National Park Service
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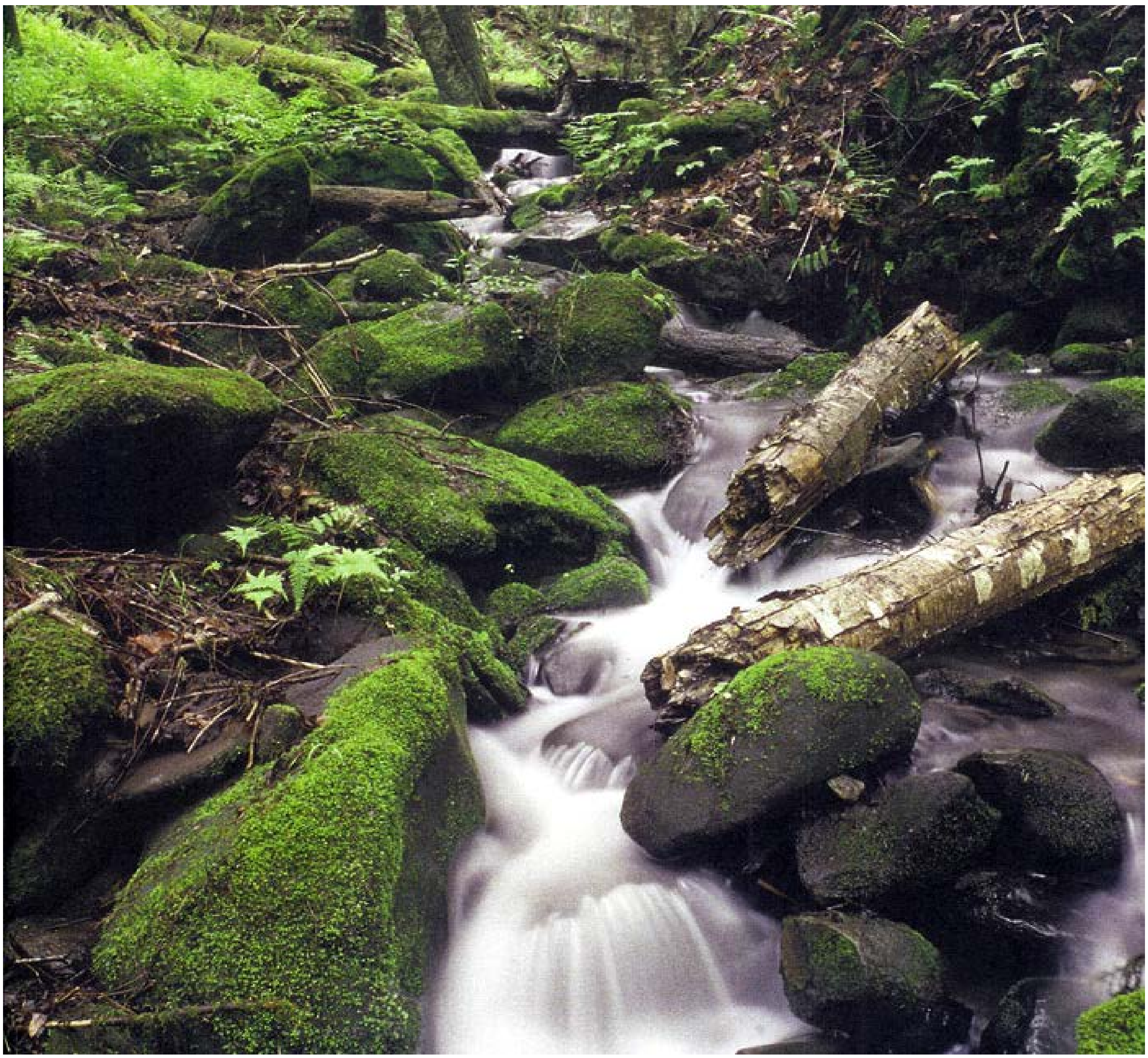
Natural Resource Stewardship and Science

Marsh-Billings-Rockefeller National Historical Park Natural Resource Condition Assessment

Natural Resource Report NPS/NERO/NRR—2014/882



ON THE COVER
Pogue Brook, Marsh-Billings-Rockefeller National Historical Park
Photograph by: Edmund Sharron

Marsh-Billings-Rockefeller National Historical Park Natural Resource Condition Assessment

Natural Resource Report NPS/NERO/NRR—2014/882

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National Park Service
Natural Resource Stewardship and Science
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Executive Summary

This Natural Resource Condition Assessment (NRCA) evaluates current condition and trend for a subset of natural resource indicators and identifies critical data gaps for Marsh-Billings-Rockefeller National Historical Park (MABI). The resources and indicators included herein reflect the park's resource setting, status of resource stewardship planning and science, and availability of data and expertise to assess current conditions for a variety of potential indicators. The goal of this report is to provide clear, credible, integrative reporting to assist and inform park managers and other stakeholders.

Located on 220 hectares (550 acres) in central Vermont, MABI preserves a nationally significant cultural landscape, and interprets conservation history and the evolving nature of land stewardship in America. The park's primary purpose is preservation, education and interpretation of the historic landscape and features. This landscape is comprised of about 50 forested stands including both naturally-regenerating forest and plantations managed for historic values, interspersed with open fields, a 5.8-ha (14.3-acre) pond, a single perennial stream, and several small wetlands. Rare species or species of concern documented in the park include five sedges, a fern, five bats, one salamander (Jefferson salamander), a mammal (long-tailed weasel) and 23 bird species.

MABI is unusual within the National Park System for its cultural mandate of continuing forest and agricultural management and timber extraction within the Park; these activities are key drivers of park natural resource condition, including soil and water quality, forest condition, maintenance of wildlife habitat, and protection of sensitive vegetation. However, additional key drivers of natural resource condition lie outside the park boundary and are largely outside the control of park managers; these external drivers include climate change, atmospheric deposition, landscape fragmentation, and the advance of invasive, exotic forest pests.

Forest management at MABI seeks to "recognize and work with ecological change in preserving the historic character of the forest." This approach attempts to preserve the overall configuration of forest stands, fields, vistas and pond that existed in the mid 1990's, and that reflects historical management of the landscape, while allowing for ecological change in some areas. This approach allows the continuing adoption of new best forest management practices alongside demonstrations of historical practices.

Using the NPS Vital Signs Indicator Framework, 25 Vital Signs of natural resource condition were selected for assessment and reporting herein. Assessment points sought to distinguish acceptable or desired conditions from those that warrant moderate or significant concern. Assessment points were derived from knowledge of ecological integrity, as well as from regulatory or program standards, park management goals, historical data and other sources.

Key findings and recommendations of this report are summarized below by resource category.

