachusetts. In: McShea, W.J., H.B. Underwood, and J.H. Rappole (eds). The science of overabundance: deer ecology and population management. Springer, Netherlands.

Hendricks, J. and J. Little 2003. Thresholds for regional vulnerability analysis. Regional vulnerability assessment program. National exposure research laboratory. U.S. EPA (E243-05). *http://www.nrac.wvu.edu/classes/resm493Q/files/final_stressor_threshold_table.pdf*

Horsley, S.B., S.L. Stout, and D.S. deCalesta. 2003. White-tailed deer impact on the vegetation dynamics of a northern hardwood forest. Ecological Applications 13: 98–118.

Huggett A. 2005. The concept and utility of "ecological thresholds" in biodiversity conservation. Biological Conservation 124: 301–310.

IUCN. 2007. Habitats classification scheme (version 3.0). International Union for the Conservation of Nature. *http://www.iucnredlist.org/info/major_habitats*

Jensen, M.E., K. Reynolds, J. Andreasen, and I.A. Goodman. 2000. A knowledge based approach to the assessment of watershed condition. Environmental Monitoring and Assessment 64: 271–283.

Jones, C., J. McCann, and S. McConville. 2000. A guide to the conservation of forest interior dwelling birds in the Chesapeake Bay Critical Area. Report to the Critical Area Commission for the Chesapeake and Atlantic Coastal Bays. *http://www.dnr.state.md.us/criticalarea/tweetyjune_2000.pdf*

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6 :21–27.

Kline, L.J., D.D. Davis, J.M. Skelly, J.E. Savage, and J. Ferdinand. 2008. Ozone sensitivity of 28 plants selections exposed to ozone under controlled conditions. Northeastern Naturalist 15: 57–66.

Koskimies, P. 1989. Birds as a tool in environmental monitoring. Annales Zoologici Fennici 26: 153–166.

Krupa, S.V. 2003. Effects of atmospheric ammonia (NH_3) on terrestrial vegetation: A review. Environmental Pollution 124: 179–221.

Liebhold, A., K. Thorpe, J. Ghent, and D.B. Lyons. 1994. Gypsy moth egg mass sampling for decision-making: a user's guide. USDA Forest Service. NA-TP-04-94. *http://www.sandyliebhold.com/pubs/Liebhold_etal_1994_guide_color.pdf*

Lussier, S.M., S.N. da Silva, M. Charpentier, J.F. Heltshe, S.M. Cormier, D.J. Klemm, M. Chintala, and S. Jayaraman. 2008. The influence of suburban land use on habitat and biotic integrity of coastal Rhode Island streams. Environmental Monitoring and Assessment 139: 119–136.

Mack, R.N, D. Simberloff, W.M. Lonsdale, H. Evans, M. Clout, and F.A. Bazzaz. 2000. Biotic invasions: causes, epidemiology, global consequences, and control. Ecological Applications 10: 689–710.

Marquis, D.A., R.L. Ernst, and S.L. Stout. 1992. Prescribing silvicultural treatments in hardwood stands of the Alleghenies (Revised). United States Department of Agriculture: Forest Service. General Technical Report NE-96.

Maryland Cooperative Extension. Undated. Pasture management: maintaining permanent pastures for livestock. Fact sheet 720. *http://extension.umd.edu/publications/pdfs/fs720.pdf*

McKee, D.J., V.V. Atwell, H.M. Richmond, W.P. Freas, and R.M. Rodriguez. 1996. Review of national ambient air quality standards for ozone, assessment of scientific and technical information. OAQPS Staff Paper. EPA-452/R-96-007.

McWilliams, W.H., T.W. Bowersox, D.A. Gansner, L.H. McCormick, and S.L. Stout 1995. Landscape-level regeneration adequacy for native hardwood forests of Pennsylvania. Proceedings, 10th Central Hardwood Forest Conference. Gen. Tech. Rep. NE-197. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station.

MD DNR, Forest Service. 2008. Interior Forest. *http://www.dnr.maryland.gov/forests/planning/sfla/indicators/interior_forest.htm*

MD DNR. Undated. A list of forest interior dwelling birds that currently or historically nested in Maryland. Maryland Department of Natural Resources, Natural Heritage Program.

Meili, M., K. Bishop, L. Bringmark, K. Johansson, J. Muthe, H. Sverdrup, and W. de Vries. 2003. Critical levels of atmospheric pollution: criteria and concepts for operational modelling of mercury in forest and lake ecosystems. The Science of the Total Environment 304: 83–106.

MONO (Monocacy National Battlefield Staff). 2009. Review Draft, Resource Stewardship Strategy, Monocacy National Battlefield. Frederick, MD.

Montgomery, M.E. 1990. Predicting defoliation by the gypsy moth using egg mass counts and a helper variable. Proceedings U.S. Department of Agriculture Interagency Gypsy Moth Research Review. USDA Forest Service. General Technical Report NE-146.

NAAQS. 2008. National Ambient Air Quality Standards. *http://www.epa.gov/air/criteria.html#6*

Norris, M., J.P. Schmit, and J. Pieper. 2007. National Capital Region Network 2005–2006 water resources monitoring report. Natural Resource Technical Report NPS/NCRN/NRTR - 2007/066. Natural Resource Program Center, Fort Collins, CO.

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

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

NPS. 2005. Wet Deposition Monitoring Protocol. U.S. Department of the Interior. D-1655. *http://www.nature.nps.gov/air/Monitoring/docs/200508FinalWetDepProtocol.pdf*

NPS. 2009. Assessment of current air quality conditions. U.S. Department of the Interior. *http://www.nature.nps.gov/air/Maps/AirAtlas/docs/2009_Assessment_of_Current_Air_Quality_Conditions.pdf*

NPS. 2010. Air quality estimates for the Inventory and Monitoring Program. *http://www.nature.nps.gov/air/Maps/AirAtlas/IM_materials.cfm*

NSDWS. 1997. National Secondary Drinking Water Standards. *http://www.sciencefaircenter.com/nsdws.tpl*

Pantus, F.J. and W.C. Dennison. 2005. Quantifying and evaluating ecosystem health: a case study from Moreton Bay, Australia. Environmental Management 36: 757–771.

Paul, M.J., J.B. Stribling, R. Klauda, P. Kazyak, M. Southerland, and N. Roth. 2003. A Physical Habitat Index for freshwater wadeable streams in Maryland. Report to the Maryland Department of Natural Resources, Annapolis, MD.

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

Schindler, D.W. 1988. Effects of acid rain on fresh water ecosystems. Science 239: 149–157.

Schmit, J.P. and J.P. Campbell. 2007. National Capital Region Network 2006 forest vegetation monitoring report. Natural Resources Technical Report NPS/NCRN/NRTR—2007/046. Natural Resource Program Center, Fort Collins, CO.

Schmit, J.P. and J.P. Campbell. 2008. National Capital Region Network 2007 forest vegetation monitoring report. Natural Resources Technical Report NPS/NCRN/NRTR—2008/125. Natural Resource Program Center, Fort Collins, CO.

Southerland, M.T., L.A Erb, G.M. Rogers and P.F. Kazyak. 2005. Maryland Biological Stream

Survey 2000–2004. Volume 7: Statewide and tributary basin results. Prepared for Maryland Department of Natural Resources.

Southerland, M.T., G.M. Rogers, M.J. Kline, R.P. Morgan, D.M. Boward, P.F. Kazyak, R.J. Klauda, and S.A. Stranko. 2007. Improving biological indicators to better assess the condition of streams. Ecological Indicators 7: 751–767.

Stewart, C.M., W.J. McShea, and B.P. Piccolo. 2007. The impact of white-tailed deer on agricultural landscapes in 3 national historical parks in Maryland. The Journal of Wildlife Management 71: 1525–1530.

Temple, Stanley A. 1986. Predicting impacts of habitat fragmentation on forest birds: a comparison of two models. In: Verner, J., M.L. Morrison, & C.J. Ralph (eds). Wildlife 2000: modeling habitat relationships of terrestrial vertebrates.

Terborgh, J. 1992. Why American songbirds are vanishing. Scientific American 266: 98–104.

Townsend, P.A., R.H. Gardner, T.R. Lookingbill, and C.C. Kingdom. 2006. National Capital Region Network—remote sensing and landscape pattern protocol for long-term monitoring of parks. University of Maryland Center for Environmental Science, Appalachian Laboratory, Frostburg, MD.

Townsend, P.A., T.R. Lookingbill, C.C. Kingdon, and R.H. Gardner. 2009. Spatial pattern analysis for monitoring protected areas. Remote Sensing of Environment 113: 1410–1420.

USDA (United States Department of Agriculture) Natural Resources Conservation Service. 2007. Maryland Field Office Technical Guide. *http://www.nrcs.usda.gov/technical/efotg/*

USDA (United States Department of Agriculture) Forest Service. 2009a. Gypsy moth in North America. *http://www.fs.fed.us/ne/morgantown/4557/gmoth/*

USDA (United States Department of Agriculture) Forest Service. 2009b. Hemlock woolly adelgid, Forest Health Protection, USDA Forest Service. *http://na.fs.fed.us/fhp/hwa/*

U.S. EPA. 2000. Ambient water quality criteria recommendations – rivers and streams in Nutrient Ecoregion IX. EPA 822-B-00-019.

U.S. EPA. 2001. Water quality criterion for the protection of human health: methylmercury. United States Environmental Protection Agency, Washington DC. EPA-823-R-01-001.

U.S. EPA. 2002. A framework for assessing and reporting on ecological condition: an SAB report. Environmental Protection Agency. Science Advisory Board. Washington, DC. EPA-SAB-EPEC-02-009.

U.S. EPA. 2003. Guidance for estimating natural visibility conditions under the regional haze rule. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Contract No. 68-D-02-0261, Work Order No. 1-06.

U.S. EPA. 2004. The Clean Air Act. Washington United States Environmental Protection Agency, Washington DC. *http://epw.senate.gov/envlaws/cleanair.pdf*

U.S. EPA. 2006. Air quality criteria for ozone and related photochemical oxidants. Volume I of III. EPA 600/R-05/004aF.

U.S. EPA. 2009. National recommended water quality criteria. *http://www.epa.gov/waterscience/criteria/wqctable/*

Wolfe, M.F., S. Schwarzbach, and R.A. Sulaiman. 1998. Effects of mercury on wildlife: a comprehensive review. Environmental Toxicology and Chemistry 17: 146–160.

Chapter 4: Natural resource conditions

4.1 REGIONAL/LANDSCAPE CONTEXT

As detailed in Section *2.1.2—Resource management issues overview*, Monocacy 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 Monocacy 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 (45% attainment of threshold condition; Table 4.1). Synthesizing 10 metrics measuring the condition of cropland and pasture habitats, these 'managed for agricultural values' habitats were assessed as being in good condition (71% attainment of threshold condition; Table 4.2). Pasture lands were in very good condition, croplands were in good condition, while forests and wetlands and waterways were in fair condition, and warm-season grasslands were in poor condition. Overall, the habitats of Monocacy National Battlefield were assessed as being in good condition, with 61% attainment of threshold condition (Table 4.3). These results are synthesized in Figure 4.4.

A red fox patrols the edge between cornfield and forest.

Forests

Forest habitat within Monocacy National Battlefield was assessed as being in fair condition, attaining desired condition in 46% of the 33 measurements across all nine metrics, collected between 2000 and 2008 (Tables 3.10, 4.1). Presence of forest interior dwelling bird species scored as very good, as did percent impervious surface (Figure 4.5), and forest connectivity (Figure 4.6) within the park (all 100% attainment). Cover of exotic trees and shrubs and presence of forest pest species were fair (both 50% attainment). The remaining metrics (forest interior area [Figure 4.7], cover of exotic herbaceous species, native tree seedling regeneration, and deer density) were very degraded, with 11%, 0%, 0%, and 0% attainment, respectively.

Wetlands and waterways

Wetland habitat within Monocacy National Battlefield was assessed as being in fair condition, attaining desired condition in 50% of 2,566 measurements across all 10 metrics, collected between 2004 and 2008 (Tables 3.10, 4.1). While physical attributes were generally in good to very good condition, nutrient concentrations and benthic infauna were assessed as degraded, acid

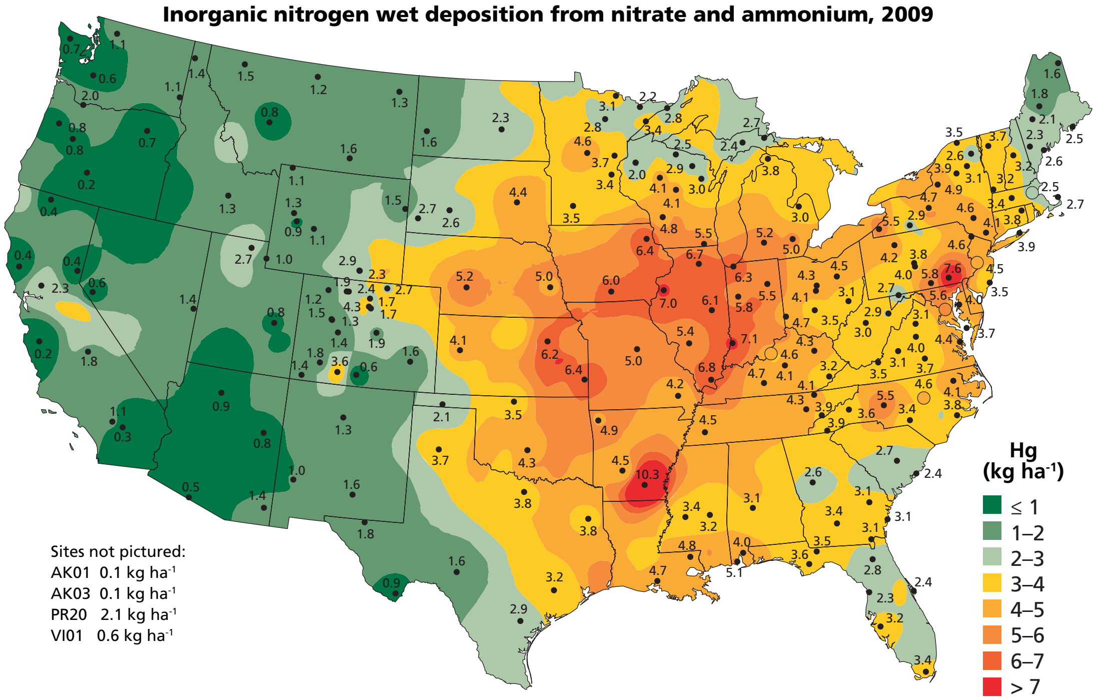


Figure 4.1. Total wet deposition of nitrate (NO_3^-) and ammonium (NH_4^+) ($kg\ ha^{-1}$) for the continental United States in 2009.[34]

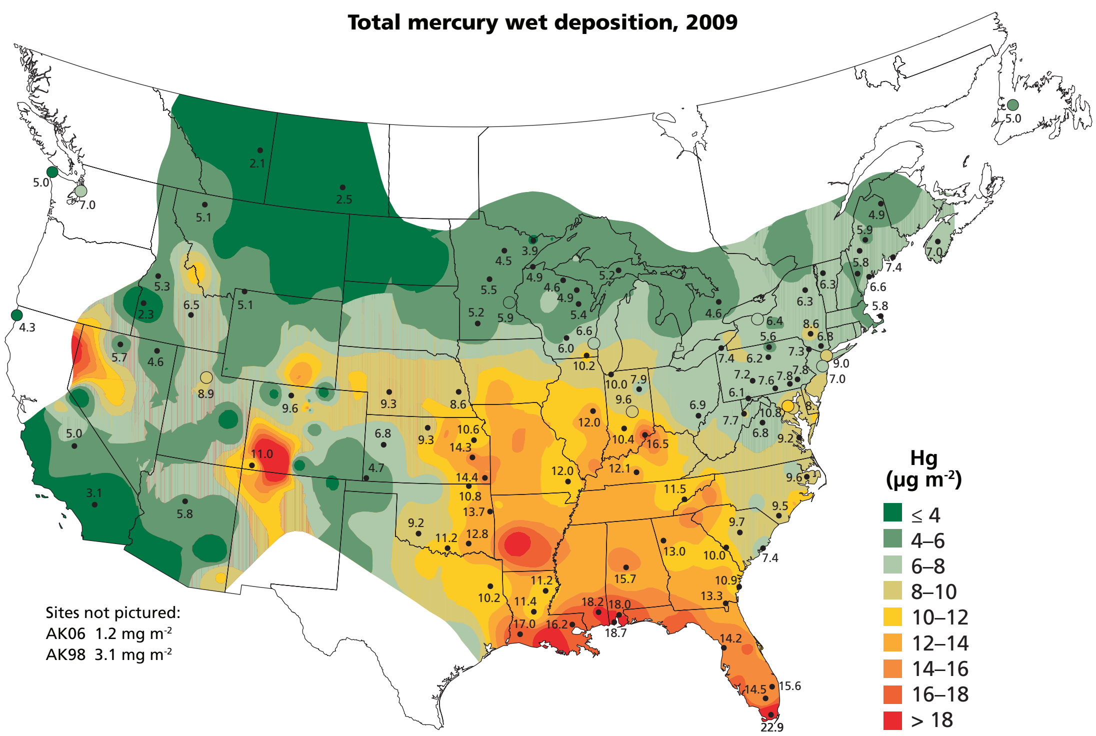


Figure 4.2. Total wet mercury (Hg) deposition ($\mu g\ m^{-2}$) for the continental United States in 2009.[35]

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*

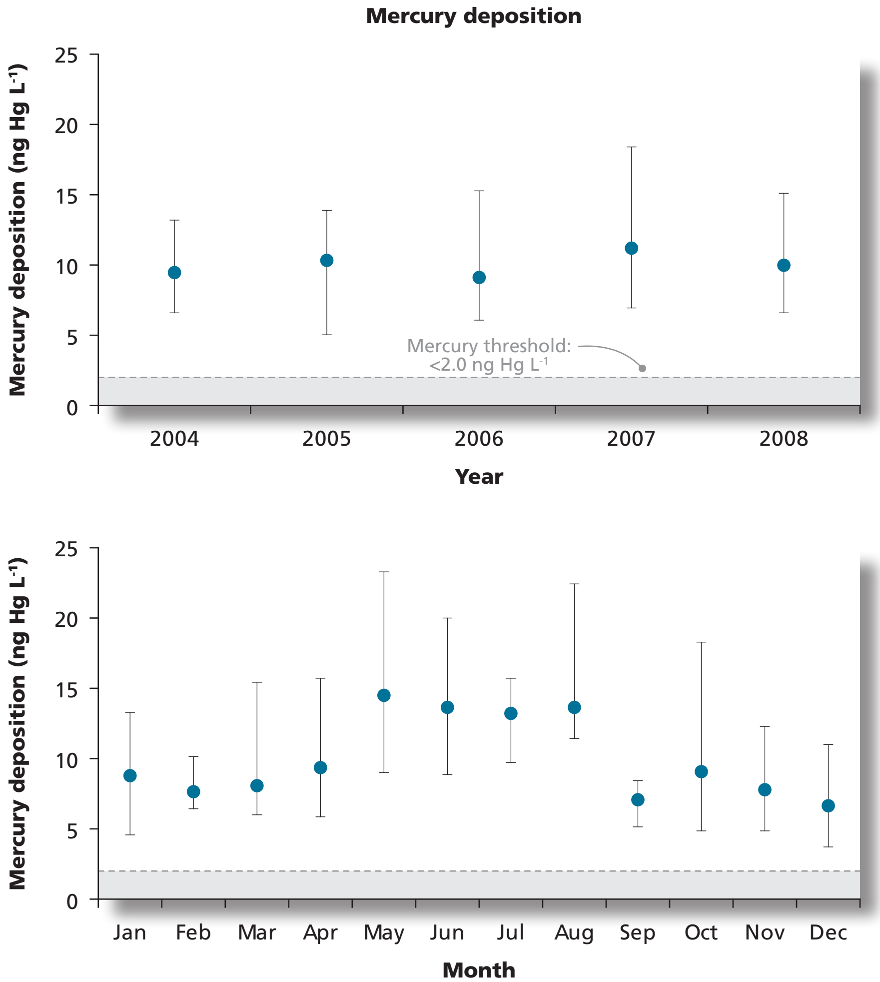


Figure 4.3. Mean monthly mercury deposition (ng Hg L^{-1}) from 2004 to 2007 at sites PA00 and MD99 (see Figure 3.6).[36] Acceptable range (Hg ≤ 2 ng L^{-1}) is shown in gray.

neutralizing capacity (100% attainment; Figure 4.8) and water temperature (100% attainment; Figure 4.9) were in very good (desired) condition, while dissolved oxygen (Figure 4.10), salinity (Figure 4.11), stream fish (all 63% attainment), and pH (62% attainment; Figure 4.12) were all in good condition. Nitrate (42% attainment; Figure 4.13) was in fair condition. Phosphate concentration (11% attainment; Figure 4.14), stream benthos, and Physical Habitat Index (both 0% attainment) were in very degraded condition.

Grasslands (warm-season)

Warm-season grasslands in Monocacy National Battlefield were assessed as being in poor condition overall, attaining desired condition in 38% of 12 measurements across five metrics, collected between 2000 and 2008 (Tables 3.10, 4.1). Impervious surface cover within the park was 3%, well below the desired threshold of 10% (Figure 4.5). Contiguous grassland area was assessed as fair (50% attainment), grassland bird diversity was degraded (25% attainment), while grassland interior area (Figure 4.15) and deer density were very degraded (17% and 0% attainment, respectively).

Croplands

Croplands in Monocacy National Battlefield were assessed as being in good condition, with 68% attainment of desired condition across 14 measurements of seven metrics (Tables 3.11, 4.2). Best management practices (BMPs) are widely implemented on agricultural lands within the park, with conservation tillage (100% attainment), cover crops (100% attainment), Nutrient Management Plans (100% attainment), and crop rotation (94% attainment) all assessed as being in very good condition. Existence of Soil and Water Conservation Plans was

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

Table 4.1. Summary of habitat-based resource condition assessment of Monocacy 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				45
Cover of exotic herbaceous species	15.0%	0	46	
Cover of exotic trees and shrubs	2.8%	50		
Presence of forest pest species	9.5%	50		
Native tree seedling regeneration	10,833 seedlings ha^{-1}	0		
Presence of forest interior dwelling species (FIDS) of birds	3.5 highly sensitive 3.5 sensitive	100		
Deer density (forest)	62.0 deer km^{-2}	0		
Impervious surface (within park)	3.0%	100		
Forest interior area	8%	11		
Forest connectivity (Dcrit; within park)	60 m	100		
Wetlands & waterways				
pH	7.3	62	50	
Dissolved oxygen (DO)	6.4 mg DO L^{-1}	63		
Water temperature	16.0 °C	100		
Acid neutralizing capacity	1,594 µeq L^{-1}	100		
Salinity	0.2	63		
Nitrate (NO_3)	3.0 mg NO_3 L^{-1}	42		
Phosphate (PO_4)	0.486 mg PO_4 L^{-1}	11		
Benthic index biological integrity (BIBI)	1.9	0		
Fish index biological integrity (FIBI)	3.3	63		
Physical habitat index (PHI)	60.5	0		
Grasslands (warm-season)				
Deer density	62.0 deer km^{-2}	0	38	
Impervious surface (within park)	3.0%	100		
Grassland bird diversity	25%	25		
Grassland interior area	12%	17		
Contiguous grassland area	14.6 ha	50		

Table 4.2. Summary of habitat-based resource condition assessment of Monocacy 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		94	68	71
Conservation tillage		100		
Cover crops		100		
Nutrient Management Plan		100		
Soil & Water Conservation Plan		73		
Crop yield concerns		6		
Deer density	62.0 deer km^{-2}	0		
Pastures				
Stocking rate		100	81	
Water source		100		
Fenced streams		100		
Nutrient Management Plan		100		
Soil & Water Conservation Plan		89		
Deer density (grassland)	62.0 deer km^{-2}	0		

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

Habitat	Area (ha)	Score (%)	Area-weighted score (%)
Forests	141	46	61
Wetlands and waterways	13	50	
Warm-season grasslands	39	38	
Croplands	253	68	
Pastures	70	81	

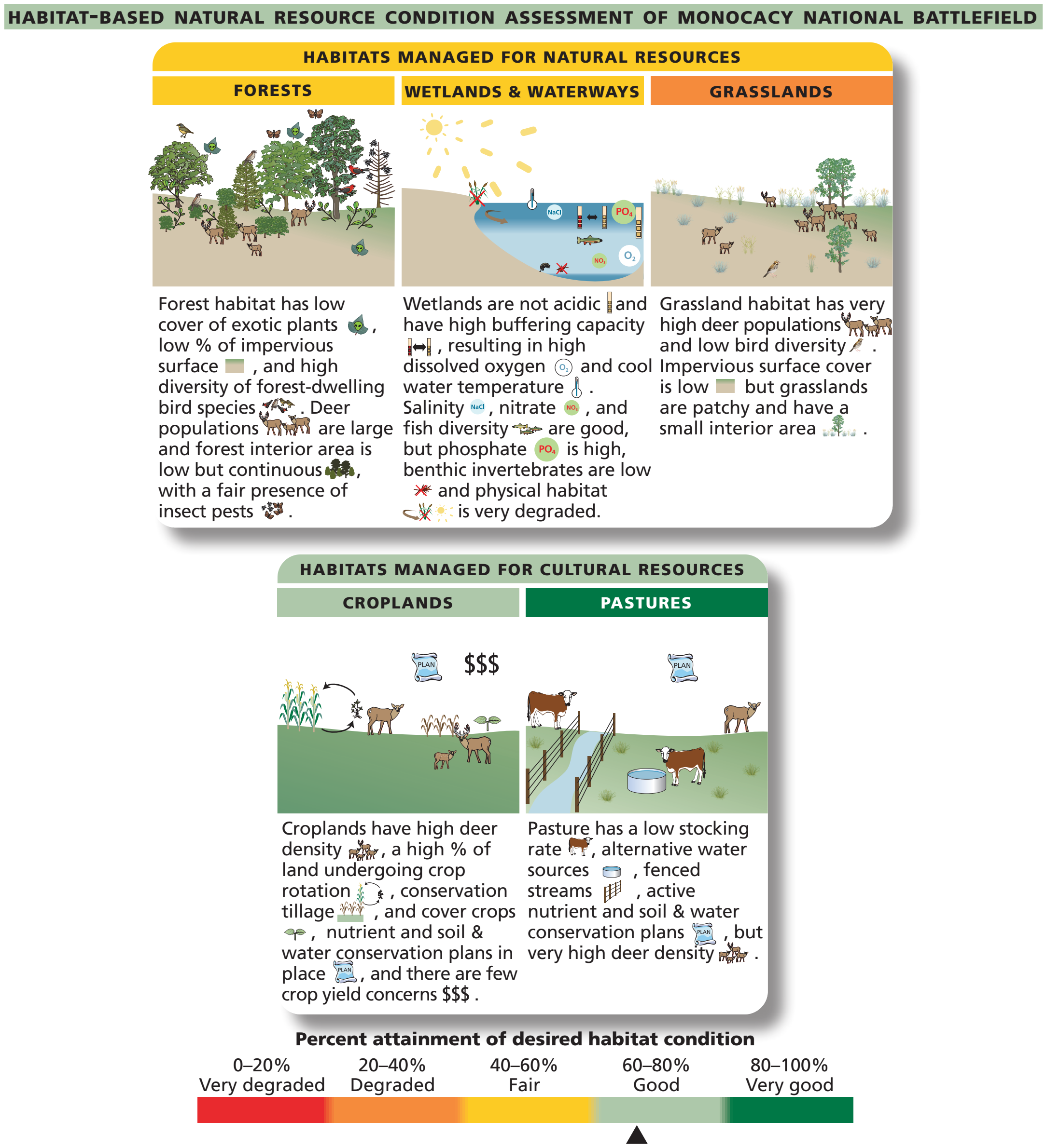
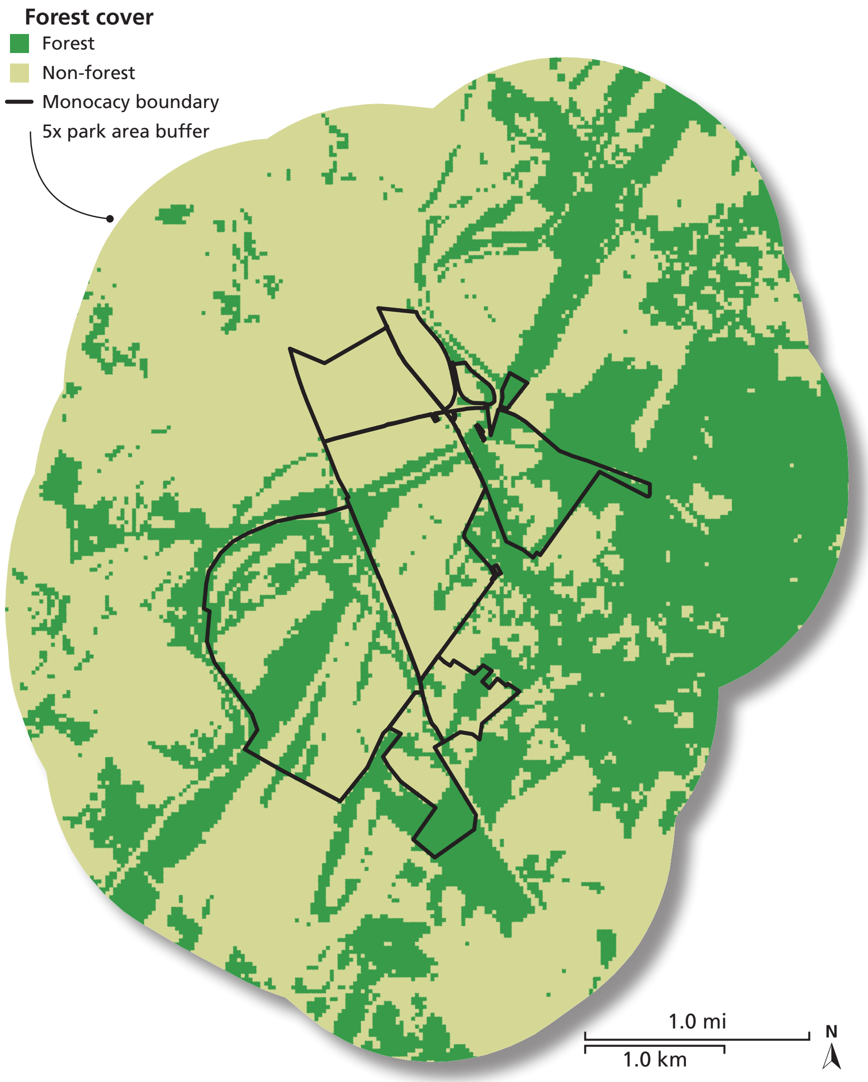


Figure 4.4. Summary results of habitat-based resource condition assessment of Monocacy National Battlefield.

Figure 4.5. GIS data layer showing percent impervious surface in 2000 within and around Monocacy 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 Monocacy 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.

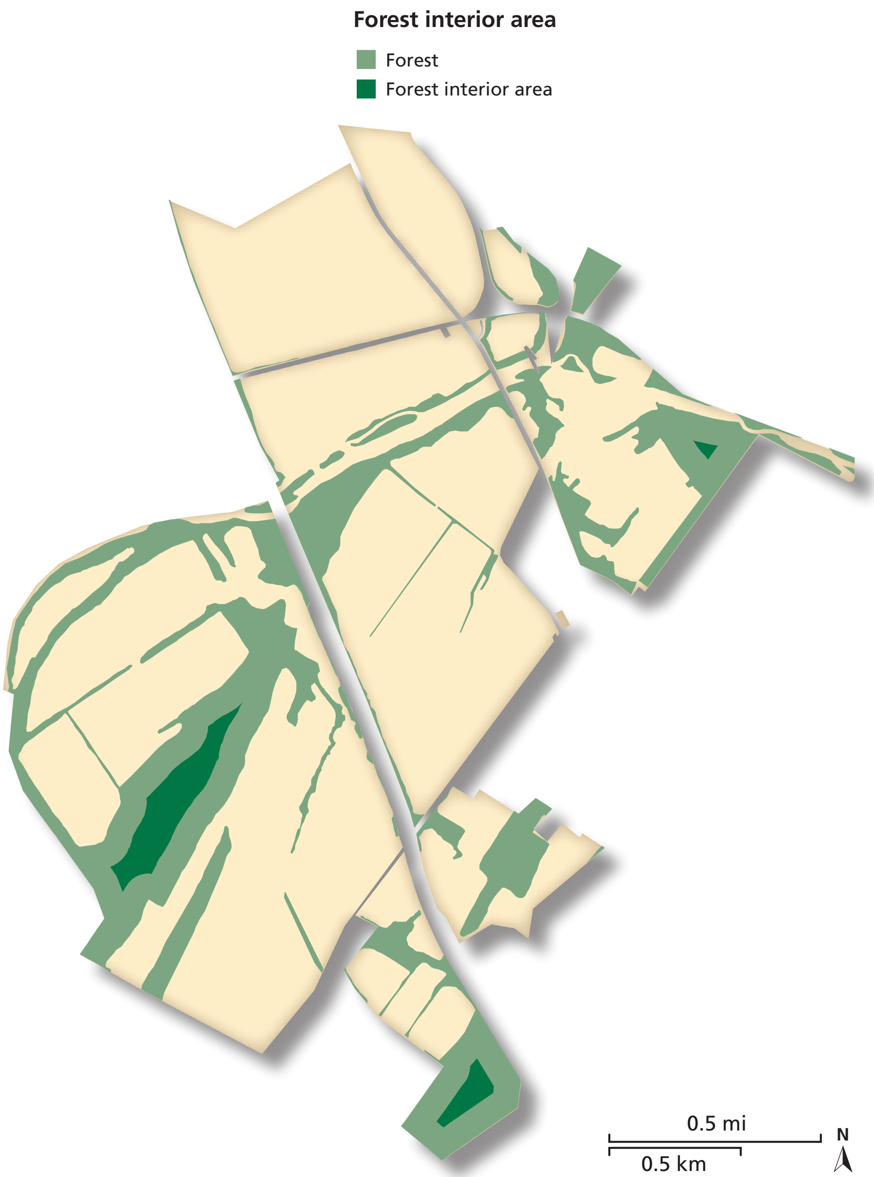


Figure 4.7. Forest area and forest interior area in Monocacy National Battlefield.[39] Forest interior area is defined as forested land cover ≥ 100 m from non-forest land cover or from primary, secondary, or county roads.

39. NCRN I&M, ANTI.

Figure 4.8. Acid neutralizing capacity (ANC; μeq L-1) from 2005 to 2008 for three stream sampling location (see Figure 3.7) in Monocacy National Battlefield.[40] Acceptable range (ANC ≥ 200 μeq L-1) is shown in gray.

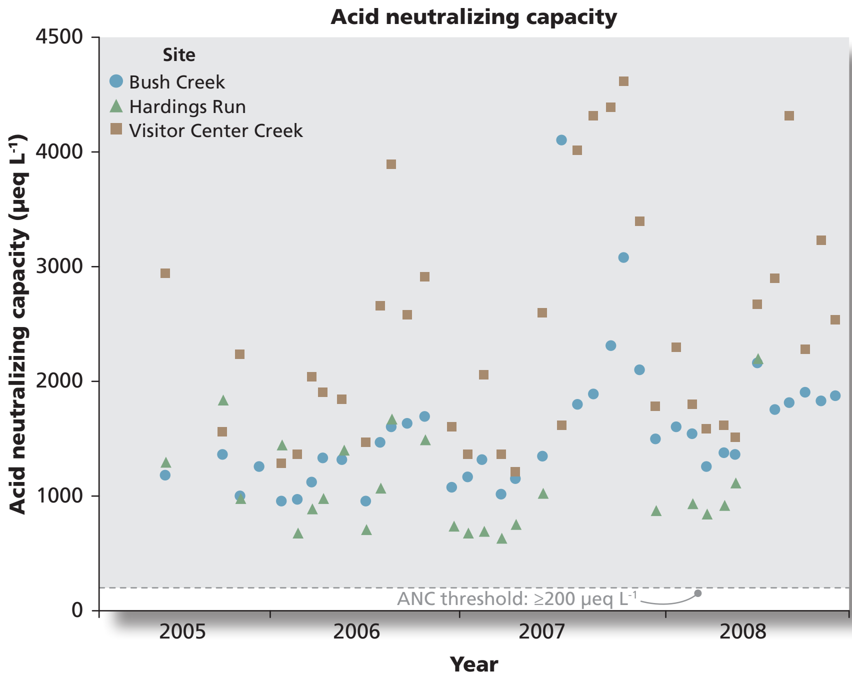
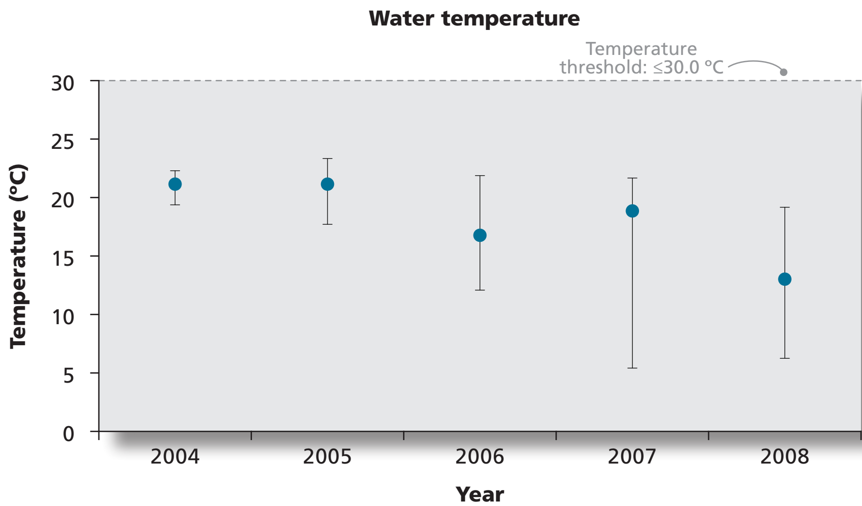
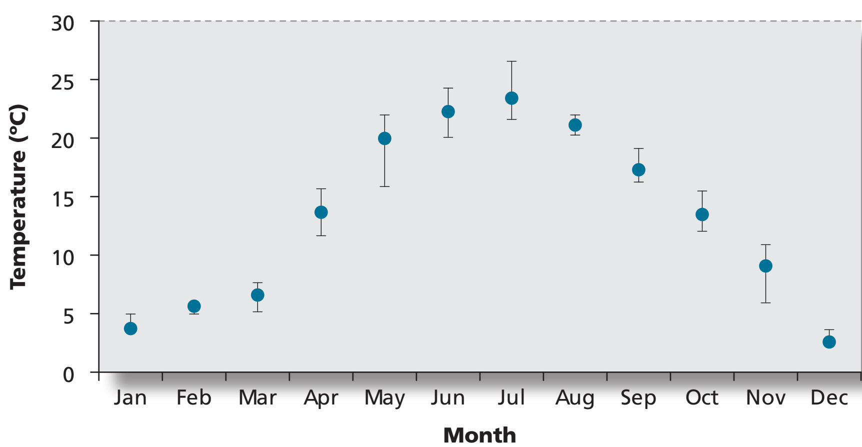


Figure 4.9. Median, 1st quartile, and 3rd quartile water temperature (°C) from 2004 to 2008 for 16 stream sampling locations (see Figure 3.7) in Monocacy National Battlefield.[41] Acceptable range (temp. ≤ 32.0°C) is shown in gray.





40. Norris et al. 2007.
41. Norris et al. 2007, ANTI.

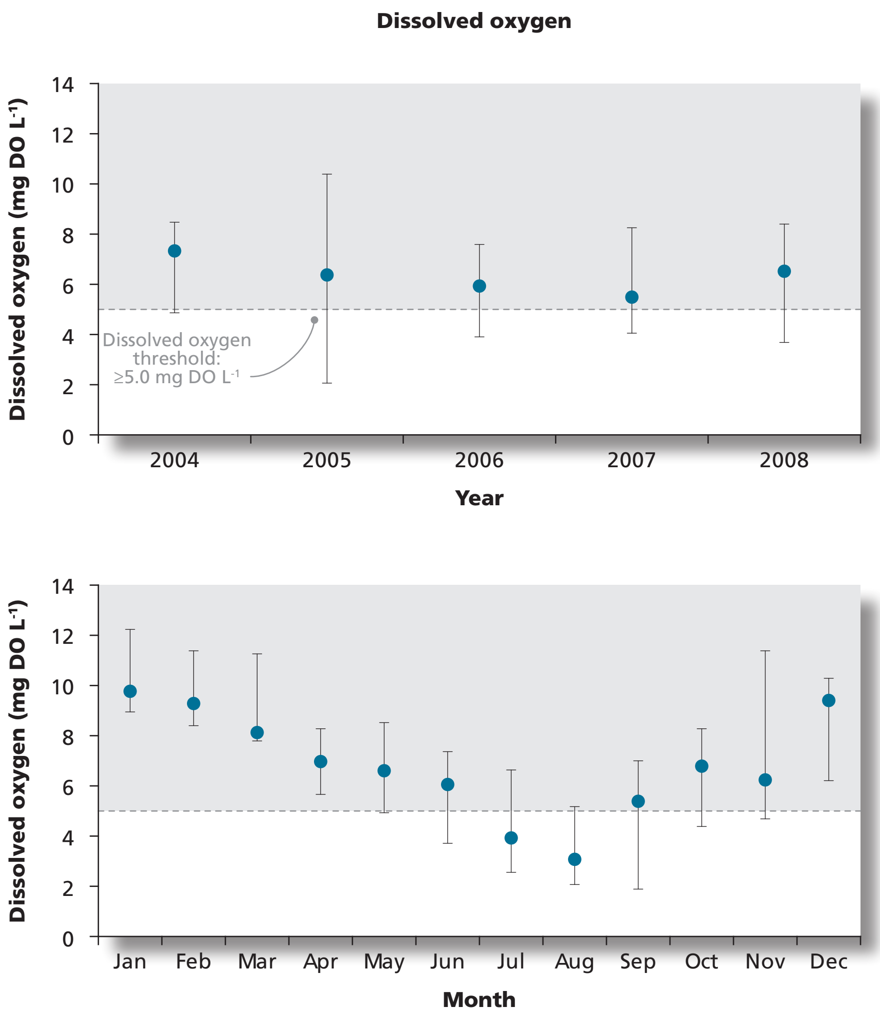
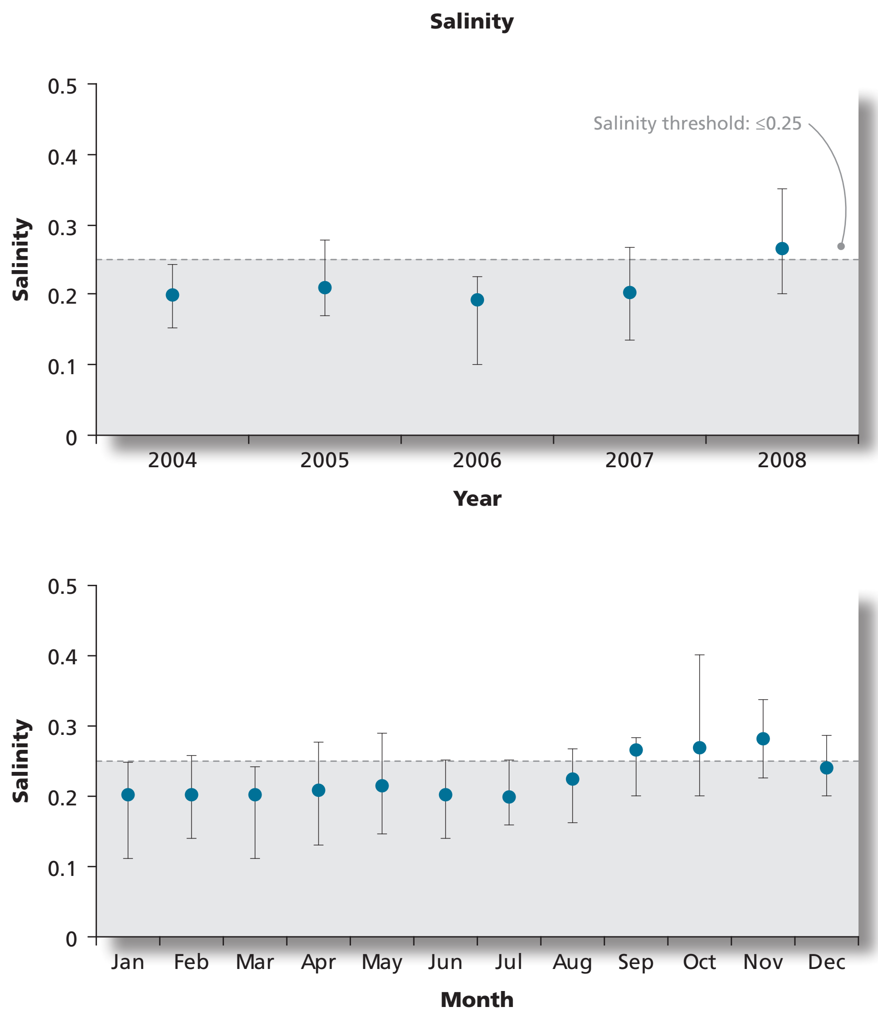


Figure 4.10. Median, 1st quartile, and 3rd quartile dissolved oxygen concentration (mg DO L^{-1}) from 2004 to 2008 for 16 stream sampling locations in Monocacy National Battlefield (see Figure 3.7).[42] Acceptable range (DO ≥ 5.0 mg L^{-1}) is shown in gray.