Air and climate

<table>
<tr><th>Key findings</th><th>Recommendations</th></tr>
<tr><td>Ozone pollution may be affecting sensitive vegetation in some years.</td><td rowspan="4">Continue to monitor and work collaboratively with federal, state and local partners to reduce air pollution.</td></tr>
<tr><td>Acidic deposition rates for both N and P have declined, but remain at levels which may cause harm to park ecosystems.</td></tr>
<tr><td>Mercury deposition exceeds levels which may cause harm to park ecosystems.</td></tr>
<tr><td>Forest soils are well buffered and fertile, but may be deficient in potassium, sensitive to nitrogen saturation and affected by aluminum toxicity.</td></tr>
<tr><td>Temperature shows an overall warming trend over the historical record.</td><td rowspan="2">Expand efforts to identify and monitor status and trend of key indicators of climate change, and to identify and monitor valued park resources at high risk to climate change impacts.</td></tr>
<tr><td>Precipitation shows an overall increasing trend over the historical record.</td></tr>
</table>

Water quantity and quality

<table>
<tr><th>Key findings</th><th>Recommendations</th></tr>
<tr><td>Assessment points for understanding water quantity condition at MABI have not been established.</td><td>Consider establishing assessment points based on monitored levels and ecological function.</td></tr>
<tr><td>Water quality in the Pogue stream showed good condition.</td><td rowspan="2">Continue to monitor.</td></tr>
<tr><td>Water quality in the Pogue may warrant moderate concern for nutrient enrichment.</td></tr>
<tr><td>Stream macroinvertebrates are a data gap.</td><td>Consider monitoring if funding permits.</td></tr>
</table>

Biological integrity

<table>
<tr><th>Key findings</th><th>Recommendations</th></tr>
<tr><td>Pond and natural forest habitats remain relatively uninvaded by exotic plants.</td><td rowspan="2">Continue invasive plant detection and management programs.</td></tr>
<tr><td>Forest plantations are mildly invaded by exotic plants.</td></tr>
<tr><td>The advance of hemlock woolly adelgid in southern Vermont is a significant concern, and the spread of emerald ash borer and Asian longhorned beetle pose enormous threats to forest resources.</td><td>Early detection of key forest pests and rapid response must continue to be a high priority.</td></tr>
<tr><td>Wetland vegetation is not monitored.</td><td>Consider monitoring using rapid assessment methods if funding permits.</td></tr>
<tr><td>Most forest stands display mature or late-successional structure, and the proportion of large trees in forest stands has increased over</td><td>Continue to monitor.</td></tr>
</table>

Key findings	Recommendations
four years.	
Snag and CWD levels are lower than desired in both naturally regenerating forests and plantations. Plantations are particularly lacking in medium to large-sized snags.	Continue to enhance levels of snags and CWD using appropriate forest management.
Low levels of tree regeneration warrant moderate concern.	Continue to monitor, and consider management options.
Beech bark disease (BBD) is impacting tree condition.	Retain any medium or larger sized beech noticeably resistant to BBD.
Tree growth rates in the park may be lower than regional means.	Continue to monitor.
Tree mortality rates are high for American beech, which is suffering from beech bark disease, and for several pine species.	Continue to monitor, and consider management options for affected species.
Deer density within the Eastern Foothills region of VT appears to be within desired levels to minimize negative impacts on vegetation.	Continue to monitor.
Preliminary assessment of deer-browse indicator species in forest plots indicates continued monitoring is warranted.	Continue to monitor and refine assessment.
Assessment of bird guilds showed good representation of specialist compared to generalist species overall.	Continue to monitor and refine assessment.
Relative abundance and species richness of birds declined in 2012.	
Sensitive species, pond-breeding salamanders and vernal pool-breeding amphibians are well represented in the amphibian community.	Consider annual monitoring to determine status and trend in key species.
Legacy trees are not explicitly monitored, but the numbers of large trees in forest plots has increased.	Consider establishing a monitoring program at key legacy tree locations.
Populations of some bat species are in dramatic decline in the park and across the region.	Consider establishing a bat monitoring program.
Mammal species richness shows good condition. Population trend of key mammal species other than bats and white-tailed deer is a data gap.	Consider monitoring key species if funding permits.
Terrestrial invertebrate populations are a data gap.	Consider monitoring selected taxa if funding permits.

Human use

Key findings	Recommendations
Forest plots show little sign of trampling.	Consider monitoring trampling at key locations adjacent to major trails and attractions.
Forest management conforms to standards for sustainability established by the Forest Stewardship Council (FSC).	Continue annual audits.

Landscapes

Key findings	Recommendations
Forest patch size is sufficient to support invertebrates, small mammals and many bird species dependent upon forest habitat, but patch configuration reduces the amount of interior or intact forest habitat.	Incorporate assessment points based on park management goals into landcover condition. Continue to monitor.
Condition of key historical and cultural vistas is a data gap.	Consider monitoring if funding permits.
Levels of anthropogenic landuse in the local neighborhood surrounding forest plots may be a moderate concern. Housing density and urban land area surrounding the park have increased since the 1970s.	Continue to monitor, and work with local partners to advocate for appropriate land uses in the park neighborhood.
Modeled data indicate anthropogenic noise may be a moderate concern.	Consider on-site monitoring if funding permits.
Modeled data indicate anthropogenic light pollution may be a moderate concern.	Consider on-site monitoring if funding permits.

Acknowledgments

We wish to thank Kyle Jones and Christina Marts of Marsh-Billings-Rockefeller National Historical Park for useful guidance and access to Park datasets; Brian Mitchell, Adam Kozlowski, and Kate Miller of the National Park Service (NPS) Northeast Temperate Network (NETN) for helpful suggestions and access to Network datasets; and Peter Sharpe of the NPS Northeast Region for useful guidance and participation in scoping and development of this report. We also thank Emma Lynch and Jeremy White of the NPS Natural Sounds & Night Skies Division (NSNSD) for providing guidance and data for assessing soundscape and lightscape, respectively. Kyle Jones, Christina Marts, Brian Mitchell, Peter Sharpe, Kate Miller, Bill Gawley, Steve Faccio and Daniel Ruddell reviewed and provided useful suggestions on preliminary drafts. This report was prepared under Task Agreement P12AC10767 between the National Park Service, Northeast Region and the Research Foundation of SUNY on behalf of the SUNY College of Environmental Science and Forestry, through the North Atlantic Coast Cooperative Ecosystem Studies Unit (CESU).

Chapter 1. NRCA Background Information

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

NRCAs Strive to Provide…

Credible condition reporting for a subset of important park natural resources and indicators

Useful condition summaries by broader resource categories or topics, and by park areas

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, however, the breadth of natural resources and number/type of indicators evaluated will vary by park
- employ hierarchical indicator frameworks, which 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
- identify or develop logical reference condition data against. 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. 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")
- emphasize spatial evaluation of conditions and GIS (map) products.. 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
- summarize key findings by park areas. 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
- 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.

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

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

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

NRCAs do not establish management targets for study indicators. Decisions about management targets must be made through sanctioned park planning and management processes. NRCAs do provide science-based information that will help park managers with an ongoing, longer term effort to describe and quantify their park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning7 and help parks report to government accountability measures. 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. 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.

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.