42. Norris et al. 2007, ANTI.

Figure 4.11. Median, 1st quartile, and 3rd quartile monthly salinity concentration from 2004 to 2008 for 16 stream sampling locations (see Figure 3.7) in Monocacy National Battlefield.[43] Acceptable range (salinity ≤ 0.25) is shown in gray.



43. Norris et al. 2007, ANTI.

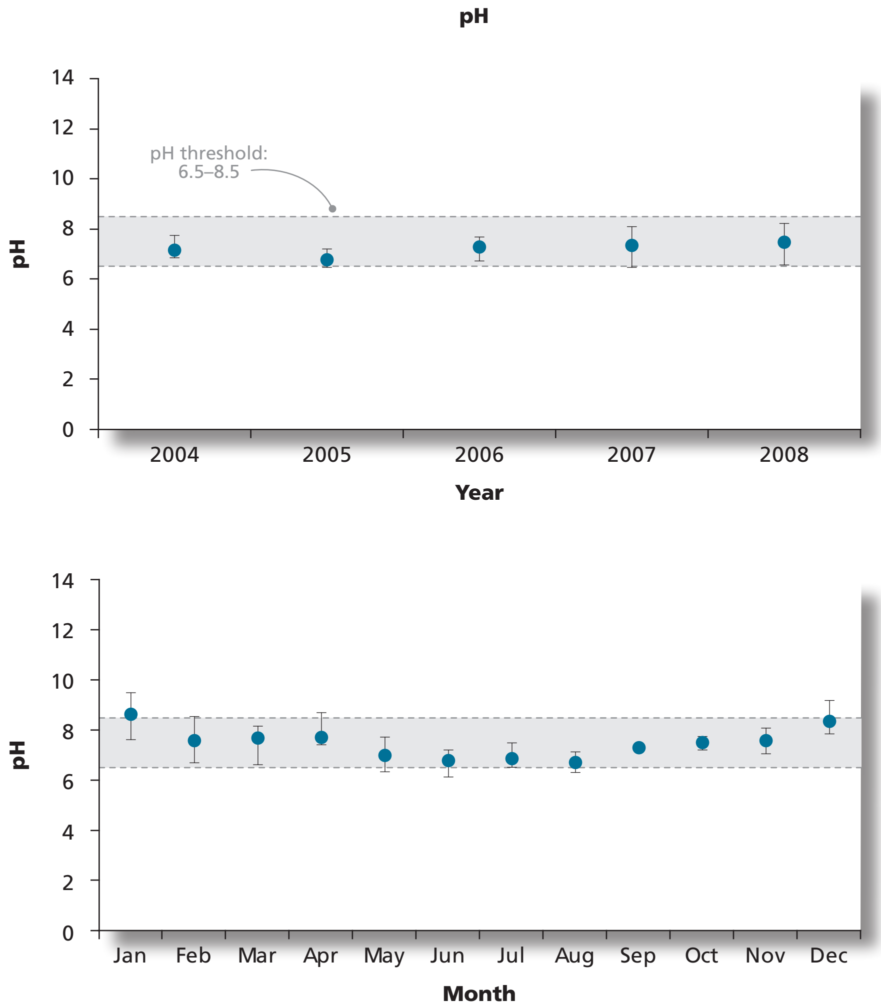
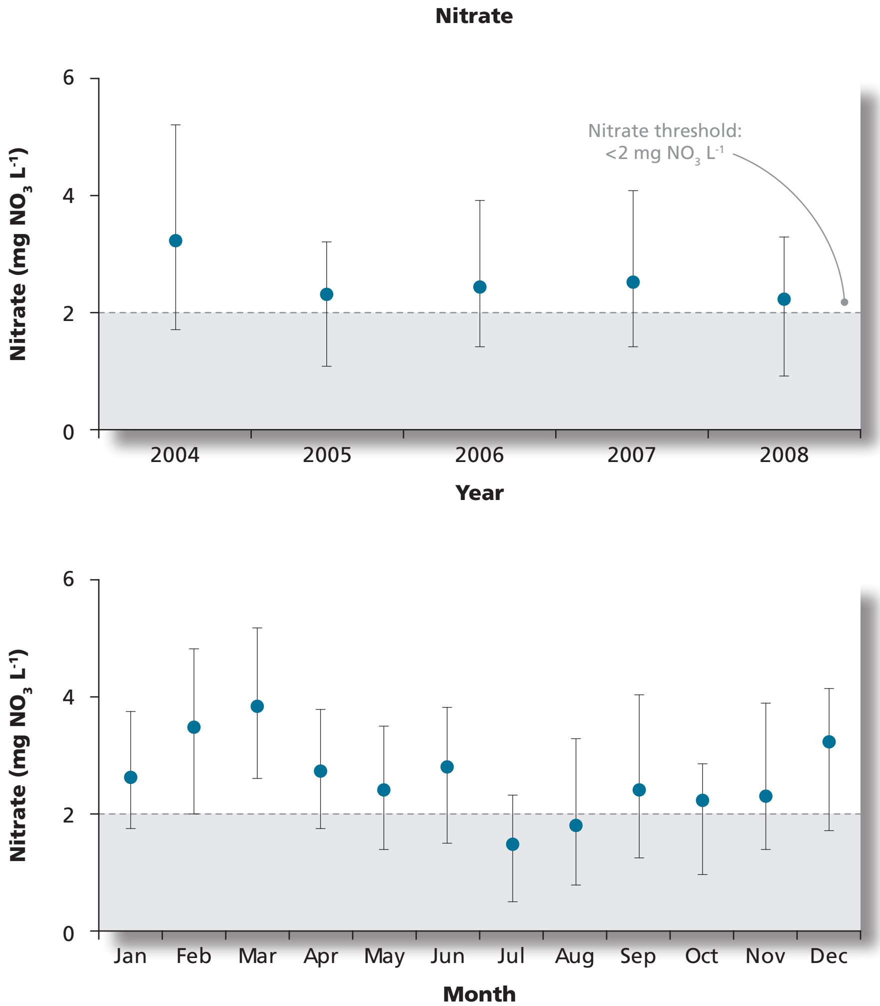


Figure 4.12. Median, 1st quartile, and 3rd quartile pH values from 2004 to 2008 for 16 stream sampling locations (see Figure 3.7) in Monocacy National Battlefield.[44] Acceptable ranges (6.5 ≤ pH ≤ 8.5) are shown in gray.

44. Norris et al. 2007, ANTI.

Figure 4.13. Median, 1st quartile, and 3rd quartile nitrate concentration (mg NO_3 L^{-1}) from 2004 to 2008 for 16 stream sampling locations (see Figure 3.7) in Monocacy National Battlefield.[45] Acceptable range (NO_3 ≤ 2.0 mg L^{-1}) is shown in gray.



45. Norris et al. 2007, ANTI.

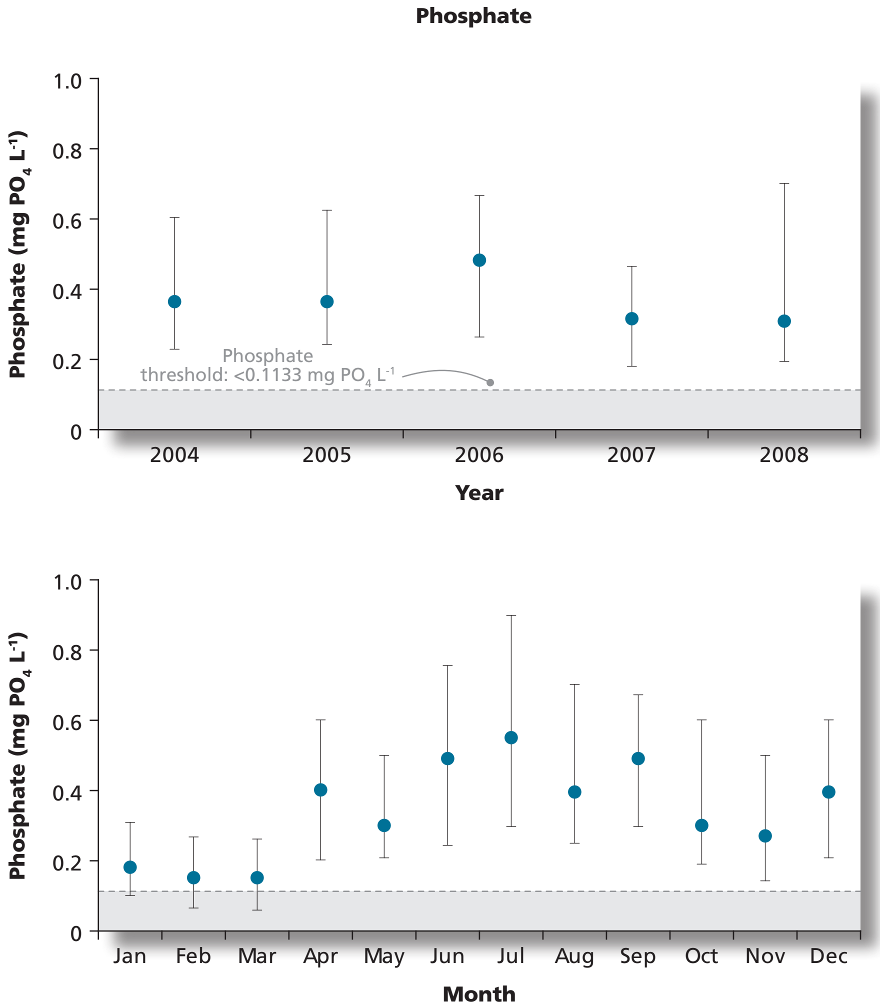


Figure 4.14. Median, 1st quartile, and 3rd quartile phosphate concentrations (mg PO_4 L^{-1}) from 2004 to 2008 for 16 stream sampling locations (see Figure 3.7) for Monocacy National Battlefield.[46] Acceptable range (PO_4 < 0.1133 mg L^{-1}) is also shown in gray.

46. Norris et al. 2007, ANTI.

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

in good condition (73% attainment), while crop yield concerns (6% attainment) and deer density (0% attainment) were in very degraded condition.

Pastures

Pasture lands in Monocacy National Battlefield was assessed as being in very good condition, with 81% attainment of desired condition across 13 measurements of 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 (89% 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 Monocacy National Battlefield were assessed to be in a poor condition (35% attainment of threshold condition; Tables 3.7, 4.4). Water

47. NCRN I&M, ANTI.

Resources and Landscape Dynamics were assessed as being in fair condition, Biological Integrity was degraded, and Air & Climate were in a very degraded condition.

Air & Climate

Using the interpolated results from NPS Air Resources Division and mercury monitoring data, Air & Climate in Monocacy 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 Monocacy National Battlefield were assessed as being in fair condition, attaining desired condition in 49% of the 2,558 measurements across all nine metrics, collected between 2004 and 2008 (Tables 3.7, 4.4). Acid neutralizing capacity (100% attainment; Figure 4.8) and water temperature (100% attainment; Figure 4.9) were in very good (desired) condition, while dissolved oxygen (63% attainment; Figure 4.10), salinity (63% attainment; Figure 4.11), and pH (62%; Figure 4.12) were all in good condition. Nitrate concentration (42% attainment; Figure 4.13) was in fair condition. Phosphate concentration (11% attainment; Figure 4.14), stream benthos, and Physical Habitat Index (both 0% attainment) were in very degraded condition.

Biological Integrity

Overall Biological Integrity within Monocacy National Battlefield was assessed to be in a degraded condition, attaining desired threshold condition in 36% of the 39 measurements across all eight metrics (Tables 3.7, 4.4). Presence of forest interior dwelling bird species was high (100% attainment), stream fish were good (63% attainment), while cover of exotic trees and shrubs (50% attainment) and presence of forest pest species (50% attainment) were in fair condition. Grassland bird diversity was poor (25% attainment). Very high deer density of 62 deer km^{-2} (161 deer mi^{-2}), low native tree seedling regeneration, and high cover of exotic herbaceous species resulted in 0% attainment of desired condition for these three metrics.

Landscape Dynamics

Landscape Dynamics were assessed both within and just surrounding Monocacy National Battlefield, and overall were in fair condition, attaining desired threshold condition in 54% attainment of desired threshold condition across all seven metrics (Tables 3.7, 4.4). Impervious surface within the park achieved the desired threshold condition of <10%; however, when a 5x park area buffer was added to the park, impervious surface rose to 12.5% cover, failing the threshold (Figure 4.5).The forest that is present is well connected both inside and adjacent to the park and so attained desired condition for forest connectivity—the forests at Monocacy National Battlefield essentially form one large irregularly shaped patch (Figure 4.6). However, forest and grassland interior area were both very low (11% and 17% attainment, respectively; Figures 4.7, 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/ncr/pdfs/nrm_booklet.pdf*

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

Categories and metrics	Mean	Attainment of threshold condition		
		Metric %	Category %	Park %
Air & Climate				
Ozone	0.080 ppm	0	0	35
Wet nitrogen (N) deposition	5.1 kg N ha^{-1} yr^{-1}	0		
Wet sulfur (S) deposition	6.2 kg S ha^{-1} yr^{-1}	0		
Visibility	14.14 dv	0		
Mercury (Hg) deposition	13.1 ng Hg L^{-1}	0		
Water Resources				
pH	7.3	62	49	
Dissolved oxygen (DO)	6.4 mg DO L^{-1}	63		
Water temperature	16.0 °C	100		
Acid neutralizing capacity	1,594 µeq L^{-1}	100		
Salinity	0.2	63		
Nitrate (NO_3)	3.0 mg NO_3 L^{-1}	42		
Phosphate (PO_4)	0.486 mg PO_4 L^{-1}	11		
Benthic index biological integrity (BIBI)	1.9	0		
Physical habitat index (PHI)	60.5	0		
Biological Integrity				
Cover of exotic herbaceous species	15.0%	0	36	
Cover of exotic trees and shrubs	2.8%	50		
Presence of forest pest species	9.5%	50		
Native tree seedling regeneration	10,833 seedlings ha^{-1}	0		
Fish index biological integrity (FIBI)	3.3	63		
Presence of forest interior dwelling species (FIDS) of birds	3.5 highly sensitive 3.5 sensitive	100		
Grassland bird diversity	25%	25		
Deer density (forest)	62.0 deer km^{-2}	0		
Deer density (grassland)	62.0 deer km^{-2}			
Landscape Dynamics				
Impervious surface (within park)	3.0%	100	54	
Impervious surface (within park) + 5X buffer	12.39%	0		
Forest interior area	8%	11		
Forest connectivity (Dcrit; within park)	60 m	100		
Forest connectivity (within park) + 5X buffer	30 m	100		
Grassland interior area	12%	17		
Contiguous grassland area	14.6 ha	50		

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 forest, wetland and waterway, 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.

The Worthington Farm in Monocacy 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 Monocacy 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 Monocacy 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 Monocacy National Battlefield.

Key findings	Management implications	Recommended next steps
Forests		
• Deer overpopulation reducing forest regeneration capacity	• Increased herbivory reducing desired plant and bird species • More road collisions	• Implement deer population control measures
• Presence of exotic plants	• Displacement of native species, reducing biodiversity	• Early detection • Exotic control measures (spraying and mechanical) • Prioritize control strategies
• Well-connected forest but with small patch sizes	• Acts as a refuge for forest interior dwelling species of birds, amphibians	• 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 Monocacy National Battlefield.

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

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

Key findings	Management implications	Recommended next steps
Grasslands (warm-season)		
• General lack of comprehensive data for grasslands	• Difficulties in assessing the health of grasslands	• Implement grassland monitoring, particularly diversity, invasive species, birds, mammals, and insects • Carry out a baseline grassland plant inventory
• Grassland areas are not contiguous and are limited in interior area	• Decreases habitat value for avian fauna and mammals (by increasing potential predation)	• 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 Monocacy National Battlefield.

Key findings	Management implications	Recommended next steps
Croplands		
• Deer overpopulation	• Reduced productivity and viability of cropland	• Implement deer population control measures
• Croplands are in high compliance with best management practice	• Suggests that croplands are being managed sustainably	• Organize and document compliance monitoring • Research new techniques in sustainable agriculture
• Nutrient management plan is in place but implementation and effectiveness not documented	• While compliant with regulations, nutrient impacts on surrounding habitats managed for natural resource values are unknown	• 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 Monocacy National Battlefield.

Key findings	Management implications	Recommended next steps
Pastures		
• Deer overpopulation	• Degrading value of pasture, impacting surrounding habitats	• Implement deer population control measures
• Nutrient management plan is in place but implementation and effectiveness not documented	• While compliant with regulations, nutrient impacts on surrounding habitats managed for natural resource values are unknown	• 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 of 62 deer per km^{-2} (161 deer mi^{-2}). The abundant presence of exotic herbaceous and woody species, as well as the presence of forest pest species such as gypsy moth and hemlock woolly adelgid, displace or degrade native species and reduce habitat value. Continued early detection of exotic species is recommended with subsequent active control measures as appropriate (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 habitats show some signs of acidification, low oxygen, and high nutrients, indicating fair wetland habitat value, which is reflected in the low benthic index of biotic integrity, low physical habitat index, and moderate fish diversity (Table 5.2). It is recommended to identify and work with partners to reduce non-point source nutrient inputs from the watershed as well as continue to implement best management practices in agricultural lands. Additionally, efforts should continue to establish riparian buffers (ideally to 50 m [160 ft]; Mayer et al. 2006) where appropriate, in consideration of cultural resources and historic vistas (using shrubs and grasses instead of trees may be appropriate in these cases). Assessment of these habitats could be improved by inclusion of metrics indicative of groundwater condition, due to the developing karst geology of the area—the carbonate rocks in karst landscapes are particularly susceptible to dissolution from both surface water and groundwater (Thorneberry–Ehrlich 2008). 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 moderately contiguous with a low grassland interior area, 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 Monocacy National Battlefield are susceptible to the very high deer populations (Table 5.4), which are the primary cause for 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 instigate soil nutrient testing 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 Monocacy 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 Monocacy 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 instigate soil nutrient testing 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 Monocacy 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. Currently available air quality data is regional, it would be beneficial to translate this data down to a park scale with modeling efforts as well as some strategic calibration, especially on major roadways within the park.

5.3.2 Water Resources

Water quality has signs of degradation, and is essential to the preservation of biotic integrity within all major habitats in the park (Table 5.7). 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 sources, both within the park and throughout the watershed, would assist in assessing potential threats, and working with watershed parters 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.

The developing karst features in and around Monocacy National Battlefield have not yet been inventoried (Thorneberry–Ehrlich 2008). Karst geology can affect stream salinity, pH, acid neutralizing capacity, and temperature (White 1993, Norris and Pieper 2010). It is recommended to further investigate the scale and distribution of karst geology surrounding the park.

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 in the park have contributed to very low native tree seedling regeneration. A better understanding of the dynamics of these forest habitats in the presence of high deer populations and their ability to recover after deer reduction would assist in clarifying sustainable deer populations for future management.

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

5.3.4. Landscape Dynamics

Many of the faunal communities that constitute features of the park are migratory or have home ranges much greater than the park. For these reasons, assessing the connectivity and ownership of habitats and lands not just within but also outside of the park will allow a better understanding of the resilience of these communities and their susceptibility to change in the future (Table 5.9). This is true for forest, wetland and waterway, and grassland habitats within the park. As a battlefield park, vegetating

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

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

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

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

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

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

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

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

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)

Goodwin, S. and G. Shriver. 2009. Avian monitoring in the National Capital Region: 2007 and 2008 Annual Report. Draft. U.S. Department of the Interior.

Mayer, P.M., S.K. Reynolds, M.D. McCutchen, and T.J. Canfield. 2006. Riparian buffer width, vegetative cover, and nitrogen removal effectiveness: a review of current science and regulations. EPA/600/R-05/118. U.S. Environmental Protection Agency, Cincinnati, OH,

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

Thorneberry–Ehrlich, T. 2008. Monocacy National Battlefield geologic resource evaluation report. Natural Resource Report NPS/NRPC/GRD/NRR—2008/051. National Park Service, Denver, CO.

White, W.B. 1993. Analysis of karst aquifers. In: Alley, W.M. (ed). Regional ground-water quality. Van Nostrand Reinhold, New York, NY.