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
(longer-term strategic planning)

Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public
("resource condition status" reporting)

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

Chapter 2. Introduction and Resource Setting

Introduction

Located on 220 hectares (550 acres) in central Vermont, Marsh-Billings-Rockefeller National Historical Park (MABI) preserves a nationally significant cultural landscape, and interprets conservation history and the evolving nature of land stewardship in America. The park was created in 1992, when Mary French and Laurance S. Rockefeller gave the Marsh-Billings-Rockefeller Mansion, the surrounding grounds, and the Mount Tom Forest to the people of the United States. Opened in June of 1998, Vermont's first national park preserves and interprets this historic property and illustrates the evolution of forest management in this country. The park encompasses the childhood home of George Perkins Marsh, one of the nation's first global environmental thinkers, and author of *Man and Nature*. In the 1870s, Frederick Billings initiated a progressive dairy farm and professionally managed forest on the site, which is now among the earliest surviving examples of a professionally managed forest in the U.S. Later, Frederick Billings' granddaughter, Mary French Rockefeller, and her husband, conservationist Laurance S. Rockefeller, continued Billings' land management practices during their ownership of the estate from the 1950s to the early 1990s. A 32-kilometer (20-mile) network of carriage roads designed and built by Frederick Billings and hiking and skiing trails extended by Mary and Laurance Rockefeller provide access to the Park and adjacent public land (NPS1999, NPS 2006a).

Enabling Legislation

Originally established in 1992 as Marsh-Billings National Historical Park (Public Law 102-350), legislation in 1998 amended the park name to be Marsh-Billings-Rockefeller National Historical Park (Public Law 105–277 § 143).

The Park was created with 5 key purposes:

- To interpret the history and evolution of conservation stewardship in America;
- To recognize and interpret the birthplace and contributions of George Perkins Marsh, pioneering environmentalist, author of Man and Nature, statesman, lawyer, and linguist;
- To recognize and interpret the contributions of Frederick Billings, pioneer in reforestation and scientific farm management, lawyer, philanthropist, and railroad builder, who extended the principles of land management introduced by Marsh;
- To recognize the significant contributions of Julia Billings, Mary Billings French, Mary French Rockefeller, and Laurance Spelman Rockefeller in perpetuating the Marsh-Billings heritage; and
- To preserve the Marsh-Billings Mansion, which is a National Historic Landmark, and its surrounding lands (16 U.S.C. § 410vv).

The enabling legislation designates the primary purposes of a designated "historic zone," comprised of the estate grounds and Mt. Tom forest, to be preservation, education and interpretation (16 U.S.C. § 410vv).

In addition, the park enabling legislation designates two additional "zones" on adjacent or nearby private property. First, 36-ha (89-acre) of the adjacent Billings Farm & Museum owned by the Woodstock Foundation, Inc. is designated to be a "protection zone" in which the primary purpose is to preserve the general character of the setting across from the Marsh-Billings Mansion in such a manner that will continue to permit current and future compatible uses. This property occupies the former Marsh-Billings farm. Second, a "scenic zone" is designated to "protect portions of the natural setting beyond the park boundaries that are visible from the Marsh-Billings Mansion." The scenic zone consists of about 120 ha (295 acres) of privately-owned land on Mount Peg and Blake Hill, over which the federal government holds scenic easements (16 U.S.C. § 410vv).

Geographic Setting

The park is located among the rolling hills and pastures of the Ottauquechee Valley in east-central Vermont, within the Vermont Piedmont subsection of the Forest Service's Ecological Units map of the eastern U.S. (Figure 2.1). MABI lies within the rural working landscape of the Prosper Valley. Farming and associated agricultural enterprises define this area, and are interspersed with forested land (Allen et al. 2007). The adjacent Billings Farm & Museum is operated as a working dairy and living museum by the Woodstock Foundation, Inc. The farm is a mix of pastures, hay meadows and cropland, with small patches of lowland woods (NPS 1999). Three other adjacent or nearby properties are in public or protected ownership. The two peaks of Mount Tom lie within the adjacent Billings Park (55 ha), which the Billings family donated to the Town of Woodstock as a public park in 1953. Billings Park is contiguous with small Faulkner Park (2 ha), owned by the Faulkner Trust. Trails link these town parks with MABI. South of MABI is the 62-ha (153-acre) King Farm, which is owned and operated by the Vermont Land Trust (NPS 1999). Some of the land north of MABI, along Vermont Route 12, is zoned for business and light industry (NPS 1999). To the west of MABI lie large areas of privately-owned contiguous forest designated as important bear habitat by the Vermont Department of Fish and Wildlife (NPS 2006a); this area is the focus of a four-town conservation initiative to preserve the forested, working landscape (Allen et al. 2007). The Appalachian National Scenic Trail passes within 2-km (1.2 miles) of MABI (Figure 2.1).

Park topography ranges from about 200 to 450 m above sea level (NPS 2006a). MABI is underlain primarily by metamorphic bedrock of the Waits River formation, including schist, phyllite, and quartzite containing thin layers of limestone (Doll 1969). Soils are frigid Dystrudepts of the Dummerston, Pomfret, Glover, and Vershire series, developed from glacial till, and range in texture from silt loam to loamy fine sand with variable stoniness (NRCS 2004). Roughly two-thirds of the soil area is designated prime forest soil under state classification, with pockets of state-designated prime agricultural soil found south of the Pogue and west of the Mansion Grounds (NPS 1999).

MABI has a humid continental climate with cold winters and warm, humid summers. The area receives approximately 100 cm (40 inches) of precipitation annually, evenly distributed through the year. The frost-free period typically lasts from late-May to mid-September, and snow usually covers the ground from mid-December to April (NPS1999; NPS 2006a).

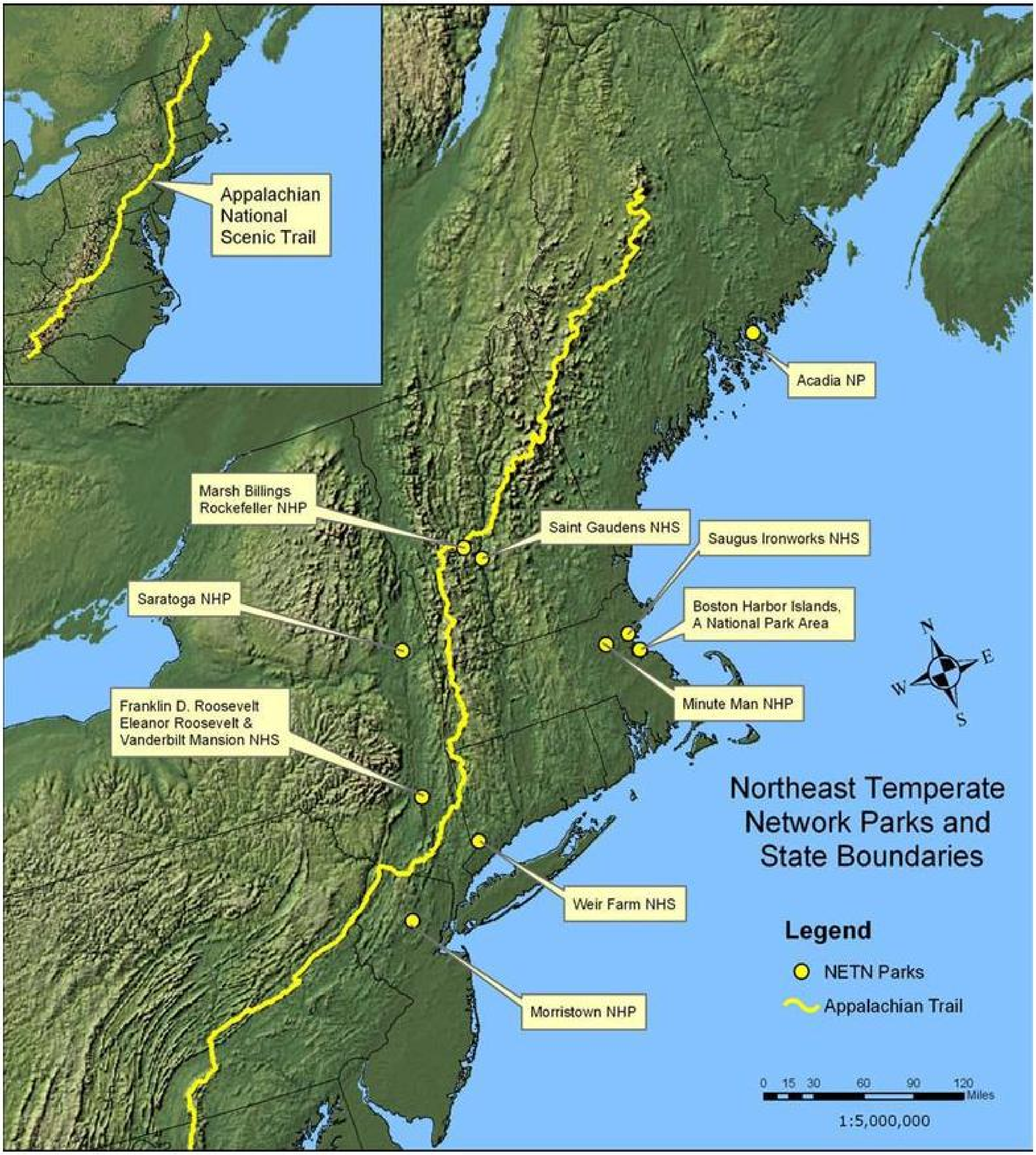

Figure 2.1. Location of Marsh-Billings-Rockefeller NHP within the NPS Northeast Temperate Network (from Mitchell et al. 2006).

Visitation Statistics

The MABI forest is accessible to the public without fee, as it has been since the time of Frederick Billings (NPS 1999). In 2012, automatic counters recorded more than 20,000 visits to the MABI forest park, and almost 12,000 people signed in at the Visitor Center, for a total of more than 32,000 visits counted (NPS 2013). Visitor use is assessed as a Vital Sign in Section 4.5.1 (Visitor usage).

Natural Resources

Ecological Units and Watershed

MABI lies within the watershed of the Ottauquechee River, which is a major tributary of the Connecticut River. Most of MABI drains into the Pogue Stream, which flows east into Barnard Brook, then south into the Ottaquechee River. However, the southern slopes of Mount Tom drain via small streams into the Ottauquechee River (NPS 2006a).

The USGS-NPS Vegetation Map for MABI recognizes 18 U.S. National Vegetation Classification (USNVC) vegetation associations at MABI, which are mapped as 19 classes (Gawler and Engstrom 2011). The 18 associations include: five plantation types (one of which is mapped jointly with a successional forest type), five upland forest types (two of which are mapped as two separate variations), three successional forest types (one of which is mapped jointly with a plantation type), one upland woodland type, one herbaceous old-field type, and three wetland communities (Figure 2.2). The matrix forest at MABI is comprised of Hemlock-Northern Hardwood Forest and Northern Hardwood Forest types. This matrix is interspersed with plantations, open fields, areas of successional forest, patches of less common communities, and a few small wetlands (Gawler and Engstrom 2011). MABI includes about 200 ha (500 acres) of forestland, comprised of about 50 forest stands.

The forest that exists today at MABI has been shaped by both by the ecological characteristics of the site and by more than two centuries of human activity and management. At the time of European settlement, the Mount Tom forest was dominated by northern hardwood species and eastern hemlock. After extensive clearing in the early 19th century, fires in 1801 and 1845, and the introduction of sheep grazing, the hills were denuded of vegetation and began eroding (NPS 1999). Frederick Billings began establishing forest plantations in the 1880s, using European softwood species which could grow quickly and stabilize the site (NPS 2006a). Establishment of new plantations and management of the forest were continued by Billing’s staff and family after his death in 1890.