Appendix A: Raw data used in Monocacy 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

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	Salinity	NO_3	PO_4
				I&M data				
NCRN_MONO_BUCK	5/23/2005	8.18	10.16	16.63			**3.2**	
NCRN_MONO_BUCK	6/20/2005	**8.73**	10.68	19.10	1056		**2.3**	
NCRN_MONO_BUCK	10/6/2005	8.08	9.22	18.40	1224		**3**	
NCRN_MONO_BUCK	11/8/2005	**8.97**	12.17	10.75	900		**2.3**	
NCRN_MONO_BUCK	12/12/2005	8.13	11.68	3.00	1130	0.200	**3**	
NCRN_MONO_BUCK	1/23/2006	7.55	13.13	5.60	856	0.100	**2.6**	
NCRN_MONO_BUCK	2/23/2006	**9.20**	11.74	5.60	864	0.100	**3.3**	
NCRN_MONO_BUCK	3/21/2006	**9.42**	7.63	5.60	1008	0.100	**2.9**	
NCRN_MONO_BUCK	4/10/2006	**9.14**	**4.62**	10.75	1192	0.100	**2.2**	
NCRN_MONO_BUCK	5/16/2006	8.20	**3.60**	15.60	1176	0.100	**2.4**	
NCRN_MONO_BUCK	6/29/2006	7.48	6.54	20.10	860	0.100	1.7	
NCRN_MONO_BUCK	7/24/2006	8.48	8.14	23.40	1320	0.200	**2.8**	
NCRN_MONO_BUCK	8/15/2006	7.98	8.42	23.40	1440	0.200	**2.9**	
NCRN_MONO_BUCK	9/13/2006	7.72	8.60	17.60	1460	0.200	**2.4**	
NCRN_MONO_BUCK	10/16/2006	**8.80**	12.16	10.40	1520	0.200	**2.5**	
NCRN_MONO_BUCK	12/7/2006	**9.13**	10.87	5.90	960	0.100	**3.2**	
NCRN_MONO_BUCK	1/4/2007	7.56	12.17	4.33	1040	0.100	1.4	**0.59**
NCRN_MONO_BUCK	1/31/2007		14.60	0.60	1180	0.100	**5.5**	**0.77**
NCRN_MONO_BUCK	3/6/2007	8.09	12.55	3.13	904	0.100	**3.45**	**0.19**
NCRN_MONO_BUCK	4/3/2007	**9.30**	11.46	15.45	1032	0.100	**2.69**	0.1
NCRN_MONO_BUCK	5/23/2007	8.19	7.93	17.80	1208	0.100	**3.97**	**0.42**
NCRN_MONO_BUCK	6/28/2007	**8.83**	8.21	25.10	3688	0.200	**3.1**	**0.24**
NCRN_MONO_BUCK	7/26/2007	**8.57**	7.72	23.80	1608	0.200	1.5	**0.27**
NCRN_MONO_BUCK	8/27/2007	**8.58**	7.73	22.90	1696	0.200	**2.6**	**0.38**
NCRN_MONO_BUCK	9/27/2007	8.22	7.64	20.00	2080	0.200	**3.3**	**0.28**
NCRN_MONO_BUCK	10/22/2007	8.01	8.05	13.60	2768	0.200	**2.2**	**0.26**
NCRN_MONO_BUCK	11/20/2007	**8.67**	11.63	7.80	1888	0.200	**3.8**	**0.26**
NCRN_MONO_BUCK	12/18/2007	8.02	13.07	2.03	1336	0.200	**4.1**	**0.38**
NCRN_MONO_BUCK	1/28/2008	**8.73**	15.90	1.27	1432	0.200	**3.9**	**0.22**
NCRN_MONO_BUCK	2/25/2008	**9.15**	14.28	5.80	1384	0.200	**4.6**	**0.27**
NCRN_MONO_BUCK	3/24/2008	**9.44**	15.08	8.22	1128	0.200	**4**	**0.26**
NCRN_MONO_BUCK	4/24/2008	8.11	10.20	15.95	1240	0.100	**3.4**	**0.74**
NCRN_MONO_BUCK	5/14/2008	7.67	9.21	13.60	1224	0.100	**4.7**	**0.34**
NCRN_MONO_BUCK	6/24/2008	**8.59**	8.93	21.50	1936	0.200	**3.7**	**0.17**
NCRN_MONO_BUCK	7/29/2008	**8.53**	9.01	23.57	1572	0.200	**3.3**	**0.31**
NCRN_MONO_BUCK	8/25/2008	8.39	8.48	21.83	1632	0.200	**2.3**	**0.27**
NCRN_MONO_BUCK	9/22/2008	**8.57**	11.18	18.13	1712	0.200	**3.3**	**0.21**
NCRN_MONO_BUCK	10/21/2008	7.73	11.16	8.10	1640	0.200	**2.6**	**0.19**
NCRN_MONO_BUCK	11/18/2008	7.80	12.70	5.25	1680	0.200	**2.8**	**0.27**
NCRN_MONO_HARU	5/23/2005	7.31	8.85	15.35			**3.1**	
NCRN_MONO_HARU	6/20/2005	7.54	7.15	18.30	1168		1.7	
NCRN_MONO_HARU	10/6/2005	7.14	**0.16**	18.05	1656		*Non-detect	

Site	Date	pH	DO	Temp	ANC	Salinity	NO_3	PO_4
				I&M data				
NCRN_MONO_HARU	11/8/2005	7.09	**4.87**	10.90	880		**3**	
NCRN_MONO_HARU	1/23/2006	7.07	11.61	5.60	1304	0.200	1.9	
NCRN_MONO_HARU	2/23/2006	7.10	7.36	5.70	616	0.100	**9.4**	
NCRN_MONO_HARU	3/21/2006	7.67	6.13	4.70	800	0.100	**4.3**	
NCRN_MONO_HARU	4/10/2006	7.68	**3.89**	11.05	880	0.100	**2.7**	
NCRN_MONO_HARU	5/18/2006	7.47	**2.71**	14.30	1256	0.100	**2.5**	
NCRN_MONO_HARU	6/29/2006	7.52	6.48	20.00	640	0.100	**3.2**	
NCRN_MONO_HARU	7/24/2006	7.59	**3.73**	22.40	960	0.100	1.8	
NCRN_MONO_HARU	8/15/2006	6.82	**0.68**	21.90	1500	0.100	0.5	
NCRN_MONO_HARU	10/16/2006	7.44	8.91	9.90	1340	0.100	**4.1**	
NCRN_MONO_HARU	12/8/2006	7.43	9.39	4.90	660	0.100	**5.1**	
NCRN_MONO_HARU	1/4/2007	7.36	11.96	3.95	616	0.100	**2.62**	**0.52**
NCRN_MONO_HARU	2/2/2007		13.15	1.30	620	0.100	**2.42**	**0.87**
NCRN_MONO_HARU	3/6/2007	7.66	11.75	2.50	576	0.100	**4.87**	**0.12**
NCRN_MONO_HARU	4/3/2007		8.28	17.10	672	0.100	**5.4**	**0.12**
NCRN_MONO_HARU	5/23/2007	7.36	6.05	16.90	928	0.100	**4.77**	**0.32**
NCRN_MONO_HARU	12/18/2007	7.52	12.45	1.30	784	0.200	**9.1**	**0.25**
NCRN_MONO_HARU	2/25/2008	7.58	10.88	5.40	840	0.200	**4.4**	**0.27**
NCRN_MONO_HARU	3/24/2008	7.77	11.47	8.20	760	0.100	**6.3**	**0.36**
NCRN_MONO_HARU	4/24/2008	7.50	8.19	17.30	824	0.200	**6.9**	**0.32**
NCRN_MONO_HARU	5/14/2008	7.40	8.50	14.60	1008	0.100	**9.6**	**0.28**
NCRN_MONO_HARU	6/24/2008	7.57	7.47	19.80	1976	0.100	**4.7**	**0.23**
NCRN_MONO_VCCR	5/23/2005	7.59	9.05	15.50			**2.3**	
NCRN_MONO_VCCR	6/20/2005	7.68	8.06	16.30	2640		**4.6**	
NCRN_MONO_VCCR	10/6/2005	7.79	5.06	15.65	1392		**14.2**	
NCRN_MONO_VCCR	11/8/2005	7.57	7.50	12.10	2000		**4.1**	
NCRN_MONO_VCCR	1/23/2006	7.53	12.25	6.93	1152	0.200	**2.9**	
NCRN_MONO_VCCR	2/23/2006	8.23	10.35	8.20	1216	0.100	**4.2**	
NCRN_MONO_VCCR	3/21/2006	8.21	6.94	6.80	1824	0.200	**7.7**	
NCRN_MONO_VCCR	4/10/2006	8.39	**3.65**	12.55	1704	0.200	**3.1**	
NCRN_MONO_VCCR	5/16/2006	7.81	**2.57**	14.70	1648	0.200	**2.5**	
NCRN_MONO_VCCR	6/29/2006	7.66	6.69	19.40	1320	0.100	1.5	
NCRN_MONO_VCCR	7/24/2006	7.57	5.24	19.00	2380	**0.300**	**5.1**	
NCRN_MONO_VCCR	8/15/2006	7.14	5.13	16.90	3500	**0.300**	**11.8**	
NCRN_MONO_VCCR	9/13/2006	7.48	7.01	16.70	2320	0.200	**3.7**	
NCRN_MONO_VCCR	10/16/2006	7.68	7.98	12.00	2620	0.200	**2.7**	
NCRN_MONO_VCCR	12/7/2006	8.34	10.00	7.80	1440	0.200	**4.1**	
NCRN_MONO_VCCR	1/4/2007	7.81	11.15	5.87	1224	0.100	**4.79**	**0.54**
NCRN_MONO_VCCR	2/2/2007		11.52	5.25	1840	0.200	**2.34**	**0.98**
NCRN_MONO_VCCR	3/6/2007	8.01	11.07	5.00	1224	0.200	**3.83**	0.07
NCRN_MONO_VCCR	4/3/2007		9.76	17.60	1088	0.200	**4.26**	**0.17**
NCRN_MONO_VCCR	5/23/2007	7.72	6.54	16.20	2328	0.200	**5.84**	**0.38**
NCRN_MONO_VCCR	6/28/2007	**5.39**	6.10	17.80	1448	**0.300**	**9.6**	**0.17**
NCRN_MONO_VCCR	7/26/2007	7.69	5.61	18.50	3600	**0.300**	**10.02**	**0.35**

Site	Date	pH	DO	Temp	ANC	Salinity	NO_3	PO_4
				I&M data				
NCRN_MONO_VCCR	8/27/2007	7.84	5.39	17.90	3872	**0.300**	**9.36**	**0.33**
NCRN_MONO_VCCR	9/27/2007	7.43	**3.41**	16.90	3944	**0.300**	**8.1**	**0.36**
NCRN_MONO_VCCR	10/22/2007	7.56	**4.44**	13.20	4152	**0.300**	**8.9**	**0.33**
NCRN_MONO_VCCR	11/20/2007	7.97	5.53	9.30	3056	**0.300**	**5**	**0.23**
NCRN_MONO_VCCR	12/18/2007	8.03	11.49	3.80	1600	0.200	**5.5**	**0.23**
NCRN_MONO_VCCR	1/28/2008	8.21	13.65	4.10	2064	0.200	**5.7**	**0.22**
NCRN_MONO_VCCR	2/25/2008	**8.94**	14.90	7.50	1608	0.200	**4.9**	**0.26**
NCRN_MONO_VCCR	3/24/2008	**8.96**	11.60	9.80	1424	0.200	**5.5**	**0.27**
NCRN_MONO_VCCR	4/24/2008	8.07	9.76	16.70	1456	0.200	**4.6**	**0.2**
NCRN_MONO_VCCR	5/14/2008	7.71	7.70	14.70	1360	0.200	**2**	**0.23**
NCRN_MONO_VCCR	6/24/2008	7.78	7.54	18.05	2400	0.200	**6.4**	**0.21**
NCRN_MONO_VCCR	7/29/2008	7.82	7.49	18.85	2608	**0.300**	**6.8**	**0.21**
NCRN_MONO_VCCR	8/25/2008	7.82	6.71	16.80	3880	**0.300**	**8.1**	**0.18**
NCRN_MONO_VCCR	9/22/2008	7.82	6.28	16.50	2048	**0.300**	**7.1**	**3.64**
NCRN_MONO_VCCR	10/21/2008	7.75	9.96	9.80	2900	0.200	**2.2**	**0.15**
NCRN_MONO_VCCR	11/18/2008	7.71	10.11	6.95	2272	0.200	**3.9**	**0.2**

Site	Date	pH	DO	Temp	ANC	Salinity	NO_3	PO_4
				MONO data				
MONO_WQ_#01	6/24/2004	6.92	**1.27**	20.2		0.233	1.1	**0.57**
MONO_WQ_#01	5/27/2004	**10.56**	**1.41**	23.4				**0.74**
MONO_WQ_#01	6/24/2004	6.92	**1.27**	20.2		0.233	1.1	**0.57**
MONO_WQ_#01	7/24/2004	6.95	**0.27**	21.5		**0.259**		
MONO_WQ_#01	8/26/2004	**6.49**	**1.49**	21.7		**0.255**	1.7	**0.43**
MONO_WQ_#01	11/16/2004	7.03	**4.72**	5.9		**0.304**		**0.27**
MONO_WQ_#01	5/9/2005	**6.49**	11.12	17.7		**0.309**		**0.17**
MONO_WQ_#01	6/9/2005	6.75	8.86	23.9		0.230		**0.24**
MONO_WQ_#01	7/12/2005	**6.46**	**1.44**	23.1		0.202		**0.93**
MONO_WQ_#01	8/18/2005	**6.15**	**2.04**	21.1		**0.254**		**0.57**
MONO_WQ_#01	4/26/2006	7.4		11.2		**0.318**		**2.67**
MONO_WQ_#01	5/30/2006	6.53	**1.51**	21.7		**0.268**		**0.63**
MONO_WQ_#01	7/17/2006	**6.34**	**0.27**	28.8		0.187		**0.26**
MONO_WQ_#01	8/21/2006	**6.24**	**0.67**	21.6		0.246		0.06
MONO_WQ_#01	9/26/2006	7.38	**1.34**	14.5		**0.267**		0.09
MONO_WQ_#01	5/10/2007	**6.46**	**3.44**	20.2		0.239		**0.26**
MONO_WQ_#01	6/12/2007	**6.18**	**0.77**	21.6		**0.265**		**0.41**
MONO_WQ_#01	7/10/2007	6.61	**1.91**	25.9		**0.251**		**0.8**
MONO_WQ_#01	8/28/2007	**6.43**	**0.98**	21.1		**0.266**		**0.17**
MONO_WQ_#01	9/26/2007	6.56	**0.98**	19.1		**0.279**		
MONO_WQ_#01	11/28/2007	8.32	**2.41**	5.2		**0.379**		0.04
MONO_WQ_#01	12/18/2007	**8.63**	**3.31**	0.9		**0.267**	0.8	
MONO_WQ_#01	1/30/2008	**11.67**	5.66	3.6		**0.372**	0.2	0.02
MONO_WQ_#01	2/25/2008	8.41	10.26	4.7		**0.340**	0.1	0.06
MONO_WQ_#01	3/11/2008	7.06	8.15	5.5		**0.351**	0.7	0.02
MONO_WQ_#01	4/15/2008	7.41	**4.34**	11.2		**0.497**	0.7	**0.3**
MONO_WQ_#01	5/5/2008	6.6	**3.63**	13.4		**0.460**	1.8	**0.2**
MONO_WQ_#01	6/9/2008	**6.36**	**1.58**	24.9		**0.396**	0.4	0.1
MONO_WQ_#01	7/8/2008	6.67	**2.52**	22.7		**0.410**	0.2	**1.3**
MONO_WQ_#01	8/10/2008	6.5	**1.6**	20.1		**0.464**	0.01	0.02
MONO_WQ_#01	9/8/2008	6.54	**1.06**	19.9		**0.433**	0.7	**0.3**
MONO_WQ_#01	10/6/2008	6.88	**1.49**	12.9		**0.424**	0.02	**0.2**
MONO_WQ_#01	11/3/2008	6.84	**2.35**	10.3		**0.439**	1.8	0.02
MONO_WQ_#01	12/9/2008	**9.23**	**3.82**	1.9		**0.387**	1.2	**0.3**
MONO_WQ_#02	5/27/2004	**10.56**	**1.09**	23.6			**8.3**	**0.71**
MONO_WQ_#02	6/24/2004	**6.1**	**3.25**	22.1		0.206	**5.7**	**0.56**
MONO_WQ_#02	7/24/2004	**6.02**	**1.85**	22.1		0.216	**8.8**	**0.86**
MONO_WQ_#02	8/26/2004	**5.85**	**3.6**	22		0.224	**6.6**	**0.69**
MONO_WQ_#02	11/16/2004	**5.75**	**2.45**	12.4		0.241	**3.6**	**0.69**
MONO_WQ_#02	5/9/2005	**5.94**	10.59	17.9		**0.310**	**7.8**	**0.98**
MONO_WQ_#02	6/9/2005	**5.68**	5.64	24.7		0.216	**8.1**	**0.52**
MONO_WQ_#02	7/12/2005	**5.75**	**1.64**	23.4		0.241	1.1	**1.12**
MONO_WQ_#02	8/18/2005	**5.45**	**2.01**	21		0.221	**23.9**	**0.8**
MONO_WQ_#02	4/26/2006	**6.4**		13.7		**0.265**	**5.1**	**0.13**

Site	Date	pH	DO	Temp	ANC	Salinity	NO_3	PO_4
				MONO data				
MONO_WQ_#02	5/30/2006	**5.75**	**2.82**	21.6		0.163	**3.5**	**1.69**
MONO_WQ_#02	7/17/2006	**5.42**	**3.26**	28.3		0.151	**2.1**	**0.81**
MONO_WQ_#02	5/10/2007	**5.37**	**1.67**	23.4		0.218	**4.4**	**0.94**
MONO_WQ_#02	6/12/2007	**5.14**	**2.95**	21.9		0.213	**2.5**	
MONO_WQ_#02	7/10/2007	**6.34**	**1.38**	21.7		0.193		**1.03**
MONO_WQ_#02	4/15/2008	7.72	**3.55**	10.4		**0.290**	**2.8**	**0.9**
MONO_WQ_#02	5/5/2008	**5.12**	5.6	15.8		0.129	**3.5**	**0.5**
MONO_WQ_#02	6/9/2008	**5.93**	**2.11**	21.1		**0.268**	**2.9**	**0.9**
MONO_WQ_#02	7/8/2008	**6.07**	**2.62**	21.3		**0.342**	1.9	**1**
MONO_WQ_#03	5/27/2004	**10.56**	**4.84**	27.8			**5.3**	**0.24**
MONO_WQ_#03	6/24/2004	**4.95**	6.35	16.3		0.102	**5.9**	**0.26**
MONO_WQ_#03	7/24/2004	**4.94**	6.81	18.4		0.080	**4.8**	**2.31**
MONO_WQ_#03	8/26/2004	**4.71**	5.17	18.3		0.079	**6.7**	**0.24**
MONO_WQ_#03	11/16/2004	**4.76**	8.79	13		0.138	**7.2**	**1.64**
MONO_WQ_#03	5/9/2005	**4.5**	10.5	14.7		**0.378**	1.2	**0.56**
MONO_WQ_#03	6/9/2005	**4.62**	6.05	25		0.088	**5.5**	**0.74**
MONO_WQ_#03	7/12/2005	**4.34**	**2.2**	24		0.090	0.7	**0.3**
MONO_WQ_#03	8/18/2005	**4.47**	**1.14**	21.8		0.090	1.8	0.11
MONO_WQ_#03	4/26/2006	**6.16**		12.1		0.085	**2.4**	**6.78**
MONO_WQ_#03	5/30/2006	**4.88**	**3.96**	22		0.077	**2**	**1.96**
MONO_WQ_#03	7/17/2006	**5.14**	**4.12**	21.8		0.078	0.3	**0.62**
MONO_WQ_#03	8/21/2006	7.15	**3.35**	19.9		0.082	1.1	**0.26**
MONO_WQ_#03	9/26/2006	7.25	5.28	14.5		0.090	**14.3**	**0.67**
MONO_WQ_#03	5/10/2007	**4.2**	**4.44**	19.2		0.072	0.7	**0.18**
MONO_WQ_#03	6/12/2007	**4.37**	**3.1**	20.1		0.067	**2.8**	**1.13**
MONO_WQ_#03	7/10/2007	**4.86**	**4.2**	26.5		0.076	**4.3**	**0.94**
MONO_WQ_#03	8/28/2007	**5.64**	**3.07**	20.5		0.072	**3.8**	**0.25**
MONO_WQ_#03	11/28/2007	7.3	**3.5**	5.5		0.153	1	**0.2**
MONO_WQ_#03	12/18/2007	**6.42**	8.72	6.6		0.124	**12**	0.09
MONO_WQ_#03	1/30/2008	8.08	7.62	6.4		0.121	**5**	**0.2**
MONO_WQ_#03	2/25/2008	**5.24**	8.65	7.9		0.126	**9.4**	**0.13**
MONO_WQ_#03	3/11/2008	**5.08**	8.03	8.3		0.125	**8.3**	0.04
MONO_WQ_#03	4/15/2008	**8.72**	6.31	13.4		0.131	**2.7**	**0.4**
MONO_WQ_#03	5/5/2008	**5.12**	5.6	15.8		0.129	**3.5**	**0.5**
MONO_WQ_#03	6/9/2008	**4.48**	**3.67**	20.6		0.135	**3.3**	
MONO_WQ_#03	7/8/2008	**4.83**	**2.7**	21.2		0.142	**3.9**	**0.9**
MONO_WQ_#03	8/10/2008	**5.14**	**2.16**	17.3		0.145	**3.3**	**0.8**
MONO_WQ_#03	9/8/2008	**5.86**	**0.98**	18.5		0.145	**4.4**	0.02
MONO_WQ_#03	10/6/2008	**6.07**	5.98	12		0.121	1.2	0.02
MONO_WQ_#03	11/3/2008	**6.49**	**4.41**	10		0.130	1	**0.3**
MONO_WQ_#03	12/9/2008	7.04	5.77	5.9		0.130	**4.6**	**0.6**
MONO_WQ_#04	5/27/2004	**10.56**	7.68	22.9			**3.7**	**0.4**
MONO_WQ_#04	5/9/2005	**5.7**	10.3	17.6		**0.388**	**6.1**	**0.36**
MONO_WQ_#04	4/26/2006	6.99		13.6		0.120		**0.29**

Site	Date	pH	DO	Temp	ANC	Salinity	NO_3	PO_4
				MONO data				
MONO_WQ_#04	5/10/2007	**5.62**	**4.26**	16.8		0.100	**5.3**	**0.84**
MONO_WQ_#06	8/26/2004	6.85	**1.08**	20.2		**0.486**	**5.2**	**1.14**
MONO_WQ_#07A	5/27/2004	**10.56**	7.56	20.1			**2.8**	**1.01**
MONO_WQ_#07A	6/24/2004	6.99	6.51	24.4		0.153	**3.7**	**0.21**
MONO_WQ_#07A	7/24/2004	7.59	7.27	22.6		0.152	1.4	**0.63**
MONO_WQ_#07A	8/26/2004	7.01	7.86	22.1		0.154	**3.3**	**0.13**
MONO_WQ_#07A	11/16/2004	6.74	11.87	8.4		0.233	**4.4**	**0.17**
MONO_WQ_#07A	5/9/2005	6.7	12.26	13.4		**0.336**	**2.9**	**0.17**
MONO_WQ_#07A	6/9/2005	6.51	6.91	22.7		0.176	**3.2**	**1.39**
MONO_WQ_#07A	7/12/2005	6.61	**2.03**	23.9		0.168	0.4	**0.61**
MONO_WQ_#07A	8/18/2005	**6.26**	**1.68**	23		0.146	**2.3**	**0.19**
MONO_WQ_#07A	4/26/2006	7.24		15.6		0.193	0.4	**0.16**
MONO_WQ_#07A	5/30/2006	**6.23**	5.43	24.8		0.156		**1.78**
MONO_WQ_#07A	7/17/2006	6.54	5.23	28.5		0.149	0.2	**0.12**
MONO_WQ_#07A	8/21/2006	**6.26**	**4.26**	21.6		0.162	0.2	**0.85**
MONO_WQ_#07A	9/26/2006	7.23	5.45	17.6		0.192		**0.62**
MONO_WQ_#07A	5/10/2007	**6.43**	5.79	21.2		0.154	**5**	**0.21**
MONO_WQ_#07A	6/12/2007	**6.4**	**4.45**	22.3		0.131	**2.5**	**0.45**
MONO_WQ_#07A	7/10/2007	6.83	**4.12**	27		0.144	1.7	**0.21**
MONO_WQ_#07A	8/28/2007	6.72	**4.03**	22.4		0.161	0.6	**0.14**
MONO_WQ_#07A	11/28/2007	**9.36**	6.2	5.3		**0.270**	1.7	**0.48**
MONO_WQ_#07A	12/18/2007	7.79	9.9	2.5		0.240	**3.2**	
MONO_WQ_#07A	1/30/2008	**8.67**	9.75	3.7		0.249	**3**	0.11
MONO_WQ_#07A	2/25/2008	6.56	8.6	5		0.225	**5**	**0.2**
MONO_WQ_#07A	3/11/2008	**8.7**	7.96	6.3		0.212	0.6	**0.38**
MONO_WQ_#07A	4/15/2008	**8.9**	6.57	15.6		**0.297**	**6.5**	**0.3**
MONO_WQ_#07A	5/5/2008	6.77	**4.6**	22.3		0.248	**4.1**	**0.3**
MONO_WQ_#07A	6/9/2008	**5.69**	**3.8**	24.8		**0.287**	1.5	
MONO_WQ_#07A	7/8/2008	6.8	**3.47**	29.3		**0.256**	0.5	**1.1**
MONO_WQ_#07A	8/10/2008	7.03	**2.45**	19		**0.266**	0.8	**0.9**
MONO_WQ_#07A	10/6/2008	6.95	7.02	12.5		**0.305**	0.5	**0.6**
MONO_WQ_#07A	11/3/2008	7.18	**4.82**	10.3		**0.307**	**3.2**	**0.6**
MONO_WQ_#07A	12/9/2008	**8.58**	6.24	2.4		0.247	1.7	**0.9**
MONO_WQ_#07B	5/27/2004	**10.56**	7.45	20.5			1.7	**0.24**
MONO_WQ_#07B	6/24/2004	7.03	6.71	25.6		0.137	**5.9**	**0.35**
MONO_WQ_#07B	7/24/2004	7.49	7.4	22.3		0.131	**2.7**	**0.44**
MONO_WQ_#07B	8/26/2004	6.86	6.71	23.2		0.139	**2.2**	**0.26**
MONO_WQ_#07B	11/16/2004	7.29	11.12	9		0.204	**5.1**	**0.14**
MONO_WQ_#07B	5/9/2005	6.68	11.36	23.2		**0.269**	**2.3**	**0.31**
MONO_WQ_#07B	6/9/2005	6.71	6.58	23.4		0.161		**0.33**
MONO_WQ_#07B	7/12/2005	**6.22**	**2.59**	23.3		0.156	0.7	**0.35**
MONO_WQ_#07B	8/18/2005	**6.37**	**2.38**	26.8		0.124	0.6	**0.26**
MONO_WQ_#07B	4/26/2006	6.72		12.4		0.181	1.1	**0.47**
MONO_WQ_#07B	5/30/2006	**6.11**	5.73	24.4		0.143	0.2	0.08