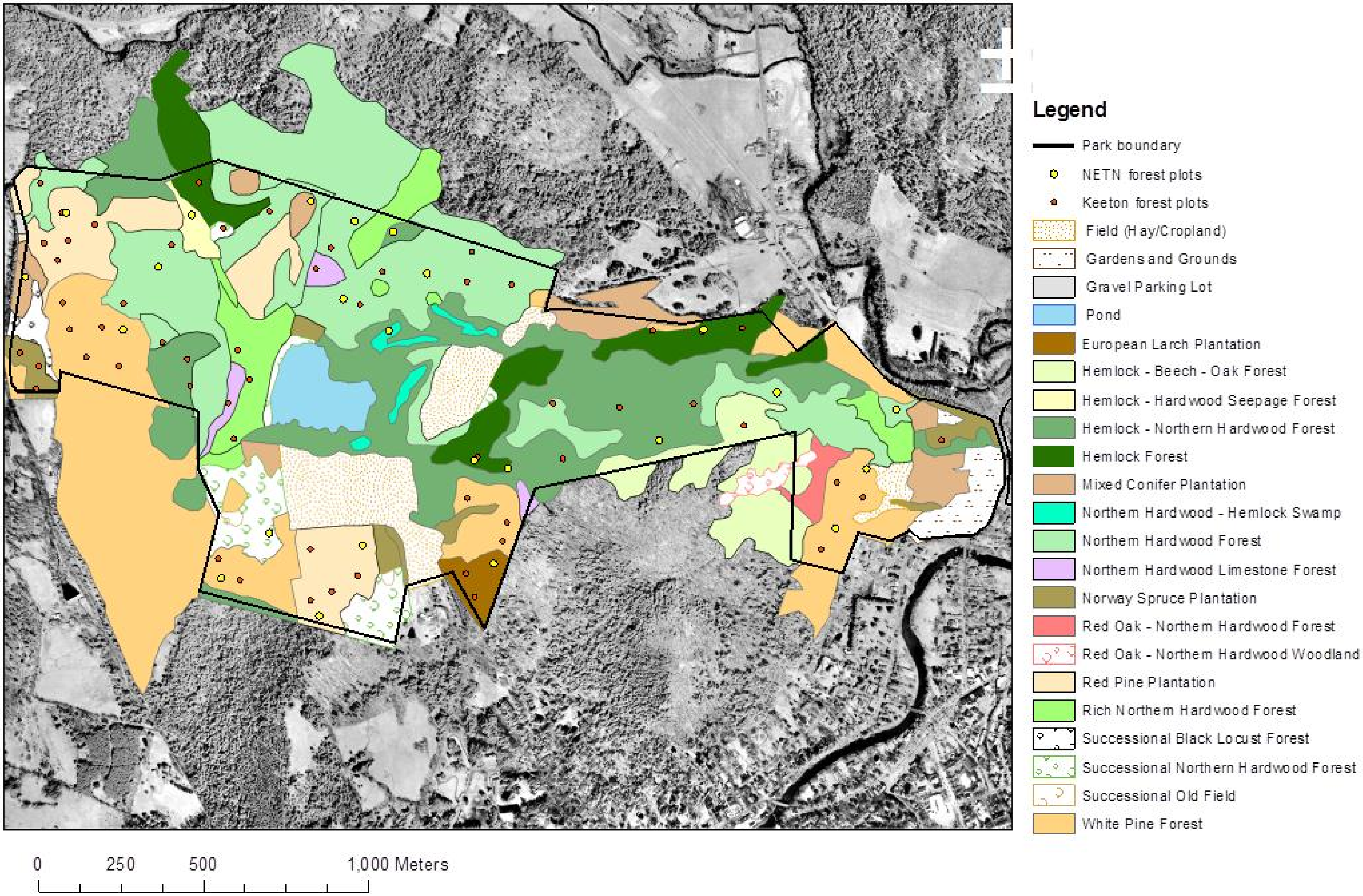

Figure 2.2. Map of Marsh-Billings-Rockefeller National Historical Park, showing mapped vegetation classes (Gawler and Engstrom 2011) and permanent forest monitoring plots (Miller et al. 2013, Keeton 2005).

Resource Descriptions

<u>Upland forest and woodland communities</u>

About 130 ha (roughly 60% of the Park land area) are covered by upland forest vegetation excluding plantation forest types (see below). The upland forest is dominated by Northern Hardwood Forest and Hemlock-Northern Hardwood Forest, with noted areas of Hemlock Forest, Rich Northern Hardwood Forest (including a Northern Hardwood Limestone Variant), two additional forest types, a woodland, and two successional forest types (Table 2.1; Gawler and Engstrom 2011). None of these associations are considered rare in Vermont or the New England region, but three are less common and considered of local importance for biodiversity. These are the Northern Hardwood Limestone Forest, Rich Northern Hardwood Forest, and Red Oak-Northern Hardwood Woodland (Gawler and Engstrom 2011).

Table 2.1. Upland forest and woodland vegetation classes and area mapped at MABI by Gawler and Engstrom (2011).

Mapped class	Area (ha.)	Description	USNVC Code
Northern Hardwood Forest	41.5	Dominated by sugar maple with white ash codominant. Often occurs on mid to lower concave slopes. Diverse herb layer.	CEGL006211
Hemlock - Northern Hardwood Forest/Hemlock Forest	48.2	Yellow birch and sugar maple are often codominant with eastern hemlock. Common on deep soils of lower slopes.	CEGL006109
Hemlock Forest	12.4	>=60% cover eastern hemlock. Occurs in deep soils on lower slopes, around the Pogue, and in the Pogue stream ravine.	
Rich Northern Hardwood Forest	10.9	A single mapped class with 3 variations: typic, fern glade and successional. Greater species richness and fern cover than NHF. Frequently found on toe-slopes. Canopy dominated by sugar maple. Locally important for biodiversity.	CEGL005008
Northern Hardwood Limestone Forest	2.2	A separate mapped class of the Rich Northern Hardwood Forest NVC. Occurs on upper slopes of West Ridge and a limestone knoll on Mount Tom. Locally important for biodiversity.	
Hemlock - Beech - Oak Forest	4.9	Eastern hemlock, American beech and northern red oak are codominant. Occurs on steep, upper slopes of Mount Tom.	CEGL006088
Red Oak - Northern Hardwood Forest	1.7	Canopy dominated by sugar maple, white ash and northern red oak. Hophornbeam (*Ostrya virginiana*) is a characteristic species. A single occurrence on the east shoulder of Mt. Tom.	CEGL006173
Successional Northern Hardwood Forest	7.4	Pole-sized hardwoods, primarily sugar maple with American beech and other hardwoods. Generally low herb richness.	CEGL006252
Successional Black Locust Forest	1.3	A single location adjacent to Prosper Rd. Canopy dominated by black locust and black cherry. Naturally regenerating to northern hardwoods and eastern hemlock.	CEGL007279
Red Oak Northern Hardwood Woodland	0.2	Open canopy of northern red oak, hophornbeam, sugar maple and white ash. A single occurrence on eastern shoulder of Mount Tom. Locally important for biodiversity.	CEGL005058

Plantations

About 60 ha (roughly 25% of the Park land area) are covered by plantations of varying size, age and species; the MABI Vegetation Map recognizes five plantation types (Table 2.2; Gawler and Engstrom 2011). Plantation stands range in size from 0.4 to 9 ha. The oldest plantations were planted by Frederick Billings, beginning in 1874, within the eastern portions of the forest and along the west side of Mount Tom, as well as along Elm and River Streets. Many of these older plantations of Norway spruce, white pine, eastern hemlock, European larch, and sugar maple have become naturalized with regeneration by native species. Plantations of Scots pine, red pine, Norway spruce, and white pine were set out during the early 20th century and establishment of new plantations continued until 1952. The younger plantations retain a greater percentage of their original planted species and planting pattern (NPS 2004b).

Several plantations laid out between 1874 and 1920 retain features which convey the early record of conservation and forestry practice here, including stands 1 (European larch, 1887), 3 (Norway spruce, 1887), 42a and 42b (Norway spruce and eastern hemlock, 1882), 46b (Norway spruce and hemlock, 1876-1877, and white pine, 1880), set out by Frederick Billings, and stands 18 (white pine, 1905), 27 (Norway spruce and white pine, 1896), 40 (sugar maple and white pine, 1897), set out by manager George Aitken (Figure 2.3). These stands illustrate the planting patterns and use of monoculture and mixed species used during this period of pioneering forestry practice. One of these, a Norway spruce plantation stretching west along the Mansion grounds hill (stand 42b), is often cited as a model of its type. Other plantations, such as stands 4 (red pine 1952), 13 (Norway spruce, 1950), 15 (white pine, 1930s), 16 (Scots pine, 1917), 17 (red pine 1917), 22 (Scots pine, 1930s), 25 (mixed pines, 1917) , 26 (red pine, 1917), 28 (Norway spruce, 1913), and 41 (white pine, 1911, and Norway spruce), notably retain integrity of design and character to evoke early 20th century forest restoration (NPS 2004b).

Table 2.2. Plantation types and area mapped by at MABI by Gawler and Engstrom (2011).

Mapped class	Area (ha.)	Description	USNVC Code
European Larch Plantation	2.3	A single location planted in 1887. Understory dominated by sugar maple and white ash.	CEGL006408
Mixed Conifer Plantation	6.9	Mature plantations of white or scotch pine; may also include red pine, Norway spruce or European larch. Scotch pine planted in 1917 and 1930. Planted on lower slopes with fertile soil.	CEGL006313
Norway Spruce Plantation	4.7	Generally planted on deep soils on lower slopes. Some stands are 100+ years. Naturally regenerating to northern hardwoods and eastern hemlock. Planted in 1880, 1887, 1913 and 1950.	CEGL007167
Red Pine Plantation	18	Planted on fertile soils in a variety of topographic positions, in 1917 and 1952. Hardwood regeneration in the understory.	CEGL007177
White Pine Forest	29.2	Includes both plantation and successional forest. Plantings occurred in 1880, 1905, 1911, and 1917, now dominated by high canopy of white pine. In successional areas, <=50% dominated by white pine. Naturally regenerating to northern hardwoods and eastern hemlock.	CEGL007178/ CEGL007944

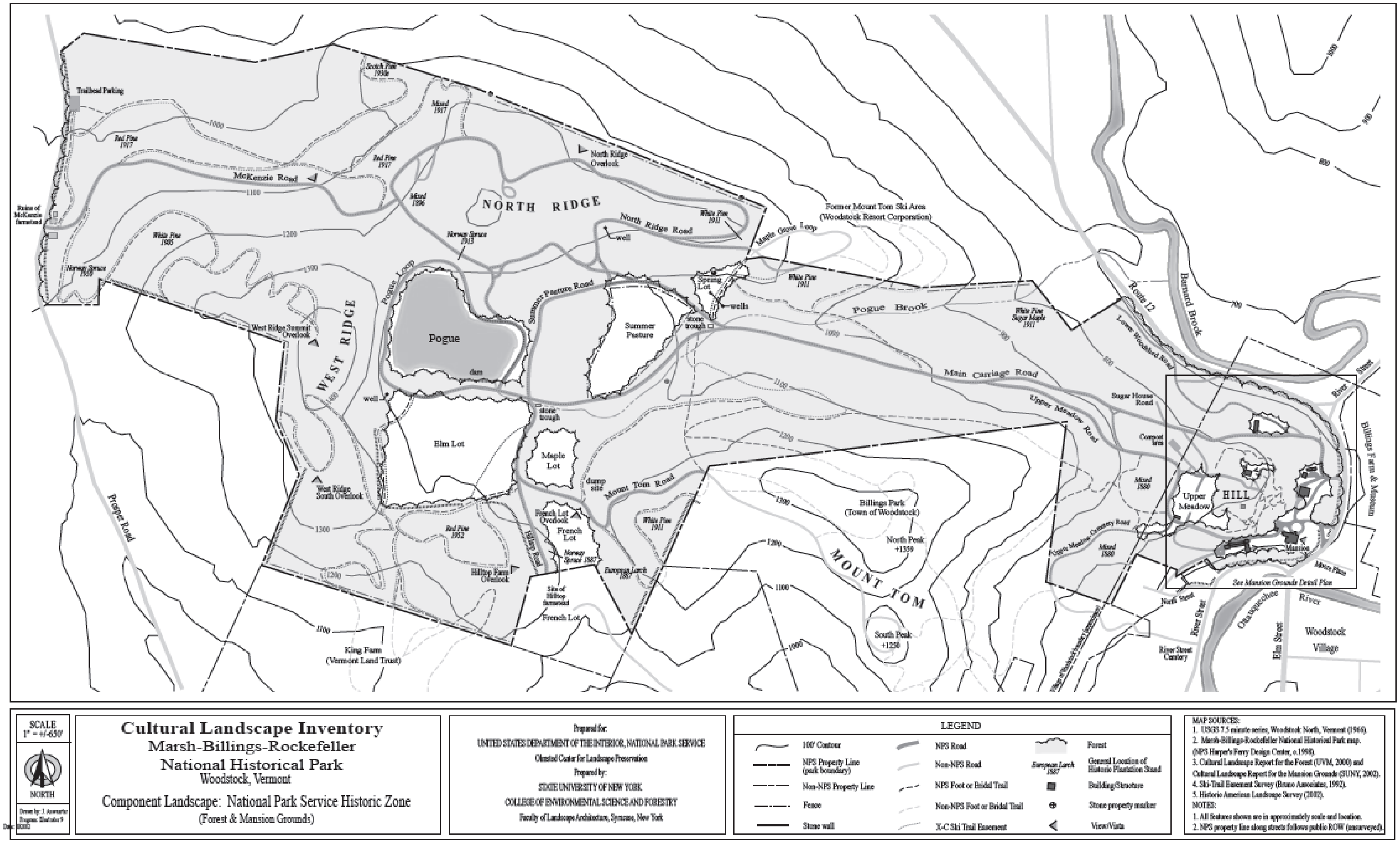

Figure 2.3. Cultural Landscape Inventory Map for Marsh-Billings-Rockefeller NHP, showing historic forest stands (excerpted from NPS 2006a).

Since the 1970s, plantations have been thinned on a regular cycle every 10 to 15-years to remove the most suppressed, damaged and diseased trees. Trees that provide beneficial wildlife habitat (e.g. cavity trees) are left in place (NPS 1999).

Legacy trees

Centuries-old hemlocks from pre-settlement days are found scattered around the Pogue and associated wetlands. Large, open-grown sugar maples dot the landscape in conifer plantations and regenerating pastures, and mark old boundaries. Rows of Norway spruce planted along carriage roads by Frederick Billings still stand and enrich the cultural landscape. These legacy trees are important historic landscape features that trace the evolution of land management over time. They also enrich the park's ecological resources by providing structural diversity and wildlife habitat (NPS 2006a). Legacy trees are assessed as a Vital Sign in Section 4.4.8 (Legacy trees).

Grassland/open field

Two small fields on gentle slopes are kept open for vistas. They are classified as Successional Old Field vegetation (CEGL006107), and have a diversity of meadow grasses and herbs, especially wild bergamot (*Monarda fistulosa*), common milkweed (*Asclepias syriaca*), and goldenrods (*Solidago* spp.). Additional hay fields and a pasture totaling about 17 ha (42 acres) are kept open, and about 4 ha (10 acres) of grounds are maintained as gardens (Gawler and Engstrom 2011).

Water resources

The only water body is the 5.8-ha (14.3-acre) Pogue, enlarged from a peatland by dredging and a dam built about 1890. The pond is fed by submerged springs and two intermittent streams flowing from the west (NPS 1999). The Park's only perennial stream, Pogue Stream, flows out from the Pogue into Barnard Brook.

Wetlands

The Pogue is a Class II Wetland protected by State of Vermont Wetland Rules (VT DEC 2010). A complex of small wetlands and vernal pools lie north and east of the Pogue, and two small wetlands lie on the park's northern boundary (Faccio 2001a, Two Rivers-Ottauquechee Regional Commission 2007). Gawler and Engstrom (2011) described three wetland associations within the Park (Table 2.3); the Northern Hardwood-Hemlock Swamp is considered to be of local importance for biodiversity. Wetland Vegetation is considered as a Vital Sign in section 4.4.3.