Site	Date	pH	DO	Temp	ANC	Salinity	NO_3	PO_4
MONO data								
MONO_WQ_#07B	7/17/2006	6.52	5.42	**30.3**		0.126	0.2	**0.51**
MONO_WQ_#07B	8/21/2006	**6.47**	5.65	21.2		0.183	0.8	**0.32**
MONO_WQ_#07B	9/26/2006	7.28	6.65	15.9		0.178	**2.2**	**0.38**
MONO_WQ_#07B	5/10/2007	**5.98**	6.33	20.1		0.133	1.7	0.09
MONO_WQ_#07B	6/12/2007	**6**	**4.55**	22		0.123	**10.4**	**1.31**
MONO_WQ_#07B	7/10/2007	6.85	**4.88**	26.6		0.132	**2.3**	**0.75**
MONO_WQ_#07B	8/28/2007	**6.35**	**3.65**	21.5		0.137	**2**	**0.85**
MONO_WQ_#07B	11/28/2007	**8.54**	6.32	5.1		**0.253**	1.5	**0.4**
MONO_WQ_#07B	12/18/2007	**9.39**	10.02	2.3		0.215	**3.5**	0.03
MONO_WQ_#07B	1/30/2008	**9.61**	8.81	2.8		0.213	**3.6**	**0.24**
MONO_WQ_#07B	2/25/2008	**6.46**	8.37	5.9		0.194	**5.3**	**0.15**
MONO_WQ_#07B	3/11/2008	**5.57**	7.98	6.5		0.188	**2.3**	**0.43**
MONO_WQ_#07B	4/15/2008	7.66	6.48	14.5		0.246	0.9	**0.4**
MONO_WQ_#07B	5/5/2008	**6.16**	5.7	18.1		0.238	**2.7**	**0.8**
MONO_WQ_#07B	6/9/2008	**6.29**	**3.5**	25		**0.256**	0.6	
MONO_WQ_#07B	7/8/2008	**6.21**	**3.25**	23.1		**0.260**	1	**1.5**
MONO_WQ_#07B	8/10/2008	**6.04**	**2.44**	18.5		0.235	1	**0.8**
MONO_WQ_#07B	10/6/2008	7.22	6.68	13.6		**0.268**	0.7	**0.8**
MONO_WQ_#07B	11/3/2008	7.03	6.02	11		**0.289**	1.9	**0.7**
MONO_WQ_#07B	12/9/2008	7.65	6.34	3.3		0.233	**3.3**	**0.6**
MONO_WQ_#07C	5/27/2004	**10.56**	7.26	22.8			1.6	**0.26**
MONO_WQ_#07C	6/24/2004	6.97	8.1	24		0.143	**2.8**	**0.35**
MONO_WQ_#07C	7/24/2004	7.25	6.95	23.4		0.159	**2.6**	**0.37**
MONO_WQ_#07C	8/26/2004	**6.38**	**3.94**	22.9		0.183	**2.3**	**0.19**
MONO_WQ_#07C	11/16/2004	7.12	11.7	10.2		**0.254**	**4.3**	**0.27**
MONO_WQ_#07C	5/9/2005	6.94	11.55	22.3		**0.276**	**2.9**	**0.24**
MONO_WQ_#07C	6/9/2005	6.96	7.23	26.2		0.170		
MONO_WQ_#07C	7/12/2005	6.74	**4.01**	26.1		0.178	0.2	**0.32**
MONO_WQ_#07C	8/18/2005	6.59	**2.17**	27.5		0.157		**0.63**
MONO_WQ_#07C	4/26/2006	8.26		16.1		0.204		**0.27**
MONO_WQ_#07C	5/30/2006	**6.47**	5.25	24.8		0.177		**1.34**
MONO_WQ_#07C	7/17/2006	6.75	5.22	29.1		0.160	0.4	**0.66**
MONO_WQ_#07C	9/26/2006	7.24	5.5	16.7		0.217	1.5	**0.49**
MONO_WQ_#07C	5/10/2007	6.98	5.76	22.1		0.148	**2**	**0.25**
MONO_WQ_#07C	6/12/2007	**6.45**	**3.8**	25.7		0.130	1.4	**1.26**
MONO_WQ_#07C	12/18/2007	**9.55**	9.97	2.5		**0.253**	**3.4**	**0.35**
MONO_WQ_#07C	1/30/2008	**9.1**	9.04	3.9		0.247	**2.4**	0.07
MONO_WQ_#07C	2/25/2008	6.73	8.78	5.2		**0.256**	1.9	0.02
MONO_WQ_#07C	3/11/2008	7.92	8.12	6.9		**0.255**	**5.7**	**0.15**
MONO_WQ_#07C	4/15/2008	**9.37**	6.76	16.5		**0.281**	**3**	**0.4**
MONO_WQ_#07C	5/5/2008	7.38	5.49	20.6		**0.286**	**3.3**	**0.4**
MONO_WQ_#07C	6/9/2008	**5.77**	**2.66**	**30.2**		**0.291**	**2.8**	
MONO_WQ_#07C	7/8/2008	6.92	**2.65**	27.9		0.241	**2.3**	**1.4**
MONO_WQ_#07C	11/3/2008	7.12	**2.73**	15.7		**0.359**	0.7	0.1

Site	Date	pH	DO	Temp	ANC	Salinity	NO_3	PO_4
				MONO data				
MONO_WQ_#07C	12/9/2008	8.07	6.12	2.8		**0.254**	**2.1**	**0.7**
MONO_WQ_#07D	5/27/2004	**10.56**	7.74	20.9			1.8	**0.22**
MONO_WQ_#07D	6/24/2004	7.13	7.37	22.1		0.178	0.1	**0.37**
MONO_WQ_#07D	7/24/2004	7.47	7.66	21		0.192	0.3	**0.59**
MONO_WQ_#07D	8/26/2004	6.73	**4.32**	21.9		0.237	1.1	**0.23**
MONO_WQ_#07D	11/16/2004	6.95	11.66	8.4		**0.257**	**4.9**	**0.43**
MONO_WQ_#07D	5/9/2005	6.96	11.45	19.7		**0.293**	1.8	**0.29**
MONO_WQ_#07D	6/9/2005	6.78	10.4	26.6		0.183		**0.68**
MONO_WQ_#07D	7/12/2005	6.83	**3.58**	24.9		0.175	**2.4**	**0.22**
MONO_WQ_#07D	8/18/2005	6.68	**2.26**	25.1		0.225	1	**0.4**
MONO_WQ_#07D	4/26/2006	7.5		15.4		0.223		**0.3**
MONO_WQ_#07D	5/30/2006	6.5	**2.05**	23.9		0.234		**0.53**
MONO_WQ_#07D	7/17/2006	6.62	**2.54**	26.8		0.208		**0.26**
MONO_WQ_#07D	9/26/2006	7.26	**3.62**	16.9		**0.251**		**0.57**
MONO_WQ_#07D	5/10/2007	7.29	**4.76**	22.2		0.161	1.1	**0.29**
MONO_WQ_#07D	6/12/2007	**6.31**	**3.54**	25.1		0.207	0.5	**0.26**
MONO_WQ_#07D	7/10/2007	6.68	**4.83**	26.5		0.214	1.2	**0.17**
MONO_WQ_#07D	8/28/2007	**6.32**	**1.99**	21.8		0.096		
MONO_WQ_#07D	12/18/2007	**10.7**	9.65	2.3		**0.266**	**2.5**	**0.55**
MONO_WQ_#07D	1/30/2008	**8.95**	9.3	3		0.245	**3.6**	0.06
MONO_WQ_#07D	2/25/2008	6.52	8.36	6		**0.259**	**2.4**	**0.24**
MONO_WQ_#07D	3/11/2008	**6.34**	7.66	6.9		**0.262**	**3.2**	**0.24**
MONO_WQ_#07D	4/15/2008	**9.25**	7.12	15.8		**0.276**	**2.3**	**0.5**
MONO_WQ_#07D	5/5/2008	7.1	5.12	20.2		0.248	**2.6**	**0.3**
MONO_WQ_#07D	6/9/2008	**5.6**	**3.22**	28.5		**0.391**	0.8	
MONO_WQ_#07D	7/8/2008	6.93	**2.89**	27.3		**0.299**	1.6	**0.9**
MONO_WQ_#07D	12/9/2008	7.88	5.92	3.4		**0.279**	1.4	**0.7**
MONO_WQ_#08A	5/27/2004	**10.56**	8.5	20			**6.7**	**0.42**
MONO_WQ_#08A	6/24/2004	7.58	8.75	20		0.188	**3.7**	**0.2**
MONO_WQ_#08A	7/24/2004	7.56	8.44	20.2		0.187	**2.2**	**0.22**
MONO_WQ_#08A	8/26/2004	7.25	7.69	20.4		0.214	**2.8**	**0.61**
MONO_WQ_#08A	11/16/2004	7.49	12.3	6.8		**0.256**	1.1	0.11
MONO_WQ_#08A	5/9/2005	6.83	9.43	11.5		**0.353**	1.7	**0.15**
MONO_WQ_#08A	6/9/2005	6.9	5.2	21.4		0.199	0.3	**0.32**
MONO_WQ_#08A	7/12/2005	6.95	**1.09**	21		0.192		**0.19**
MONO_WQ_#08A	8/18/2005	6.61	**1.13**	20.6		0.215	0.3	**0.82**
MONO_WQ_#08A	4/26/2006	6.94		10.8		0.225	0.4	**0.15**
MONO_WQ_#08A	5/30/2006	7.27	6.62	20.4		0.238	0.2	**0.2**
MONO_WQ_#08A	7/17/2006	7.93	8.08	25.9		0.198	1	**0.88**
MONO_WQ_#08A	8/21/2006	6.93	6.88	20.4		0.240		**0.39**
MONO_WQ_#08A	9/26/2006	7.38	7.06	15.3		**0.266**		**0.46**
MONO_WQ_#08A	5/10/2007	6.79	5.89	20		0.176	1.4	0.03
MONO_WQ_#08A	6/12/2007	7.29	5.1	19.9		0.208	**2.1**	**0.46**
MONO_WQ_#08A	7/10/2007	7.3	**4.59**	23.7		0.225	**2.5**	**0.46**

Site	Date	pH	DO	Temp	ANC	Salinity	NO_3	PO_4
MONO data								
MONO_WQ_#08A	8/28/2007	7.36	**4.13**	21		0.243	0.8	**0.31**
MONO_WQ_#08A	9/26/2007	7.39	**3.8**	19.7		**0.264**	**2.3**	**0.17**
MONO_WQ_#08A	10/24/2007	7.23	**4.1**	19.3		**0.264**	**2.6**	**0.31**
MONO_WQ_#08A	11/28/2007	**10.53**	5.11	8		**0.297**	1	**0.13**
MONO_WQ_#08A	12/18/2007	8.5	8.1	6.5		**0.306**	0.8	**0.15**
MONO_WQ_#08A	1/30/2008	**8.57**	6.6	3.4		**0.290**	0.4	**0.16**
MONO_WQ_#08A	2/25/2008	**8.97**	6.67	7.4		**0.305**	1.8	0.07
MONO_WQ_#08A	3/11/2008	**5.63**	6.7	10.4		0.231	0.4	0.08
MONO_WQ_#08A	4/15/2008	7.66	6.01	12.7		**0.311**	1.8	**0.8**
MONO_WQ_#08A	5/5/2008	**6.1**	6.47	14.4		**0.330**	0.5	**0.2**
MONO_WQ_#08A	6/9/2008	**6.27**	**4.82**	22.4		**0.392**	1.3	**1**
MONO_WQ_#08A	7/8/2008	7.45	**3.52**	21.6		**0.341**	1.5	**0.7**
MONO_WQ_#08A	8/10/2008	**6.25**	**2.82**	20		**0.424**	0.9	**0.7**
MONO_WQ_#08A	9/8/2008	**5.85**	**2.02**	19.9		**0.335**	**4.4**	**0.7**
MONO_WQ_#08A	10/6/2008	7.4	**1.68**	15.4		**0.400**	**6.1**	**0.6**
MONO_WQ_#08A	11/3/2008	7.71	**4.3**	13.6		**0.358**	1.3	**0.6**
MONO_WQ_#08A	12/9/2008	7.52	**4.36**	2.6		**0.305**	1.7	**1**
MONO_WQ_#08B	5/27/2004	**10.56**	8.65	19.3			0.9	**0.24**
MONO_WQ_#08B	6/24/2004	**6.1**	**3.25**	22.1		0.181	**5.7**	**0.56**
MONO_WQ_#08B	7/24/2004	7.67	8.67	20.6		0.199	1.5	**0.25**
MONO_WQ_#08B	8/26/2004	7.14	7.21	21.1		0.206	1.7	**0.26**
MONO_WQ_#08B	11/16/2004	8.02	13.06	5.9		**0.262**	1.1	**0.14**
MONO_WQ_#08B	5/9/2005	7.46	10.47	16.7		**0.312**	1	**1.04**
MONO_WQ_#08B	6/9/2005	6.96	13.83	22.2		0.192	1.5	**0.22**
MONO_WQ_#08B	7/12/2005	7.1	**1.18**	21.1		0.194	0.2	**0.23**
MONO_WQ_#08B	8/18/2005	6.67	**2.22**	20.2		0.217		**1.4**
MONO_WQ_#08B	4/26/2006	7.45		11.7		0.219		0.1
MONO_WQ_#08B	5/30/2006	7.12	6.58	20.5		0.241	0.7	**0.28**
MONO_WQ_#08B	7/17/2006	8.03	7.68	27.3		0.184	0.6	**0.83**
MONO_WQ_#08B	8/21/2006	7.15	6.76	20.5		0.243		**0.38**
MONO_WQ_#08B	9/26/2006	7.39	7.56	13.5		**0.279**	0.6	**0.6**
MONO_WQ_#08B	5/10/2007	6.65	6.1	19.4		0.175	1.4	**0.21**
MONO_WQ_#08B	6/12/2007	6.96	5.14	19.8		0.209	**3.9**	**0.76**
MONO_WQ_#08B	7/10/2007	7.46	**4.14**	29.5		0.205	0.8	**0.37**
MONO_WQ_#08B	8/28/2007	7.32	**4.42**	20.3		0.248	1.4	**0.34**
MONO_WQ_#08B	9/26/2007	7.35	**4.48**	18.3		**0.273**	1	**0.34**
MONO_WQ_#08B	10/24/2007	7.31	**4.5**	18.5		**0.274**	1.8	**0.28**
MONO_WQ_#08B	11/28/2007	**9.58**	6.92	5		**0.320**	1.8	0.02
MONO_WQ_#08B	12/18/2007	**8.64**	9.89	2.3		**0.331**	1.5	0.06
MONO_WQ_#08B	1/30/2008	**10.58**	9.68	3.7		**0.290**	**2.6**	0.06
MONO_WQ_#08B	2/25/2008	8.42	8.21	4.9		**0.316**	0.8	0.02
MONO_WQ_#08B	3/11/2008	**6.4**	7.96	6.7		**0.264**	1.5	0.02
MONO_WQ_#08B	4/15/2008	**9.4**	8.32	8.5		**0.340**	1.7	**0.6**
MONO_WQ_#08B	5/5/2008	**6.3**	7.54	12.5		**0.349**	0.3	**0.4**

Site	Date	pH	DO	Temp	ANC	Salinity	NO_3	PO_4
				MONO data				
MONO_WQ_#08B	6/9/2008	6.82	**4.67**	22.1		**0.394**	**2.3**	**0.8**
MONO_WQ_#08B	7/8/2008	7.48	**4.01**	21.8		**0.344**	1	**0.3**
MONO_WQ_#08B	8/10/2008	6.91	**2.72**	19.4		**0.417**	0.7	**0.8**
MONO_WQ_#08B	9/8/2008	7.05	**1.55**	19.1		**0.341**	0.8	**0.7**
MONO_WQ_#08B	10/6/2008	7.54	7.62	13.4		**0.417**	1.2	**0.9**
MONO_WQ_#08B	11/3/2008	7.89	**4.97**	11.4		**0.355**	**3.4**	**0.5**
MONO_WQ_#08B	12/9/2008	8.45	6.15	2.4		**0.297**	**2.1**	**0.5**
MONO_WQ_#09A	5/27/2004	**10.56**	7.26	24.5			0.1	
MONO_WQ_#09A	6/24/2004	7.04	7.42	22.3		0.117	**3**	**0.67**
MONO_WQ_#09A	7/24/2004	7.07	6.61	22.6		0.161	0.5	**0.38**
MONO_WQ_#09A	8/26/2004	6.52	5.05	21.6		0.194	1.9	**0.17**
MONO_WQ_#09A	11/16/2004	6.93	11.03	10.3		0.171	**7.2**	0.08
MONO_WQ_#09A	5/9/2005	6.79	11.44	18.9		**0.384**		
MONO_WQ_#09A	6/9/2005	6.58	6.1	23.2		0.148		**0.62**
MONO_WQ_#09A	7/12/2005	6.62	**1.98**	23.5		0.144		**0.29**
MONO_WQ_#09A	8/18/2005	**6.42**	**1.67**	23.2		0.181	1.6	**0.54**
MONO_WQ_#09A	4/26/2006	7.15		13.9		0.125	0.4	**0.64**
MONO_WQ_#09A	5/30/2006	**6.19**	**4.01**	22.3		0.204		**0.32**
MONO_WQ_#09A	7/17/2006	6.6	**3.4**	23.2		0.188		**0.49**
MONO_WQ_#09A	9/26/2006	7.03	6.26	16.4		**0.265**	**2**	**0.52**
MONO_WQ_#09A	5/10/2007	**6.29**	5.86	21.7		0.098	**3.2**	0.08
MONO_WQ_#09A	6/12/2007	**6.14**	**3.52**	21.9		0.169	1.5	**0.55**
MONO_WQ_#09A	7/10/2007	6.76	**1.74**	27.2		**0.280**	0.3	**1.35**
MONO_WQ_#09A	8/28/2007	**6.28**	**2.53**	21.2		**0.323**	0.8	**0.44**
MONO_WQ_#09A	11/28/2007	8.13	**3.52**	5.8		**0.332**	1.9	**0.34**
MONO_WQ_#09A	12/18/2007	**9.23**	10.54	2.2		0.214	**5.3**	0.04
MONO_WQ_#09A	1/30/2008	**10.5**	8.89	3.3		0.222	1.6	0.11
MONO_WQ_#09A	2/25/2008	7.52	9.37	4.7		0.178	**3.6**	0.03
MONO_WQ_#09A	3/11/2008	6.85	8.82	5.4		0.174	**3.4**	0.02
MONO_WQ_#09A	4/15/2008	**8.56**	7.1	12.4		0.208	**3.7**	**0.4**
MONO_WQ_#09A	5/5/2008	6.89	6.65	15.2		0.171	1.4	**0.5**
MONO_WQ_#09A	6/9/2008	**6.47**	**4.07**	24.3		0.226	0.6	**2**
MONO_WQ_#09A	7/8/2008	6.5	**3.38**	23.1		**0.258**	1.5	**0.9**
MONO_WQ_#09A	8/10/2008	6.72	**2.23**	19		**0.463**	0.1	**0.8**
MONO_WQ_#09A	10/6/2008	6.66	**3.07**	13.4		**0.507**	0.02	0.02
MONO_WQ_#09A	11/3/2008	7.07	**4.69**	11.1		**0.426**	0.9	**0.5**
MONO_WQ_#09A	12/9/2008	**10.13**	6.95	2.6		0.224	1.3	**0.6**
MONO_WQ_#09B	5/27/2004	**10.56**	8.22	20.8			**3.5**	
MONO_WQ_#09B	6/24/2004	7.74	9.29	20		0.249	**3.8**	**0.77**
MONO_WQ_#09B	7/24/2004	7.77	8.47	21.3		0.245		**0.14**
MONO_WQ_#09B	8/26/2004	7.23	6.21	21.5		**0.261**	**4.3**	**0.51**
MONO_WQ_#09B	11/16/2004	7.66	13.16	7.9		**0.310**	**3.2**	**0.74**
MONO_WQ_#09B	5/9/2005	7.27	10.86	16.1		**0.323**	1.8	**0.2**
MONO_WQ_#09B	6/9/2005	7.41	8.83	22.9		**0.279**		**0.6**

Site	Date	pH	DO	Temp	ANC	Salinity	NO_3	PO_4
				MONO data				
MONO_WQ_#09B	7/12/2005	7.22	**1.34**	21.2		**0.252**	0.4	**0.44**
MONO_WQ_#09B	8/18/2005	7.01	**1.95**	20.6		**0.291**	**3.8**	**0.5**
MONO_WQ_#09B	4/26/2006	**8.6**		11.7		**0.266**	**3.9**	**0.4**
MONO_WQ_#09B	5/30/2006	7.31	7.4	21.3		**0.286**	1.4	**0.14**
MONO_WQ_#09B	7/17/2006	7.73	7.75	27.3		**0.251**		**1.01**
MONO_WQ_#09B	9/26/2006	7.17	7.06	15.1		**0.276**	**2.5**	**0.9**
MONO_WQ_#09B	5/10/2007	7	6.58	19.3		0.212	0.8	**0.43**
MONO_WQ_#09B	6/12/2007	6.84	**4.8**	21		**0.274**	**2**	**0.17**
MONO_WQ_#09B	8/28/2007	7.22	**4.4**	21.4		**0.352**	**2.5**	**0.52**
MONO_WQ_#09B	11/28/2007	**8.93**	6.88	4.7		**0.424**	1.4	**0.46**
MONO_WQ_#09B	12/18/2007	8.11	10.75	1.1		**0.432**	**4.2**	
MONO_WQ_#09B	1/30/2008	**11.58**	9.63	3.5		**0.413**	1.2	**0.14**
MONO_WQ_#09B	2/25/2008	7.56	9.15	4.4		**0.373**	0.3	0.1
MONO_WQ_#09B	3/11/2008	6.97	8.73	4.9		**0.356**	**4**	**0.15**
MONO_WQ_#09B	4/15/2008	**9.27**	7.98	8.6		**0.372**	**2.2**	**0.6**
MONO_WQ_#09B	5/5/2008	**8.7**	7.49	11.9		**0.362**	1.1	**0.2**
MONO_WQ_#09B	6/9/2008	7.06	**4.14**	23.2		**0.443**	1.7	**1.8**
MONO_WQ_#09B	7/8/2008	7.48	**3.68**	22.3		**0.455**	0.8	**1**
MONO_WQ_#09B	8/10/2008	7.29	**2.67**	19.1		**0.550**	1.3	**0.8**
MONO_WQ_#09B	9/8/2008	7.3	**1.16**	19.6		**0.463**	0.6	**1**
MONO_WQ_#09B	10/6/2008	7.57	6.82	12.4		**0.524**	0.02	**0.6**
MONO_WQ_#09B	11/3/2008	7.94	5.27	10.6		**0.495**	1.6	**0.6**
MONO_WQ_#09B	12/9/2008	**10.85**	6.93	2.1		**0.370**	**2.9**	**0.4**
Mean		7.33	6.35	16.04	1594	0.23	2.95	0.49
Std error		0.06	0.16	0.36	82.8	0.00	0.13	0.03

Table A-3. Benthic Index of Biotic Integrity. Values that do not meet the threshold (<3.0) are in bold. Site locations are shown in Figure 3.8.