Vernal pools

Amphibian breeding has been documented in five vernal pools occurring north and east of the Pogue and in two vernal pools just past the park's south border on the King Farm; two additional vernal pools in the park with no documented breeding may be used as "stepping stones" for dispersing juveniles (Faccio 2001a). A radio-tracking study of Jefferson and spotted salamanders (*Ambystoma jeffersonium* and *A. maculatum*) in MABI reported the "life-zone" of important salamander habitat to extend 175 m from the edge of breeding vernal pools, and cover a 37-hectare area east of the Pogue (Faccio 2001b).

Table 2.3. Wetland types and area mapped at MABI by Gawler and Engstrom (2011).

Mapped class	Area (ha.)	Description	USNVC Code
Northern Hardwood - Hemlock Swamp	1.9	Red maple and black ash codominant, with sub-canopy of eastern hemlock. Narrow basins within the Hemlock-NHF. Locally important for biodiversity.	CEGL006502
Hemlock - Hardwood Seepage Forest	1.4	One location at the base of a moderate slope. Well-developed herb layer of ferns, sedges and herbs including Jack in the pulpit (*Arisaema triphyllum*), longstalk sedge (*Carex pedunculata*), and heartleaf foamflower (*Tiarella cordifolia*).	CEGL006380
Enriched Hardwood Forest Seep	<0.02	Small patches on lower slopes. Herbaceous community characterized by common ladyfern (*Athyrium filix-femina*), sensitive fern (*Onoclea sensibilis*), and jewelweed (*Impatiens capensis*).	CEGL006409

Rare plants

No federally listed rare plant species have been documented at MABI. One state-listed threatened plant species (Male fern, *Dryopteris filix-mas*) is cultivated at MABI, but has not been documented in natural communities (Hughes and Cass 1997, Gawler and Engstrom 2011). Six rare or uncommon plant species (including five sedges) were documented in natural communities at MABI by the USGS mapping project (Gawler and Engstrom 2011). These plants are: summer sedge (*Carex aestivalis*), Minnesota or white bear sedge (*Carex albursina*), Back's sedge (*Carex backii*), Hitchcock's sedge (*Carex hitchcockiana*), spreading sedge (*Carex laxiculmis*), and glade fern (*Diplazium pycnocarpon*). All are ranked S3 (vulnerable in Vermont; VNHI 2012b). A seventh species (American milletgrass, *Milium effusum*) noted as rare by that report, is not currently considered vulnerable in Vermont (VNHI 2012b).

Common moonwort (*Botrychium lunaria*) was reported to be present in the park historically and as late as 1970 (Hughes and Cass 1997). All reports of this plant in VT are now considered to be misreported occurrences of Mingan moonwort (*Botrychium minganense,* a state-endangered plant), and neither of these moonworts was found by Hughes and Cass (1997). Hughes and Cass (1997) also searched for state-vulnerable (S3) leathery grape fern (*Botrychium multifidum*) and state-imperiled (S2) broad beech fern (*Phegopteris hexagonoptera*), both of which were reported to grow in the park, but neither species was found. The state-threatened autumn coral-root (*Corallorhiza odontorhiza*) has been reported present at MABI (NPS 1999), but was not documented by Hughes and Cass (1997).

Wildlife

Thirty-two mammal species occur on the certified species list of mammals present or probably present in the Park, including moose (*Alces alces*), black bear (*Ursus americanus*), coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), fisher (*Martes pennanti*), muskrat (*Ondatra zibethicus*), woodchuck (*Marmota monax*) and seven bat species (NPS 2014a). Twenty-three of these mammals were detected by the Park mammal inventory (Gilbert et al. 2008) and all seven bat species were documented by the Park bat inventory (Reynolds and McFarland 2001). In addition to these 32 certified species, Virginia opossum (*Didelphis virginiana*) has been sighted and photographed in the park; a bobcat (*Lynx rufus*) was documented in the park by automated camera in 2011; and two river otter (*Lutra canadensis*) sightings were reported in 2010 (Jones 2011).

The Park bird inventory detected 91 bird species, with 73 species confirmed or suspected to be breeding in park (Faccio 2003); 58 species have been detected by ongoing monitoring beginning in 2006 (Faccio and Mitchell 2013). The Park amphibian and reptile inventory documented 13 amphibian species (six salamanders and seven frogs), and five reptiles (three snakes and two turtles; Faccio 2001a). The only two fish species documented to occur in the Pogue (yellow perch [*Perca flavescens*] and large-mouthed bass [*Micropterus salmoides*]) were introduced (Mather et al. 2003, NPS 2014a); the former is native to the area.

No federally protected rare animal species have been documented in the Park. However, three bat species documented in the park are newly listed as endangered by the State of Vermont (*Myotis lucifugus, M. septentrionalis*, and *Perimyotis subflavus*), and two other bat species documented in the park are considered Species of Greatest Conservation Need (SGCN) in Vermont (*Lasiurus cinereus* and *Lasionycteris noctivagans*; VNHI 2012a). Two additional SGCN in Vermont, the Jefferson salamander (*Ambystoma jeffersonianum*) and the long-tailed weasel (*Mustela frenata*) are found in the park. Twenty-three of the monitored bird species are considered Partners in Flight (PIF) species of regional or national concern (Table 2.4; Faccio and Mitchell 2013).

Table 2.4. Bird species detected by monitoring (2006-2012) at MABI which are Partners-in-flight (PIF) species of concern. CBSD = Common Bird in Steep Decline; RC = Regional Concern Species; RS = Regional Stewardship Species; UCC = USA/Canada Concern Species; UCS = USA/Canada Stewardship Species. Adapted from Faccio and Mitchell (2013).

Bird Species	PIF Code
Broad-winged Hawk (*Buteo platypterus*)	RS UCS
Chimney Swift (*Chaetura pelagica*)	CBSD
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	UCS
Hairy Woodpecker (*Picoides villosus*)	UCS
Eastern Wood Pewee (*Contopus virens*)	RC
Eastern Kingbird (*Tyrannus tyrannus*)	RC
Blue-headed Vireo (*Vireo solitarius*)	UCS
Red-eyed Vireo (*Vireo olivaceus*)	UCS
Black-capped Chickadee (*Poecile atricapillus*)	UCS
Winter Wren (*Troglodytes troglodytes*)	UCS
Veery (*Catharus fuscescens)*	RC RS UCS
Wood Thrush (*Hylocichla mustelina*)	RC UCC
Cedar Waxwing (*Bombycilla cedrorum*)	UCS
Black-throated Blue Warbler (*Dendroica caerulescens*)	RS UCS
Black-throated Green Warbler (*Dendroica virens*)	RS UCS
Blackburnian Warbler (*Dendroica fusca*)	RS UCS
Black-and-White Warbler (*Mniotilta varia*)	RS UCS
American Redstart (*Setophaga ruticilla*)	RS UCS
Ovenbird (*Seiurus aurocapillus*)	UCS
Common Yellowthroat (*Geothlypis trichas*)	UCS
Scarlet Tanager (*Piranga olivacea*)	RC
Song Sparrow (*Melospiza melodia*)	UCS
Bobolink (*Dolichonyx oryzivorus*)	CBSD RC UCC

Landscape

The landscape at MABI is a nationally significant cultural resource, recognized for the historic forest conservation practices which were pioneered here, as well as for association with the prominent individuals who lived here, and as an example of historic agriculture and landscape design. The Historic zone at MABI is significant under National Historic Register Criterion A, for its association with conservation in forestry and as an example of a model farm in the history of agriculture in Vermont; under Criterion B for its for association with the prominent conservationists George Perkins Marsh, Frederick Billings, and Laurance Spelman Rockefeller; and under Criterion C as an example of a model farm in Vermont and as an example of landscape design during the Country Place Era, including the work of a master, Charles A. Platt (16 U.S.C. § 410vv, NPS 2004b). The landscape includes historic plantations, open fields and scenic vistas interspersed with naturally regenerating forest.