Site name	BIBI
NCRW-115-N-2004	**2.00**
NCRW-217-N-2004	**1.50**
NCRW-316-N-2004	**2.25**
MONY-101-N-2004	**1.00**
MONY-102-N-2004	**2.50**
MONY-103-N-2004	**1.38**
MONY-201-N-2004	**2.00**
MONY-301-N-2004	**2.75**
Mean	1.92
Std error	0.21

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-115-N-2004	**73.11**
NCRW-217-N-2004	**58.81**
NCRW-316-N-2004	**78.97**
MONY-101-N-2004	**35.47**
MONY-102-N-2004	**56.56**
MONY-103-N-2004	**30.76**
MONY-201-N-2004	**75.87**
MONY-301-N-2004	**74.12**
Mean	60.46
Std error	6.62

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 (%)
MONO-0044	2006	20
MONO-0106	2008	10
Mean		15.0
Std error		5.0

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		
MONO-0044	2006	0	0	
MONO-0106	2008	0	0	
		Trees		
MONO-0044	2006	814.3	14784.3	**5.5**
MONO-0106	2008	0	23932	0
Mean				2.75
Std error				2.75

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 (%)
MONO-0044	2006	**16**
MONO-0106	2008	3
Mean		9.5
Std error		6.5

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
MONO-0044	2006	13333	**13333**
MONO-0106	2008	8333	**8333**
Mean			10833
Std error			2500

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-115-N-2004	2004	**2.67**
NCRW-217-N-2004	2004	3.67
NCRW-316-N-2004	2004	4.67
MONY-101-N-2004	2004	3.67
MONY-102-N-2004	2004	**2.33**
MONY-103-N-2004	2004	**1.00**
MONY-201-N-2004	2004	3.67
MONY-301-N-2004	2004	4.67
Mean		3.29
Std error		0.44

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			
Dendroica caerulescens	Black-throated blue warbler	✓	—	
Dryocopus pileatus	Pileated woodpecker	✓	—	
Empidonax virescens	Acadian flycatcher	✓	✓	
Parula americana	Northern parula	✓	✓	
Setophaga ruticilla	American redstart	✓	—	
Number of species		5	2	
Mean				3.5
Std error				1.5
	Sensitive			
Hylocichla mustelina	Wood thrush	✓	✓	
Picoides villosus	Hairy woodpecker	✓	—	
Piranga olivacea	Scarlet tanager	✓	—	
Seiurus aurocapillus	Ovenbird	✓	—	
Vireo olivaceus	Red-eyed vireo	✓	✓	
Number of species		5	2	
Mean				3.5
Std error				1.5

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

Species	Common name	Functional group			
		1	2	3	4
Ammodramus savannarum	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	**58.8**	48.60	71.14
2002	**46.76**	35.34	61.88
2003	**63.53**	47.17	85.67
2004	**71.57**	63.56	80.58
2005	**58.52**	49.21	69.59
2006	**48.64**	31.30	75.57
2007	**70.99**	31.30	161.00
2008	**77.26**	37.78	158.02
Mean	62.01		
Std error	3.87		

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

Scientific name	Common name/s	Status
	Vascular plants	
Abutilon theophrasti	butterprint, buttonweed, Indian mallow, velvetleaf, velvetleaf (or butter-print), velvetleaf Indian mallow	Non-Native
Acalypha rhomboidea	Virginia threeseed mercury	Native
Acer negundo	ashleaf maple, box elder, boxelder, boxelder maple, california boxelder, manitoba maple, western boxelder	Native
Acer platanoides	Norway maple	Non-Native
Acer rubrum	red maple	Native
Acer saccharinum	silver maple	Native
Acer saccharum	sugar maple	Native
Adiantum pedatum	maidenfern, maidenhair, maidenhair fern, northern maidenhair	Native
Aesculus hippocastanum		Non-Native
Aesculus sylvatica	oainted buckeye, painted buckeye	Native
Ageratina altissima var. altissima	white snakeroot	Native
Agrimonia gryposepala	agrimony, tall hairy agrimony, tall hairy grooveburr	Native
Agrimonia pubescens	groovebur, roadside agrimony, soft agrimony, soft groovebur	Native
Agrostis gigantea	black bent, redtop, water bentgrass	Non-Native
Agrostis perennans	autumm bentgrass, upland bent, upland bentgrass	Native
Agrostis stolonifera		Native
Ailanthus altissima	ailanthus, copal tree, tree of heaven, tree-of-heaven	Non-Native
Albizia julibrissin	mimosa, mimosa tree, powderpuff tree, silk tree, silktree	Non-Native
Alisma subcordatum	American water plantain, waterplaintain	Native
Alliaria petiolata	garlic mustard, garlic-mustard	Non-Native
Allium canadense	Canada garlic, meadow garlic, meadow onion, wild onion	Native
Allium tricoccum	ramp, small white leek, wild leek	Native
Allium vineale	wild garlic	Non-Native
Amaranthus hybridus	green pigweed, slim amaranth, smooth amaranth, smooth pigweed	Native
Amaranthus retroflexus	careless weed, Pigweed, red-root amaranth, redroot amaranth, redroot pigweed, rough pigweed	Non-Native
Amaranthus spinosus		Native
Ambrosia artemisiifolia	annual ragweed, common ragweed, low ragweed, ragweed, Roman wormwood, short ragweed, small ragweed	Native
Ambrosia trifida		Native
Amelanchier arborea	allegheny serviceberry, apple shadbush, common serviceberry, downy serviceberry, serviceberry, shadblow	Native
Amphicarpaea bracteata	American hogpeanut, hog-peanut	Native
Anagallis arvensis	pimpernel, scarlet pimpernel	Non-Native
Anemone virginiana	tall thimbleweed, Virginia anemone	Native
Anemonella thalictroides		Native
Antennaria plantaginifolia	plantainleaf pussytoes, woman's tobacco	Native
Anthemis cotula	chamomile, dog fennel, dogfennel, mayweed, mayweed chamomile, mayweed dogfennel, stinking chamomile, stinkweed	Non-Native
Apium graveolens	wild celery	Non-Native
Aplectrum hyemale	Adam and Eve, puttyroot	Native

Scientific name	Common name/s	Status
Vascular plants		
Apocynum cannabinum	common dogbane, dogbane, hemp dogbane, Indian hemp, Indian-hemp, Indianhemp, prairie dogbane	Native
Arabis laevigata	smooth rock-cress, smooth rockcress	Native
Arabis lyrata	lyrate rockcress	Native
Arabis shortii	Short's rockcress	Native
Arctium minus	bardane, beggar's button, burdock, common burdock, lesser burdock, lesser burrdock, small burdock, smaller burdock, wild burdock, wild rhubarb	Non-Native
Arisaema triphyllum	Indian jack in the pulpit, Jack in the pulpit, Jack-in-the-pulpit	Native
Artemisia biennis	biennial sagewort, biennial wormwood	Non-Native
Artemisia vulgaris	common wormwood, mugwort	Non-Native
Arthraxon hispidus	hairy jointgrass, small carpgrass	Non-Native
Asarum canadense	Canadian wild ginger, Canadian wildginger	Native
Asclepias incarnata	rose milkweed, swamp milkweed	Native
Asclepias syriaca	broadleaf milkweed, common milkweed	Native
Asclepias tuberosa	butterfly milkweed, butterflyweed	Native
Asimina triloba	pawpaw	Native
Asplenium montanum	mountain spleenwort	Native
Asplenium platyneuron	ebony spleenwort	Native
Asplenium rhizophyllum	walking fern	Native
Aster dumosus	rice button aster	Native
Aster simplex		Native
Athyrium filix-femina	common ladyfern, lady fern, ladyfern, subarctic lady fern	Native
Avena sativa	common oat, Common oats, oat, oatgrass (common), oats, wild oats	Non-Native
Barbarea vulgaris	garden yellow rocket, garden yellow-rocket, garden yellowrocket, winter cress, yellow rocket	Non-Native
Berberis thunbergii	Japanese barberry	Non-Native
Betula lenta	sweet birch	Native
Betula nigra	river birch	Native
Bidens bipinnata	Spanish needles, spanish-needles	Native
Bidens coronata	crowned beggarticks	Native
Bidens frondosa	bur marigold, devil's beggartick, devil's beggarticks, devil's bootjack, devil's-pitchfork, devils beggartick, pitchfork weed, sticktight, sticktights, tickseed sunflower	Native
Bidens pilosa	beggar's tick, cobbler's pegs, fisi'uli, hairy beggarticks, kofe tonga, mata-karo, Spanish needle, Spanish needles	Non-Native
Boehmeria cylindrica	small-spike false nettle, smallspike false nettle, smallspike falsenettle	Native
Botrychium biternatum	sparselobe grapefern	Native
Botrychium dissectum	cut-leaf grape fern, cutleaf grapefern	Native
Botrychium multifidum	broadleaf grapefern, leathery grape fern, leathery grapefern	Native
Botrychium virginianum	rattlesnake fern	Native
Brassica nigra	black mustard, shortpod mustard	Non-Native
Brassica rapa	bird's rape, birdsrape mustard, field mustard, rape, rape mustard, turnip rape, wild mustard, wild rutabaga, wild turnip	Non-Native
Bromus catharticus	rescue brome, rescue grass, rescuegras, rescuegrass	Non-Native
Bromus ciliatus	fringed brome	Native

Scientific name	Common name/s	Status
Vascular plants		
Bromus commutatus	hairy brome, hairy chess, meadow brome	Non-Native
Bromus inermis	awnless brome, smooth brome	Non-Native
Bromus pubescens	hairy wood brome grass, hairy woodland brome	Native
Bromus sterilis	barren bromegrass, poverty brome, sterile brome	Non-Native
Bromus tectorum	cheat grass, cheatgrass, downy brome, early chess, military grass, wild oats	Non-Native
Calystegia sepium ssp. sepium	hedge false bindweed	Non-Native
Campsis radicans	common trumpetcreeper, cow-itch, trumpet creeper	Native
Capsella bursa-pastoris	shepardspurse, shepherd's purse, shepherd's-purse, shepherdspurse	Non-Native
Cardamine bulbosa	bulb bittercress, bulbous bitter-cress, bulbous bittercress	Native
Cardamine concatenata	cutleaf toothwort	Native
Carduus acanthoides	plumeless thistle, spiny plumeless thistle, spiny plumeless-thistle	Non-Native
Carduus nutans	chardon penche, musk thistle, nodding plumeless thistle, nodding plumeless-thistle, nodding thistle, plumeless thistle	Non-Native
Carex abscondita	thicket sedge	Native
Carex albicans var. albicans	whitetinge sedge	Native
Carex amphibola	amphibious sedge, eastern narrowleaf sedge	Native
Carex annectens	yellowfruit sedge	Native
Carex argyrantha	hay sedge	Native
Carex blanda	bland sedge, eastern woodland sedge, woodland sedge	Native
Carex caroliniana	Carolina sedge	Native
Carex cephalophora	oval-leaf sedge, oval-leaved sedge, ovalleaf sedge	Native
Carex conjuncta	soft fox sedge	Native
Carex digitalis	slender wood sedge, slender woodland sedge	Native
Carex frankii	Frank's sedge	Native
Carex glaucodea	blue sedge	Native
Carex grayi	Gray's sedge	Native
Carex grisea		Native
Carex hirsutella	fuzzy wuzzy sedge, hirsute sedge	Native
Carex intumescens	greater bladder sedge	Native
Carex jamesii	James' sedge	Native
Carex laevivaginata	smoothsheath sedge, wooly sedge	Native
Carex laxiculmis	spreading sedge	Native
Carex laxiflora	broad looseflower sedge	Native
Carex lurida	shallow sedge	Native
Carex molesta	troublesome sedge	Native
Carex normalis	greater straw sedge	Native
Carex oligocarpa	eastern few-fruit sedge, richwoods sedge	Native
Carex platyphylla	broad-leaved sedge, broadleaf sedge	Native
Carex radiata	eastern star sedge	Native
Carex rosea	rosy sedge	Native
Carex swanii	swan sedge, Swan's sedge	Native
Carex tonsa var. rugosperma	parachute sedge	Native
Carex tribuloides	blunt broom sedge	Native

Scientific name	Common name/s	Status
Vascular plants		
Carex virescens	ribbed sedge	Native
Carex vulpinoidea	common fox sedge, fox sedge	Native
Carex willdenowii	Willdenow's sedge	Native
Carpinus caroliniana	American hornbeam, american hornbean	Native
Carya alba	mockernut hickory	Native
Carya cordiformis	bitternut hickory	Native
Carya glabra	pignut hickory	Native
Carya ovata	carya ovata australis, shag-bark hickory, shagbark hickory	Native
Castanea dentata	American chestnut	Native
Catalpa bignonioides	southern catalpa	Native
Catalpa speciosa	northern catalpa	Native
Caulophyllum thalictroides	blue cohosh	Native
Celastrus orbiculatus	Asian bittersweet, Asiatic bittersweet, oriental bittersweet	Non-Native
Celtis occidentalis	common hackberry, hackberry, western hackberry	Native
Centaurea maculosa	spotted knapweed	Non-Native
Cephalanthus occidentalis	buttonbush, common buttonbush	Native
Cerastium fontanum ssp. vulgare	big chickweed, common mouse-ear chickweed	Non-Native
Cerastium vulgatum	big chickweed, mouseear chickweed	Non-Native
Cercis canadensis	eastern redbud, Redbud	Native
Chaerophyllum procumbens	spreading chervil	Native
Chamaesyce maculata	large spurge, spotted sandmat, spotted spurge	Native
Chelidonium majus	celandine	Non-Native
Chelone glabra	white turtlehead	Native
Chenopodium album	common lambsquarters, lambsquarters, lambsquarters goosefoot, white goosefoot	Non-Native
Chenopodium ambrosioides	Mexican tea, Mexican-tea	Non-Native
Chimaphila maculata	striped prince's pine, striped prince's-pine	Native
Cichorium intybus	blue sailors, chicory, coffeeweed, Common chicory, succory	Non-Native
Cicuta bulbifera	bulb waterhemlock, bulblet-bearing water hemlock, bulblet-bearing water-hemlock	Native
Cimicifuga racemosa	black bugbane	Native
Cinna arundinacea	stout wood reed-grass, stout woodreed, sweet wood-reed, sweet wood-reed	Native
Circaea canadensis		Native
Circaea lutetiana ssp. canadensis	broad-leaf enchanter's-nightshade, broadleaf enchanter's nightshade	Native
Circaea quadrisulcata		Native
Cirsium arvense	Californian thistle, Canada thistle, Canadian thistle, creeping thistle, field thistle	Non-Native
Cirsium vulgare	bull thistle, common thistle, spear thistle	Non-Native
Claytonia virginica	narrow-leaved spring beauty, Spring beauty, Virginia springbeauty	Native
Clematis virginiana	devil's darning needles, devil's-darning-needles, virgin's bower, Virginia bower	Native
Collinsonia canadensis	richweed	Native
Commelina communis	Asiatic dayflower, common dayflower	Non-Native

Scientific name	Common name/s	Status
Vascular plants		
Conium maculatum	cigue maculee, cigue tachetee, deadly hemlock, poison hemlock, poison parsley, poison-hemlock	Non-Native
Conoclinium coelestinum	blue mistflower	Native
Conopholis americana	American squawroot, squaw-root	Native
Conyza canadensis	Canada horseweed, Canadian horseweed, horseweed, horseweed flea-bane, mares tail, marestail	Native
Cornus amomum	silky dogwood	Native
Cornus florida	flowering dogwood	Native
Cornus rugosa	round-leaf dogwood, roundleaf dogwood	Native
Coronilla varia	crownvetch, purple crown-vetch, purple crownvetch, Varia crownvetch	Non-Native
Corydalis flavula	pale corydalis, yellow fumewort	Native
Cruciata pedemontana	piedmont bedstraw	Non-Native
Cryptotaenia canadensis	Canadian honewort, honewort	Native
Cuphea viscosissima	blue waxweed	Native
Cuscuta gronovii	scaldweed	Native
Cynanchum laeve	climbing milkweed, honeyvine, honeyvine milkweed, sandvine	Native
Cynodon dactylon	Bermudagrass, chiendent pied-de-poule, common bermudagrass, devil-grass, grama-seda, manienie, motie molulu	Non-Native
Cyperus strigosus	stawcolored flatsedge, strawcolor flatsedge, strawcolor nutgrass, straw-colored flatsedge, strawcolored nutgrass	Native
Dactylis glomerata	cocksfoot, orchard grass, orchardgrass	Non-Native
Danthonia spicata	poverty danthonia, poverty oatgrass, poverty wild oat grass	Native
Datura stramonium	Jamestown weed, jimsonweed, mad apple, moonflower, stinkwort, thorn apple	Non-Native
Daucus carota	bird's nest, Queen Anne's lace, wild carrot	Non-Native
Delphinium tricorne	dwarf larkspur, rock larkspur	Native
Delphinium virescens	Carolina larkspur, plains larkspur, prairie larkspur	Unknown
Dennstaedtia punctilobula	eastern hayscented fern	Native
Dentaria laciniata		Native
Desmodium canescens	hoary tickclover, hoary ticktrefoil	Native
Desmodium nudiflorum	bare-stemmed tick-treefoil, barestem tickclover, nakedflower ticktrefoil	Native
Desmodium perplexum	perplexed ticktrefoil	Native
Dianthus armeria	Deptford pink, Deptford's pink	Non-Native
Dicentra canadensis	squirrel corn	Native
Dicentra cucullaria	dutchman's breeches, Dutchman's-breeches, Dutchmans breeches, dutchmans britches	Native
Dichanthelium boscii	Bosc's panicgrass	Native
Dichanthelium depauperatum	starved panicgrass	Native
Dichanthelium dichotomum var. dichotomum	cypress panicgrass	Native
Digitaria filiformis	slender crabgrass	Native
Dioscorea quaternata	fourleaf yam	Native
Diospyros virginiana	common persimmon, eastern persimmon, Persimmon	Native
Dipsacus fullonum ssp. sylvestris	common teasel, Fuller's teasel, teasel	Non-Native
Dipsacus sylvestris	common teasel, Fuller's teasel	Non-Native
Dryopteris carthusiana	spinulose wood fern, spinulose woodfern	Native

Scientific name	Common name/s	Status
Vascular plants		
Dryopteris intermedia	intermediate woodfern	Native
Dryopteris marginalis	marginal woodfern, woodfern	Native
Dryopteris spinulosa		Native
Duchesnea indica	India mockstrawberry, Indian strawberry	Non-Native
Echinochloa crus-galli	barnyard grass, barnyardgrass, cockspur, Japanese millet, large barnyard grass, watergrass	Non-Native
Eclipta prostrata	eclipta, false daisy, yerba de tago, yerba de tajo	Native
Elaeagnus umbellata	autumn olive, oleaster	Non-Native
Eleocharis ovata	ovate spikerush, ovoid spike-rush, ovoid spikerush	Native
Eleusine indica	crowsfoot grass, goose grass, goosegrass, Indian goose grass, Indian goosegrass, manienie ali'I, silver crabgrass, wiregrass	Non-Native
Elymus hystrix var. hystrix	eastern bottle-brush grass, eastern bottlebrush grass	Native
Elymus repens	quackgrass	Non-Native
Elymus riparius	river wild-rye, riverbank wildrye	Native
Elymus villosus	hairy wild rye, hairy wildrye, slender wild-rye	Native
Elymus virginicus	Virginia wild rye, Virginia wildrye	Native
Elymus wiegandii	Wiegand's wildrye	Native
Epifagus virginiana	beechdrops	Native
Erigenia bulbosa	harbinger of spring	Native
Erigeron annuus	annual fleabane, eastern daisy fleabane	Native
Erigeron philadelphicus	Philadelphia daisy, Philadelphia fleabane	Native
Erigeron pulchellus	poor robin fleabane, robin's plantain	Native
Erythronium americanum	dogtooth violet	Native
Eupatorium fistulosum	Joe Pye weed, trumpetweed	Native
Eupatorium perfoliatum	bonset, common boneset	Native
Eurybia divaricata	white wood aster	Native
Eurybia macrophylla	bigleaf aster	Native
Fagus grandifolia	American beech	Native
Festuca rubra	ravine fescue, red fescue	Native
Festuca subverticillata	nodding fescue	Native
Floerkea proserpinacoides	false mermaid-weed, false mermaidweed, falsemermaid	Native
Forsythia viridissima	greenstem forsythia	Non-Native
Fraxinus americana	white ash	Native
Fraxinus pennsylvanica	green ash	Native
Fraxinus pennsylvanica var. subintegerrima		Native
Galactia volubilis	downy milkpea	Native
Galearis spectabilis	showy orchid, showy orchis	Native
Galinsoga parviflora	gallant soldier, gallant-soldier, gallantsoldier, littleflower quickweed	Non-Native
Galinsoga quadriradiata	fringed quickweed, hairy galinsoga, shaggy soldier, shaggy-soldier	Non-Native
Galium aparine	bedstraw, catchweed bedstraw, cleavers, cleaverwort, goose grass, scarthgrass, sticky-willy, stickywilly, white hedge	Native
Galium asprellum	rough bedstraw	Native
Galium circaezans	licorice bedstraw, wild licorice, woods bedstraw	Native
Galium concinnum	shining bedstraw	Native

Scientific name	Common name/s	Status
Vascular plants		
Galium mollugo	false baby's breath	Non-Native
Galium tinctorium	dye bedstraw, stiff marsh bedstraw	Native
Galium triflorum	fragrant bedstraw, sweet bedstraw, sweetscented bedstraw	Native
Gaylussacia baccata	black huckleberry	Native
Geranium maculatum	spotted crane's-bill, spotted geranium, wild crane's-bill	Native
Geranium pusillum	small geranium, small-flower crane's-bill	Non-Native
Geum canadense	white avens	Native
Geum macrophyllum	large-leaf avens, largeleaf avens	Native
Glechoma hederacea	creeping charlie, gill-over-the-ground, ground ivy, groundivy, haymaids	Non-Native
Gleditsia triacanthos	common honeylocust, Honey locust, honey-locust, honeylocust, honey-locusts	Native
Glyceria striata	fowl manna grass, fowl mannagrass	Native
Goodyera pubescens	downy rattlesnake plantain, downy rattlesnake-plantain	Native
Gymnocladus dioicus	Kentucky coffeetree, Kentucy coffeetree	Native
Hackelia virginiana	beggar's-lice, beggarslice, sticktight, virginia stickseed	Native
Hamamelis virginiana	American witchhazel, witch-hazel, witchhazel	Native
Hedeoma pulegioides	American false pennyroyal	Native
Hedera helix	English ivy	Non-Native
Helenium autumnale	bitterweed, common sneezeweed, fall sneezeweed, false sunflower	Native
Helianthus decapetalus	thinleaf sunflower	Native
Hemerocallis fulva	orange day lily, orange daylily, tawny daylily	Non-Native
Hepatica americana		Native
Hepatica nobilis var. obtusa	roundlobe hepatica	Native
Hesperis matronalis	dame rocket, dame's rocket, dames rocket, dames violet, mother-of-the-evening	Non-Native
Heuchera americana	alumroot, American alumroot	Native
Hibiscus syriacus	althea, rose of Sharon, rose-of-sharon, shrub althea, shrub-althea	Non-Native
Hieracium scabrum	rough hawkweed	Native
Hieracium venosum	rattlesnakeweed	Native
Houstonia longifolia	long-leaf summer bluet, longleaf bluet, longleaf summer bluet	Native
Humulus japonicus	Japanese hop	Non-Native
Hydrangea arborescens	smooth hydrangea, wild hydrangea	Native
Hydrophyllum virginianum	Shawnee salad, Shawnee-salad	Native
Hylotelephium telephioides	Allegheny stonecrop	Native
Hypericum canadense	lesser Canadian St. Johnswort	Native
Hypericum perforatum	common St Johnswort, common St. John's wort, common St. Johnswort, Klamath weed, Klamathweed, St. John's wort, St. Johnswort	Non-Native
Hypericum punctatum	spotted St. Johnswort	Native
Hypoxis hirsuta	common goldstar, eastern yellow star-grass	Native
Ilex aquifolium	English holly	Non-Native
Impatiens capensis	jewelweed, spotted touch-me-not	Native
Impatiens pallida	pale snapweed, pale touch-me-not	Native
Ipomoea hederacea	entireleaf morningglory, ivy-leaf mornin-glory, ivyleaf morning-glory, ivyleaf morningglory, ivyleaf morninglory, Mexican morningglory	Non-Native
Ipomoea lacunosa	pitted morningglory, white morninglory, whitestar	Native

Scientific name	Common name/s	Status
	Vascular plants	
Ipomoea purpurea	common morning-glory, common morningglory, common morninglory, tall morning-glory, tall morningglory	Non-Native
Juglans cinerea	butternut	Native
Juglans nigra	black walnut	Native
Juncus effusus	common rush, lamp rush	Native
Juncus tenuis	field rush, path rush, poverty rush, slender rush, slender yard rush, wire-grass	Native
Juniperus virginiana	eastern red-cedar, eastern redcedar, red cedar juniper	Native
Justicia americana	American water-willow, common water-willow, spike justica	Native
Kalmia latifolia	mountain laurel	Native
Lactuca biennis	tall blue lettuce, wild blue lettuce	Native
Lactuca floridana	Florida lettuce, woodland lettuce	Native
Lactuca serriola	China lettuce, prickly lettuce, wild lettuce	Non-Native
Lamium purpureum	purple deadnettle, red deadnettle	Non-Native
Laportea canadensis	Canada lettuce, Canada woodnettle, Canadian wood-nettle, Canadian woodnettle	Native
Leersia oryzoides	rice cut grass, rice cutgrass	Native
Leonurus cardiaca	common motherwort, motherwort	Non-Native
Lepidium campestre	cream-anther field pepperwort, field pepperweed	Non-Native
Lespedeza virginica	slender lespedeza	Native
Ligustrum vulgare	European privet, wild privet	Non-Native
Linaria vulgaris	butter and eggs, butterandeggs, flaxweed, greater butter-and-eggs, Jacob's ladder, ramsted, wild snapdragon, yellow toadflax	Non-Native
Lindera benzoin	northern spicebush, spicebush	Native
Lindernia dubia	moistbank pimpernel, shortstalk lindernia, yellow-seed false pimpernel, yellowseed false pimpernel	Native
Liriodendron tulipifera	tulip poplar, tuliptree, yellow poplar, yellow-poplar	Native
Lobelia cardinalis	Cardinal flower, cardinalflower	Native
Lobelia inflata	Indian tobacco, Indian-tobacco	Native
Lobelia siphilitica	great blue lobelia	Native
Lobelia spicata	pale-spike lobelia, pale-spiked lobelia, palespike lobelia	Native
Lolium perenne	italian ryegrass, perennial rye grass, perennial ryegrass	Non-Native
Lolium pratense	meadow fescue, meadow ryegrass	Non-Native
Lonicera japonica	Chinese honeysuckle, Japanese honeysuckle	Non-Native
Lonicera maackii	Amur honeysuckle, Amur honeysuckle bush	Non-Native
Lonicera morrowii	Morrow's honeysuckle	Non-Native
Ludwigia alternifolia	bushy seedbox, seedbox	Native
Ludwigia palustris	marsh primrose-willow, marsh seedbox	Native
Luzula multiflora	common wood-rush, common woodrush	Native
Lychnis alba	white cockle	Native
Lycopus americanus	American bugleweed, American water horehound, American waterhore-hound, cut-leaf water-horehound, water horehound, waterhorehound	Native
Lycopus virginicus	Virginia bugleweed, virginia bugleweed, Virginia water horehound	Native
Lysimachia ciliata	fringed loosestrife, fringed yellow-loosestrife	Native
Lysimachia nummularia	creeping jenny, moneywort	Non-Native

Scientific name	Common name/s	Status
Vascular plants		
Maclura pomifera	bois d'arc, osage orange, osage-orange, osageorange	Native
Magnolia X soulangiana	Chinese magnolia	Non-Native
Maianthemum racemosum ssp. racemosum	false Solomon's-seal, feather Solomons seal, feathery false lily of the vally, feathery false Solomon's-seal	Native
Malus sylvestris	European crabapple	Non-Native
Malva neglecta	buttonweed, cheeseplant, cheeseweed, common mallow, dwarf mallow, roundleaf mallow	Non-Native
Matricaria discoidea	disc mayweed, pineapple weed, pineappleweed	Non-Native
Medeola virginiana	Indian cucumber	Native
Medicago lupulina	black medic, black medic clover, black medick, hop clover, hop medic, nonesuch, yellow trefoil	Non-Native
Melilotus alba	white sweetclover	Non-Native
Melilotus officinalis	yellow sweet-clover, yellow sweetclover	Non-Native
Menispermum canadense	Canadian moonseed, common moonseed	Native
Mentha X piperita	peppermint	Non-Native
Mertensia virginica	Virginia bluebells	Native
Microstegium vimineum	Japanese stiltgrass, Nepalese browntop	Non-Native
Mimulus alatus	sharpwing monkeyflower	Native
Mimulus ringens	Allegheny monkey-flower, Allegheny monkeyflower, ringen monkey-flower	Native
Mitchella repens	partridgeberry	Native
Mollugo verticillata	carpetweed, green carpetweed	Native
Monarda fistulosa	wildbergamot beebalm	Native
Monotropa uniflora	Indianpipe, one-flower Indian-pipe	Native
Morus alba	mulberry, white mulberry	Non-Native
Morus rubra	red mulberry	Native
Muhlenbergia frondosa	wire-stem muhly, wirestem muhly	Native
Muhlenbergia schreberi	nimblewill, nimblewill muhly	Native
Nepeta cataria	catmint, catnip, catwort, field balm	Non-Native
Nyssa sylvatica	black gum, black tupelo, blackgum	Native
Oenothera biennis	common evening primrose, common evening-primrose, common eveningprimrose, evening primrose (common), hoary eveningprimrose, king's-cureall	Native
Onoclea sensibilis	sensitive fern	Native
Ornithogalum umbellatum	Pyrenees Star of Bethlehem, sleepydick, Star-of-Bethlehem	Non-Native
Osmorhiza claytonii	Clayton's sweetroot, hairy sweet-cicely	Native
Osmorhiza longistylis	aniseroot, longstyle sweetroot	Native
Ostrya virginiana	eastern hophornbeam, hophornbeam	Native
Oxalis grandis	great yellow woodsorrel	Native
Oxalis stricta	common yellow oxalis, erect woodsorrel, sheep sorrel, sourgrass, toad sorrel, upright yellow wood-sorrel, upright yellow woodsorrel, yellow woodsorrel	Native
Packera aurea	golden ragwort	Native
Panicum rigidulum var. pubescens	redtop panicgrass	Native
Parietaria pensylvanica	Pennsylvania pellitory	Native
Paronychia canadensis	smooth forked nailwort	Native

Scientific name	Common name/s	Status
Vascular plants		
Paronychia fastigiata	clusterstem nailwort, hairy forked nailwort	Native
Parthenocissus quinquefolia	American ivy, fiveleaved ivy, Virginia creeper, woodbine	Native
Paspalum dilatatum	dallas grass, dallis grass, dallisgrass, herbe de miel, herbe sirop, hiku nua, palpalum dilate, water grass	Non-Native
Paulownia tomentosa	princess tree, princesstree, royal paulownia	Non-Native
Pennisetum glaucum	pearl millet, pearl-millet, yellow bristlegrass	Non-Native
Perilla frutescens	beefsteak, beefsteak mint, beefsteakplant, Purple mint	Non-Native
Phalaris arundinacea	reed canary grass, reed canarygrass	Native
Phleum pratense	common timothy, timothy	Non-Native
Phlox divaricata	wild blue phlox	Native
Phlox paniculata	fall phlox	Native
Phryma leptostachya	American lopseed, lopseed	Native
Phyla lanceolata	frog fruit, lanceleaf fogfruit, lanceleaf frog fruit, northern fogfruit	Native
Physalis longifolia var. subglabrata	longleaf groundcherry	Native
Phytolacca americana	American pokeweed, common pokeweed, inkberry, pigeonberry, poke, pokeberry, pokeweed	Native
Picea abies	Norway spruce	Non-Native
Pilea pumila	Canada clearweed, Canadian clearweed	Native
Pinus rigida	pitch pine	Native
Pinus strobus	easter white pine, eastern white pine, northern white pine, soft pine, weymouth pine, white pine	Native
Pinus virginiana	jersey pine, scrub pine, Virginia pine	Native
Plantago lanceolata	buckhorn plantain, English plantain, lanceleaf Indianwheat, lanceleaf plantain, narrowleaf plantain, ribgrass, ribwort	Non-Native
Plantago major	broadleaf plantain, buckhorn plantain, common plantain, great plantain, rippleseed plantain	Native
Plantago rugelii	black-seed plantain, blackseed plantain, Rugel's plantain	Native
Platanus occidentalis	American sycamore, sycamore	Native
Poa annua	annual blue grass, annual bluegrass, walkgrass	Non-Native
Poa pratensis	Kentucky bluegrass	Non-Native
Poa sylvestris	woodland bluegrass	Native
Poa trivialis	rough bluegrass	Non-Native
Podophyllum peltatum	may apple, mayapple	Native
Polygonatum biflorum	king Solomon's seal, King Solomon's-seal, smooth Solomon's seal, Solomon's seal	Native
Polygonum arifolium	halberdleaf tearthumb	Native
Polygonum aviculare	prostrate knotweed, yard knotweed	Non-Native
Polygonum caespitosum	bristled knotweed, bunchy knotweed, oriental ladysthumb	Non-Native
Polygonum coccineum	longroot smartweed	Native
Polygonum erectum	devil's shoestring, erect knotweed, wireweed	Native
Polygonum hydropiperoides	swamp smartweed	Native
Polygonum lapathifolium	curltop ladysthumb, curlytop knotweed, curlytop smartweed, dock-leaf smartweed, nodding smartweed, pale smartweed, smartweed	Native
Polygonum pensylvanicum	Pennsylvania knotweed, Pennsylvania smartweed, pinkweed, pinweed	Native
Polygonum perfoliatum	Asiatic tearthumb, mile-a-minute weed	Non-Native

Scientific name	Common name/s	Status
	Vascular plants	
Polygonum persicaria	lady's-thumb, ladysthumb, ladysthumb smartweed, smartweed, spotted knotweed, spotted ladysthumb, spotted smartweed	Non-Native
Polygonum sagittatum	arrow-leaf tearthumb, arrowleaf knotweed, arrowleaf tearthumb, arrowvine	Native
Polygonum virginianum	jumpseed, Virginia smartweed	Native
Polypodium virginianum	rock polypody	Native
Polystichum acrostichoides	Christmas fern	Native
Populus deltoides	common cottonwood, cottonwood, eastern cottonwood, plains cottonwood	Native
Potentilla canadensis	dwarf cinquefoil	Native
Potentilla recta	roughfruit cinquefoil, sulfur (or erect) cinquefoil, sulfur cinquefoil, sulphur cinquefoil	Non-Native
Potentilla simplex	common cinquefoil, oldfield cinquefoil, oldfield fivefingers, spreading cinquefoil	Native
Prenanthes trifoliolata	gall of the earth	Native
Prunella vulgaris	common selfheal, heal all, healall, selfheal	Native
Prunus avium	sweet cherry	Non-Native
Prunus cerasus	sour cherry	Non-Native
Prunus serotina	black cherry, black chokecherry	Native
Prunus virginiana	chokecherry, chokecherry (common), common chokecherry, Virginia chokecherry	Native
Pyrus communis	common pear, pear	Non-Native
Pyrus malus		Native
Quercus alba	white oak	Native
Quercus bicolor	swamp white oak	Native
Quercus coccinea	scarlet oak	Native
Quercus palustris	pin oak	Native
Quercus prinus	chestnut oak	Native
Quercus rubra	northern red oak	Native
Quercus velutina	black oak	Native
Ranunculus abortivus	early woodbuttercup, kidney-leaf buttercup, littleleaf buttercup, smallflower buttercup, smallflower crowfoot	Native
Ranunculus acris	meadow buttercup, tall buttercup	Non-Native
Ranunculus bulbosus	blister flower, bulbous buttercup, bulbous crowfoot, gowan, St. Anthony's turnip, yellow weed	Non-Native
Ranunculus recurvatus	blisterwort, littleleaf buttercup	Native
Ranunculus sardous	hairy buttercup	Non-Native
Ranunculus sceleratus	celeryleaf buttercup, cursed buttercup	Native
Raphanus raphanistrum	wild radish	Non-Native
Rhexia mariana	Maryland meadowbeauty	Native
Rhus glabra	smooth sumac	Native
Rhus typhina	staghorn sumac	Native
Robinia pseudoacacia	black locust, false acacia, yellow locust	Native
Rorippa nasturtium-aquaticum	watercress	Native
Rorippa sylvestris	creeping yellow cress, creeping yellowcress, keek, yellow fieldcress	Non-Native
Rosa multiflora	multiflora rose	Non-Native

Scientific name	Common name/s	Status
Vascular plants		
Rubus allegheniensis	Allegheny blackberry	Native
Rubus occidentalis	black raspberry	Native
Rubus phoenicolasius	Japanese wineberry, wine raspberry, wineberry	Non-Native
Rubus strigosus		Native
Rudbeckia hirta	blackeyed Susan, blackeyedsusan	Native
Rudbeckia laciniata	cutleaf coneflower, green-head coneflower	Native
Rumex crispus	Curley dock, curly dock, narrowleaf dock, sour dock, yellow dock	Non-Native
Rumex hastatulus	heartwing dock, heartwing sorrel	Native
Rumex obtusifolius	bitter dock, bluntleaf dock	Non-Native
Salix nigra	black willow	Native
Sambucus canadensis	american elder	Native
Sambucus nigra ssp. canadensis	blue elder, common elderberry, elder, elderberry, Mexican elderberry	Native
Sanguinaria canadensis	bloodroot	Native
Sanicula canadensis	Canada sanicle, Canadian blacksnakeroot	Native
Saponaria officinalis	bouncing bet, bouncing-bett, bouncingbet, bouncingbet soapweed, soapwort, sweet Betty	Non-Native
Sassafras albidum	sassafras	Native
Saururus cernuus	lizard's tail, lizards tail	Native
Saxifraga virginiensis	early saxifrage	Native
Scirpus atrovirens	dark-green bulrush, green bulrush	Native
Scrophularia marilandica	carpenter's square, maryland figwort	Native
Scutellaria elliptica	hairy skullcap	Native
Scutellaria nervosa	veiny skullcap	Native
Sedum ternatum	woodland stonecrop	Native
Senecio obovatus	round-leaf groundsel, roundleaf ragwort	Native
Senna hebecarpa	American senna	Native
Seseli libanotis	mooncarrot	Non-Native
Setaria faberi	Chinese foxtail, Chinese millet, giant bristlegrass, giant foxtail, Japanese bristlegrass, nodding foxtail, tall green bristlegrass	Non-Native
Setaria pumila	cattail grass, yellow bristle grass, yellow bristlegrass	Non-Native
Sicyos angulatus	blueeyedgrass, bur cucumber, burcucumber, oneseed burr cucumber, wall bur cucumber	Native
Sida spinosa	prickly fanpetals, prickly sida	Native
Silene cucubalus		Non-Native
Silene latifolia ssp. alba	bladder campion, bladder-campion, evening lychnis, white campion, white cockle	Non-Native
Silene stellata	whorled catchfly, widowsfrill	Native
Sisymbrium officinale	hairypod hedgemustard, hedge mustard, hedge tumblemustard, hedge-mustard, hedgemustard, hedgeweed, wild mustard	Non-Native
Sisyrinchium angustifolium	blue eyegrass, blue-eyed grass, common blue eyedgrass, common blue-eyedgrass, narrowleaf blue-eyed grass	Native
Smilax glauca	cat greenbrier	Native
Smilax rotundifolia	bullbriar, common catbriar, common greenbrier, greenbrier, horsebriar, roundleaf greenbriar, roundleaf greenbrier	Native
Solanum carolinense	apple of Sodom, bull nettle, Carolina horsenettle, devil's tomato, horsenettle, sand briar	Native

Scientific name	Common name/s	Status
Vascular plants		
Solanum dulcamara	bitter nightshade, bittersweet nightshade, blue nightshade, climbing nightshade, European bittersweet, fellenwort, woody nightshade	Non-Native
Solanum nigrum	black nightshade, deadly nightshade, garden nightshade	Non-Native
Solidago bicolor	white goldenrod	Native
Solidago caesia	wreath goldenrod	Native
Solidago canadensis	Canada goldenrod, Canadian goldenrod, common goldenrod	Native
Solidago flexicaulis	zigzag goldenrod	Native
Solidago juncea	early goldenrod	Native
Solidago nemoralis	dyersweed goldenrod, gray goldenrod	Native
Solidago rugosa	wrinkleleaf goldenrod	Native
Sonchus asper	perennial sowthistle, prickly sowthistle, spiny sowthistle, spiny-leaf sow-thistle	Non-Native
Sorghastrum nutans	Indiangrass, yellow indian-grass	Native
Sorghum halepense	aleppo milletgrass, herbe de Cuba, Johnson grass, Johnsongrass, sorgho d'Alep, sorgo de alepo, zacate Johnson	Non-Native
Sphenopholis obtusata	prairie wedgegrass, prairie wedgescale	Native
Stachys palustris	marsh hedgenettle	Native
Stachys tenuifolia	slender betony, smooth hedge-nettle, smooth hedgenettle	Native
Staphylea trifolia	American bladdernut, american bladdernut	Native
Stellaria graminea	grass-leaf starwort, grassleaved stichwort, grasslike starwort, grassy starwort, lesser starwort, little starwort	Non-Native
Stellaria media	chickweed, common chickweed, nodding chickweed	Non-Native
Stellaria pubera	star chickweed	Native
Symphyotrichum cordifolium	common blue wood aster	Native
Symphyotrichum divaricatum	southern annual saltmarsh aster	Native
Symphyotrichum lanceolatum var. lanceolatum	white panicle aster	Native
Symphyotrichum patens var. patens	late purple aster	Native
Symphyotrichum shortii	Short's aster	Native
Symplocarpus foetidus	skunk cabbage	Native
Taraxacum officinale	blowball, common dandelion, dandelion, faceclock	Non-Native
Teucrium canadense	American germander, Canada germander, Candad germander, germander, hairy germander, wood sage	Native
Teucrium canadense var. canadense	American germander, Canada germander	Native
Thalictrum dioicum	early meadow-rue	Native
Thalictrum polygamum		Native
Thalictrum thalictroides	rue anemone	Native
Thelypteris noveboracensis	New York fern	Native
Tilia americana	American basswood	Native
Toxicodendron radicans	eastern poison ivy, poison ivy, poisonivy	Native
Tragopogon dubius	common salsify, goat's beard, goatsbeard, meadow goat's-beard, salsifis majeur, salsify, Western goat's beard, western salsify, wild oysterplant, yellow goat's beard, yellow salsify	Non-Native
Tridens flavus	Purpletop, purpletop tridens	Native
Trifolium aureum	golden clover	Non-Native