Since the 1880s, when Frederick Billings established a network of carriage roads and trails, visitors have enjoyed this varied landscape of hills and valleys, naturally regenerating forest and plantations, agricultural fields, and the Pogue. The landscape reflects the interplay between human activity and forest management responding to and working with the natural systems and ecological constraints of this site, as well as 19th century landscape design – which informed the placement of cultural landscape features. The estate's grounds include an azalea-rhododendron garden, rock gardens, terraces and a hillside woodland garden designed by notable landscape architects (NPS 1999). Existing fields convey the historic agricultural use of the forest, and existing patterns of wolf trees and stone walls further illustrate the forest history (NPS 2004b).

Resource Issues Overview

Key natural resources issues affecting MABI include global and regional threats with serious impacts on natural resources, including climate change, atmospheric deposition, habitat fragmentation, invasive exotic species including forest pests and pathogens, as well as local issues related to park management (Mitchell et al. 2006). These global and regional threats originate primarily outside of the park's borders. Climate change is already having measurable impacts on many species across the globe, and is expected to have dramatic impacts over the coming century (IPCC 2007). Atmospheric deposition is a key concern affecting forest health and soil quality across the region (Likens et al. 1996, Driscoll et al. 2001), and the advance of invasive exotic forest pests is a substantial threat to forest resources (Gandhi and Herms 2010). MABI is a relatively small park, and landscape fragmentation of surrounding land can have large impacts on park resources. Much of the privately-owned land adjacent to the national park is zoned for five-acre residential development, but some of the land north of MABI, along Vermont Route 12, is zoned for business and light industry (NPS 1999).

MABI is unusual within the National Park System due to its cultural mandate of continuing forest and agricultural management and resource extraction within the Park; these activities are key drivers of natural resource condition at MABI, including soil and water quality, forest condition, maintenance of wildlife habitat, and protection of sensitive vegetation (NPS 2004c).

Resource Stewardship

Management Directives and Planning Guidance

The Mount Tom forest is a nationally significant cultural landscape with a long tradition of enlightened forest management by the Billings and Rockefeller families. NPS defines "cultural landscapes" as geographic areas (including both cultural and natural resources and the wildlife therein) associated with a historic event, activity, or person or exhibiting other cultural or aesthetic values (NPS 1999). The NPS Organic Act of 1916 directs NPS to "conserve the scenery and the natural and historic objects and wild life... unimpaired for the enjoyment of future generations" (16 USC 1).

The Park's enabling legislation establishes the primary purpose of the Historic zone (comprised of estate grounds and Mt. Tom forest) to be preservation, education and interpretation (16 U.S.C. § 410vv). In a letter appended to the enabling legislation (Public Law 102-350), then NPS Director James Ridenour established the need for ongoing active forest management for preservation and interpretation of the forest resource at MABI.

The selected alternative within the Park's General Management Plan (GMP) established that MABI is to be managed in partnership by the NPS and the Woodstock Foundation Inc., a private foundation which owns and operates the Billings Farm & Museum, to manage, operate and interpret the cultural landscape. The GMP further established that:

- park managers will continue to actively manage the forest as part of the park's cultural landscape;
- areas containing features, materials, vistas, and spaces contributing to the forest's historical significance will be managed with an emphasis on preservation, with significant features replaced as necessary "in-kind";
- historical practices that may appear to conflict with normally accepted management practices will be evaluated to determine whether or not they are consistent with good stewardship and whether they should continue;
- areas containing significant natural features, such as federal- or state-listed rare or endangered species, will be managed for preservation;
- areas that do not contain primary historic or significant natural features may be used for special forestry activities in support of the park purpose and that relate to the overall interpretive program; and
- park managers, in cooperation with others, will inventory and monitor plant and animal populations, specifically any threatened, rare or endangered species. (NPS 1999)

The Park's Forest Management Plan and Environmental Assessment (FMP; NPS 2006a) built upon this foundation by establishing the following seven management goals:

- **Retain Historic Character**: The Forest will be managed as a cultural landscape to retain features and characteristics that illustrate the evolution of reforestation and forest management on Mount Tom, interpret the stewardship ethic promoted by the Marsh, Billings, and Rockefeller families, and preserve the essential characteristics of a model nineteenth-century country estate.

- **Sustain and Enhance Ecological Health**: The Park will sustain and seek to enhance the forest's ecological health using best thinking and practices in ecological science and forest management.

- **Model Sustainable Management Practices**: The Park will draw upon contemporary sustainable forestry and agricultural practices in managing the Mount Tom Forest.

- **Provide Diverse Place-Based Education and Interpretation Opportunities**: The Park will provide programs and opportunities for Park visitors, school groups, private woodland owners, conservation professionals, and others to learn about the history of conservation and the principles of contemporary forest management through hands-on, place-based programs.

- **Promote Visitor Use and Recreation**: The Park will continue to manage the Forest for diverse recreational experiences and visitor enjoyment.

- **Enhance Watershed and Community Connections**: The Park will continue to pursue opportunities to work in concert with others to sustain the forest's diverse values and achieve greater watershed and community benefits.

- **Utilize Adaptive Management to Evaluate and Refine Management Activities**: The Park will employ a program of adaptive management to better understand change in the Forest, and to evaluate and refine forest management activities by integrating new science, results from monitoring programs, and best management practices of the day. Ongoing public involvement will encourage a dialogue on the evolving nature of land stewardship and help to inform the Park's forest management.

To achieve these goals, the Forest Management Plan developed the NPS-preferred management alternative "Recognize and Work with Ecological Change in Preserving the Historic Character of the Forest." Under this approach, MABI forest management seeks to "preserve broad landscape patterns and representative features that contribute to the distinctive historic character of the Forest, while working with the forces of ecological change and continuing to apply best current thinking and practices in forest management." This approach balances the need for preserving the Forest's historic character (as directed by the National Historic Preservation Act) with the need for conserving park resources unimpaired (as directed by the NPS Organic Act). It recognizes the dynamic nature of both the ecological systems found here and the human forces acting upon them (NPS 2006a).

Under this approach, management of plantations is site-specific. Plantations along principal carriage roads or that frame key views are managed to illustrate the character of reforestation techniques used on Mount Tom from 1887 to 1952, and a few key plantations, such as those adjacent to the Mansion grounds, are carefully maintained using trees which are direct descendants or genetic legacies of historic stock. New plantations along field edges or in key locations are established using