Scientific name	Common name/s	Status
	Vascular plants	
Trifolium campestre	Field (Big-hop) clover, field clover, large hop clover, lesser hop clover, low hop clover	Non-Native
Trifolium pratense	red clover	Non-Native
Trifolium repens	Dutch clover, ladino clover, white clover	Non-Native
Trillium sessile	toadshade	Native
Triticum aestivum	common wheat, wheat	Non-Native
Tsuga canadensis	canada hemlock, eastern hemlock, hemlock spruce	Native
Ulmus americana	American elm	Native
Ulmus rubra	slippery elm	Native
Urtica dioica	California nettle, slender nettle, stinging nettle, tall nettle	Non-Native
Uvularia perfoliata	perfoliate bellwort	Native
Uvularia sessilifolia	sessile-leaf bellwort, sessileleaf bellwort	Native
Vaccinium pallidum	Blue Ridge blueberry, blueridge blueberry	Native
Vaccinium stamineum	deerberry	Native
Vaccinium vacillans		Native
Verbascum blattaria	moth mullein, white moth mullein	Non-Native
Verbascum thapsus	big taper, common mullein, flannel mullein, flannel plant, great mullein, mullein, velvet dock, velvet plant, woolly mullein	Non-Native
Verbena urticifolia	white verbena, white vervain	Native
Verbesina alternifolia	wingstem	Native
Veronica americana	American speedwell, brooklime	Native
Veronica arvensis	common speedwell, corn speedwell, rock speedwell, wall speedwell	Non-Native
Veronica officinalis	common gypsyweed	Native
Veronica persica	bird-eye speedwell, birdeye speedwell, birdseye speedwell, Persian speedwell, winter speedwell	Non-Native
Veronica serpyllifolia	thyme-leaf speedwell, thymeleaf speedwell	Non-Native
Viburnum acerifolium	mapleleaf viburnum	Native
Viburnum dentatum	arrow-wood viburnum, arrowwood, southern arrowwood	Native
Viburnum prunifolium	blackhaw	Native
Vinca minor	common periwinkle, lesser periwinkle, myrtle	Non-Native
Viola bicolor	field pansy	Native
Viola palmata	early blue violet, trilobed violet	Native
Viola papilionacea	common blue violet, hooded blue violet, meadow violet	Native
Viola pensylvanica		Native
Viola pubescens	downy yellow violet	Native
Viola sororia	common blue violet, hooded blue violet	Native
Viola striata	striped cream violet	Native
Vitis aestivalis	summer grape	Native
Vitis riparia	river-bank grape, riverbank grape	Native
Vitis vulpina	fox grape, frost grape, wild grape	Native
Wolffia brasiliensis	Brazilian watermeal	Native
Xanthium strumarium	cocklebur, cockleburr, common cocklebur, rough cocklebur, rough cockleburr	Native
Zea mays	corn	Non-Native

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

Scientific name	Common name/s	Status
Fish		
Ambloplites rupestris	rock bass	Non-Native
Ameiurus natalis	yellow bullhead	Native
Anguilla rostrata	American eel	Native
Campostoma anomalum	central stoneroller	Native
Carassius auratus	goldfish	Non-Native
Catostomus commersoni	white sucker	Native
Clinostomus funduloides	rosyside dace	Native
Cottus bairdii	mottled sculpin	Native
Cottus caeruleomentum	Blue Ridge sculpin	Native
Cottus girardi	Potomac sculpin	Native
Cyprinella analostana	satinfin shiner	Native
Cyprinella spiloptera	spotfin shiner	Native
Cyprinus carpio	common carp, European carp	Non-Native
Esox lucius X masquinongy	tiger muskie	Non-Native
Etheostoma blennioides	greenside darter	Native
Etheostoma caeruleum	rainbow darter	Native
Etheostoma flabellare	fantail darter	Native
Etheostoma olmstedi		Native
Exoglossum maxillingua	cutlip minnow, cutlips minnow	Native
Hypentelium nigricans	northern hog sucker	Native
Ictalurus punctatus	channel catfish, graceful catfish	Non-Native
Lepomis auritus		Native
Lepomis cyanellus	green sunfish	Non-Native
Lepomis gibbosus	kiver, pumpkinseed	Native
Lepomis macrochirus	bluegill	Non-Native
Lepomis megalotis	longear sunfish	Non-Native
Luxilus cornutus	common shiner	Native
Margariscus margarita	pearl dace	Native
Micropterus dolomieu	smallmouth bass	Non-Native
Micropterus salmoides	largemouth bass	Non-Native
Nocomis micropogon	river chub	Native
Notropis buccatus	silverjaw minnow	Native
Notropis hudsonius	spottail shiner	Native
Notropis procne	swallowtail shiner	Native
Notropis rubellus	rosyface shiner	Native
Oncorhynchus mykiss	rainbow trout, redband trout, steelhead	Non-Native
Pimephales notatus	bluntnose minnow	Non-Native
Pomoxis annularis	white crappie	Non-Native
Pomoxis nigromaculatus	black crappie	Native
Rhinichthys atratulus	blacknose dace, eastern blacknose dace	Native
Rhinichthys cataractae	longnose dace	Native
Semotilus atromaculatus	creek chub	Native
Semotilus corporalis	fallfish	Native

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

Scientific name	Common name/s	Status
Amphibians		
Ambystoma maculatum	Spotted Salamander	Native
Ambystoma opacum	Marbled Salamander	Native
Anaxyrus americanus americanus	Eastern American Toad	Native
Desmognathus fuscus fuscus	Northern Dusky Salamander	Native
Eurycea bislineata	Northern Two-lined Salamander, Two-lined Salamander	Native
Eurycea longicauda guttolineata	Three-lined Salamander	Native
Gyrinophilus porphyriticus porphyriticus	Northern Spring Salamander	Native
Notophthalmus viridescens viridescens	Red-spotted Newt	Native
Plethodon cinereus	Eastern Red-backed Salamander, Redback Salamander, Red-backed Salamander	Native
Plethodon glutinosus	Northern Slimy Salamander, Slimy Salamander	Native
Pseudacris crucifer crucifer	Northern Spring Peeper	Native
Pseudacris triseriata feriarum		Native
Pseudotriton ruber ruber	Northern Red Salamander	Native
Rana catesbeiana	American Bullfrog, Bullfrog	Native
Rana clamitans melanota	Green Frog, Northern Green Frog	Native
Rana palustris	Pickerel Frog	Native

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

Scientific name	Common name/s	Status
Reptiles		
Agkistrodon contortrix mokasen	Northern Copperhead	Native
Carphophis amoenus amoenus	Eastern Worm Snake	Native
Chelydra serpentina serpentina	common snapping turtle	Native
Chrysemys picta picta	Eastern Painted Turtle	Native
Clemmys guttata	Spotted Turtle	Native
Clemmys insculpta	ornate box turtle, Wood Turtle	Native
Coluber constrictor constrictor	Northern Black Racer	Native
Diadophis punctatus edwardsii	Northern Ringneck Snake	Native
Elaphe obsoleta obsoleta	Black Rat Snake	Native
Eumeces laticeps	Broad-headed Skink	Native
Lampropeltis triangulum triangulum	Eastern Milk Snake	Unknown
Opheodrys vernalis	Smooth Greensnake	Native
Sceloporus undulatus hyacinthinus	Northern Fence Lizard	Native
Sternotherus odoratus	Common Musk Turtle	Native
Storeria dekayi dekayi	Northern Brown Snake	Native
Storeria occipitomaculata occipitomaculata	Northern Redbelly Snake	Native
Terrapene carolina carolina	Eastern Box Turtle	Native
Thamnophis sauritus sauritus	Eastern Ribbon Snake	Native
Thamnophis sirtalis sirtalis	Common Garter Snake	Native
Trachemys scripta elegans	Red-eared Slider	Non-Native

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

Scientific name	Common name/s	Status
Birds		
Actitis macularia	Spotted Sandpiper	Native
Agelaius phoeniceus	Red-winged Blackbird	Native
Aix sponsa	Wood Duck	Native
Ammodramus savannarum	grasshopper sparrow	Native
Anas platyrhynchos	mallard	Native
Anas rubripes	American Black Duck	Native
Archilochus colubris	Ruby-throated Hummingbird	Native
Ardea herodias	Great Blue Heron	Native
Aythya affinis	Lesser Scaup	Native
Bombycilla cedrorum	Cedar Waxwing	Native
Bonasa umbellus	ruffed grouse	NA
Branta canadensis	Canada Goose	Native
Bubo virginianus	Great Horned Owl	Native
Buteo jamaicensis	red-tailed hawk	Native
Buteo lagopus	Roughleg, Rough-legged Hawk	Native
Buteo lineatus	Red-shouldered Hawk	Native
Buteo platypterus	Broad-winged Hawk	Native
Butorides virescens		Native
Cardinalis cardinalis	Northern Cardinal	Native
Carduelis tristis	American Goldfinch	Native
Carpodacus mexicanus	House Finch	Non-Native
Cathartes aura		Native
Certhia americana	brown creeper	Native
Ceryle alcyon	Belted Kingfisher	Native
Chaetura pelagica	Chimney Swift	Native
Charadrius vociferus	killdeer	Native
Circus cyaneus	Northern Harrier	Native
Coccyzus americanus	Yellow-billed Cuckoo	Native
Colaptes auratus	Northern Flicker	Native
Columba livia	Common Pigeon, Rock Dove, Rock Pigeon	Non-Native
Contopus virens	Eastern Wood Pewee, Eastern Wood-Pewee	Native
Coragyps atratus	Black Vulture	Native
Corvus brachyrhynchos	American Crow	Native
Corvus ossifragus	Fish Crow	Native
Cyanocitta cristata	Blue Jay	Native
Dendroica coronata	Yellow-rumped Warbler	Native
Dendroica magnolia	Magnolia Warbler	Native
Dendroica striata	Blackpoll Warbler	Native
Dryocopus pileatus	Pileated Woodpecker	Native
Dumetella carolinensis	Gray Catbird, Grey Catbird	Native
Empidonax virescens	Acadian Flycatcher	Native
Falco sparverius	American Kestrel	Native
Geothlypis trichas	Common Yellowthroat	Native

Scientific name	Common name/s	Status
	Birds	
Guiraca caerulea	Blue Grosbeak	Native
Haliaeetus leucocephalus	Bald Eagle	Native
Helmitheros vermivorus	Worm-eating Warbler	Native
Hirundo rustica	Barn Swallow	Native
Hylocichla mustelina	Wood Thrush	Native
Icterus galbula	Baltimore oriole, northern oriole	Native
Icterus spurius	Orchard Oriole	Native
Junco hyemalis	Dark-eyed Junco	Native
Lanius ludovicianus	Loggerhead Shrike	NA
Larus delawarensis	Ring-billed Gull	Native
Lophodytes cucullatus	Hooded Merganser	Native
Melanerpes carolinus	Red-bellied Woodpecker	Native
Meleagris gallopavo	Wild Turkey	Native
Melospiza melodia	Song Sparrow	Native
Mergus merganser	Common Merganser	Native
Mimus polyglottos	Northern Mockingbird	Native
Mniotilta varia	Black-and-white Warbler	Native
Molothrus ater	Brown-headed Cowbird	Native
Myiarchus crinitus	Great Crested Flycatcher	Native
Oporornis agilis	Connecticut Warbler	Native
Oporornis formosus	Kentucky Warbler	Native
Parula americana	Northern Parula	Native
Parus bicolor	Tufted Titmouse	Native
Parus carolinensis	Carolina Chickadee	Native
Passer domesticus	House Sparrow	Non-Native
Passerina cyanea	Indigo Bunting	Native
Picoides pubescens	downy woodpecker	Native
Picoides villosus	hairy woodpecker	Native
Pipilo erythrophthalmus	Eastern Towhee, Rufous-sided Towhee	Native
Piranga olivacea	Scarlet Tanager	Native
Polioptila caerulea	blue-gray gnatcatcher, Blue-grey Gnatcatcher	Native
Pooecetes gramineus	Vesper Sparrow	Native
Quiscalus quiscula	Common Grackle	Native
Regulus calendula	Ruby-crowned kinglet	Native
Regulus satrapa	Golden-crowned Kinglet	Native
Sayornis phoebe	Eastern Phoebe	Native
Seiurus motacilla	Louisiana Waterthrush	Native
Setophaga ruticilla	American Redstart	Native
Sialia sialis	Eastern Bluebird	Native
Sitta carolinensis	White-breasted Nuthatch	Native
Sphyrapicus varius	Yellow-bellied Sapsucker	Native
Spizella passerina	Chipping Sparrow	Native
Spizella pusilla	Field Sparrow	Native
Stelgidopteryx serripennis	Northern rough-winged swallow	Native

Scientific name	Common name/s	Status
Birds		
Strix varia	Barred Owl	Native
Sturnella magna	Eastern Meadowlark	Native
Sturnus vulgaris	Common Starling, European Starling	Non-Native
Tachycineta bicolor	Tree Swallow	Native
Thryothorus ludovicianus	Carolina Wren	Native
Toxostoma rufum	Brown Thrasher	Native
Troglodytes aedon	House Wren	Native
Turdus migratorius	American Robin	Native
Tyrannus tyrannus	Eastern Kingbird	Native
Vermivora ruficapilla	Nashville Warbler	Native
Vireo flavifrons	Yellow-throated Vireo	Native
Vireo gilvus	Warbling Vireo	Native
Vireo griseus	White-eyed Vireo	Native
Vireo olivaceus	red-eyed vireo	Native
Vireo philadelphicus	Philadelphia Vireo	Native
Zenaida macroura	Mourning Dove	Native
Zonotrichia albicollis	White-throated Sparrow	Native

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

Scientific name	Common name/s	Status
Mammals		
Blarina brevicauda	mole shrew, northern short-tailed shrew, short-tailed shrew	Native
Castor canadensis	american beaver, beaver	Native
Cryptotis parva	bee shrew, least shrew, little short-tailed shrew	Native
Didelphis virginiana	Virginia opossum	Native
Eptesicus fuscus	big brown bat	Native
Glaucomys volans	southern flying squirrel	Native
Lasionycteris noctivagans	silver-haired bat	Native
Lasiurus borealis	eastern red bat, red bat	Native
Lasiurus cinereus	hoary bat	Native
Marmota monax	woodchuck	Native
Mephitis mephitis	striped skunk	Native
Microtus pennsylvanicus	meadow vole	Native
Microtus pinetorum	pine vole, woodland vole	Native
Mus musculus	house mouse	Non-Native
Mustela frenata	long-tailed weasel	Native
Mustela vison	American Mink, mink	Native
Myotis keenii	Keen's myotis	Native
Myotis lucifugus	little brown bat, little brown myotis	Native
Myotis sodalis	Indiana bat	Native
Odocoileus virginianus	white-tailed deer	Native
Ondatra zibethicus	muskbeaver, muskrat	Native
Parascalops breweri	Brewer's mole, Hairy-tailed Mole	Native
Peromyscus leucopus	white-footed mouse	Native
Peromyscus maniculatus	deer mouse	Native
Pipistrellus subflavus	eastern pipistrelle	Native
Procyon lotor	common raccoon, northern raccoon, Raccoon	Native
Rattus norvegicus	Norway rat	Non-Native
Reithrodontomys humulis	eastern harvest mouse	Native
Scalopus aquaticus	Eastern Mole, topos	Native
Sciurus carolinensis	eastern gray squirrel, gray squirrel	Native
Sylvilagus floridanus	Eastern Cottontail	Native
Synaptomys cooperi	southern bog lemming	Native
Tamias striatus	eastern chipmunk	Native
Tamiasciurus hudsonicus	red squirrel	Native
Urocyon cinereoargenteus	common gray fox, Gray Fox	Native
Ursus americanus	American Black Bear, black bear	Native
Vulpes vulpes	Red Fox	Native
Zapus hudsonius	meadow jumping mouse	Native

Appendix B: Information used in Monocacy 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 Natural Capital Region Network. Inventory and Monitoring Program, Center for Urban Ecology, Washington, DC.

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

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 Monocacy 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.

Athanas, C. 2001. Mammal inventory at Monocacy National Battlefield, final report. 46. Abstract: The goal of this study was to establish a species list and some relative abundance estimates for small mammals at Monocacy National Battlefield.

Bates, S. 2006. National Capital Region deer survey report - Fall 2005.

Bates, S. 2008. 2008 Monocacy small mammal occupancy estimation report.

Bates, S. 2009. National Capital Region Network 2007 deer monitoring report. NPS/NCRN/NRTR—2009/183. National Park Service, Fort Collins, CO.

Brewer, G. and K. Kalasz. 1999. Progress Report 1 for Inventory of the Avifauna of Monocacy National Battlefield. Frostburg, MD: Frostburg State University.

Brewer, G. and K. Kalasz. 2000. Bird inventory of Monocacy National Battlefield, Frederick Co, Maryland. 60. Notes: A study was done from 1999-2000 to determine the species diversity and richness of birds.

Conneely, B. 2004. Monocacy National Battlefield water quality monitoring plan.

Czwartacki, S. and K. Yetman. 2004. Lower Monocacy stream corridor survey. Maryland Department of Natural Resources. Notes: Watershed Assessment and Targeting Division, Watershed Services, Maryland Department of Natural Resources.

Davidson, W.R. 2002. Deer herd health check, Monocacy National Battlefield Park. 5. Abstract: Five white-tailed deer were collected from Monocacy National Battlefield Park on August 27, 2002. This report presents results of health checks performed on these deer. General health information, lists of helminths and protozoans found, results of Notes: Includes letter from Dr. William R. Davidson to Duane Marcus of Antietam National Battlefield Park.

Ford, B. 2001. Monocacy National Battlefield Park deer studies conducted by Frederick Community College. Abstract: Study by general ecology students of deer fecal pellet counts and deer driving surveys. Includes maps of study areas.

Gates, E. and J. Johnson. 2005. Bat inventories of the National Capital Region Parks.

Hilderbrand, R., D. Boward, and R. Raesly. 2005. Inventory and monitoring protocols for water resources of National Capital Region parks.

Kawecki, C. and L. Wollerman. 1993. Draft statement for management, Monocacy National Battlefield. Notes: Prepared by ENSP 470 for the NPS.

Kenworthy, J.P. and V.L. Santucci. 2004. Paleontological resource inventory and monitoring—National Capital Region Network.

Maryland Department of Natural Resources Natural Heritage And Biodiversity Conservation Program. 1998. Natural areas inventory for rare, threatened and endangered plants and selected animals with management recommendations: Monocacy National Battlefield. 36. Abstract: Results of reconnaissance and inventory activities conducted during the 1997 field season at all landscapes/waterways in natural condition on the Monocacy National Bettlefield property.

Maryland Department of Natural Resources, J. Hunicke, and K. Yetman. 2004. Upper Monocacy River stream corridor assessment survey.

Maryland Department of Natural Resources, K. Schultz, J. Hunicke, and S. Moore. 2005. Upper Monocacy River Watershed Restoration Action Strategy.

Maryland Department of Natural Resources. 2003. Lower Monocacy River watershed characterization. Notes: In support of Frederick County's Watershed Restoration Action Strategy for the Lower Monocacy River Watershed.

Maryland Department of Natural Resources. 2004. Lower Monocacy River Watershed Restoration Action Strategy.

Maryland Department of the Environment. 2007. Total Maximum Daily Loads of fecal bacteria for the Lower Monocacy River basin in Carroll, Frederick, and Montgomery Counties, Maryland—draft.

Monocacy National Battlefield Staff. 2008. Review draft, Resource Stewardship Strategy, Monocacy National Battlefield. Frederick, MD.

Monocacy Scenic River Local Advisory Board and Maryland Department of Natural Resources. 1990. Maryland Scenic Rivers: The Monocacy.

Motivans, K. 1995. Vegetation and aquatic survey of the Bush Creek Tract with emphasis on rare, threatened, and endangered species of plants and freshwater mussels, Monocacy National Battlefield, Bush Creek Tract, Frederick County, Maryland, Final Report. 26. Annapolis, MD: Maryland Natural Heritage Program. Abstract: Results of a 1995 survey to record dominant plant species and identify vegetation community types present in Monocacy National Battlefield Park. Rare plant species and freshwater mussels were also searched for.

National Park Service, Water Resources Division. 2000. Baseline water quality data inventory and analysis: Monocacy National Battlefield. Technical Report NPS/NRWRD/NRTR—99/253. Water Resources Division, National Park Service, Fort Collins, CO.

Norris, M., J.P. Schmit and J. Pieper. 2007. National Capital Region Network 2005–2006 water resources monitoring report. NPS/NCRN/NRTR—2007/066. Natural Resource Program Center, Fort Collins, CO.

Pauley, T.K. and M.B. Watson. 2003. Annual report for herpetological inventories of Capital Region Parks for year 2002.

Pauley, T.K., M.B. Watson, and J.C. Mitchell. 2005. Final report: reptile and amphibian inventories in eight parks in the National Capital Region.

Raesly, R., R. Hildebrand, and P. Kazyak. 2004. Final report: inventory and biological monitoring of fishes in National Parks of the National Capital Region.

Schmit, J.P. and J.P. Campbell. 2007. National Capital Region Network 2006 forest vegetation monitoring report. NPS/NCRN/NRTR-2007/046. Natural Resource Program Center, Fort Collins, CO.

Schmit, J.P., J.P. Campbell, and J. Parrish. 2009. National Capital Region Network 2008 forest vegetation monitoring report. NPS/NCRN/NRTR —2009/181 National Park Service, Fort Collins, CO.

Southworth, S. and D. Denenny. 2006. Geologic map of the National Parks in the National Capital Region, Washington, DC, Virginia, Maryland, and West Virginia. Map. USGS, Reston, VA.

Thornberry–Ehrlich, T. 2008. Monocacy National Battlefield geologic resource evaluation report. NPS/NRPC/GRD/NRR—2008/051 Geologic Resources Division, Denver, CO. *http://www.nature.nps.gov/geology/inventory/publications/reports/mono_gre_rpt_view.pdf*

VARGIS and NatureServe. 2005. NCRN vegetation mapping—ground control report.

Weeks, D., M. Norris, and A. Banasik. 2007. Water resources stewardship report Monocacy National Battlefield—final report. Notes: Final report.

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

Acronym	Description
ANC	Acid neutralizing capacity
ANTI	Antietam National Battlefield (NPS—NCRN)
ASMIS	Archeological Sites Management Information Systems
BIBI	Benthic Index of Biotic Integrity
BMP	Best Management Practice
CATO	Catoctin Mountain Park (NPS—NCRN)
CHOH	Chesapeake & Ohio Canal National Historical Park (NPS—NCRN)
CLI	Cultural Landscape Inventory
COMAR	Code of Maryland Regulations
CWPT	Civil War Preservation Trust
DC	District of Columbia
DO	Dissolved oxygen
FIBI	Fish Index of Biotic Integrity
FIDS	Forest Interior Dwelling Species of birds
GIS	Geographic Information Systems
GMP	General Management Plan
GWMP	George Washington Memorial Parkway (NPS—NCRN)
HAFE	Harpers Ferry National Historical Park (NPS—NCRN)
I&M	Inventory & Monitoring Program (NPS)
IAN	Integration & Application Network (UMCES)
IBI	Index of Biotic Integrity
IMPROVE	Interagency Monitoring of Protected Visual Environments
IUCN	International Union for Conservation of Nature
LCS	List of Classified Structures
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
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)

NPS 894/108048, June 2011

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA™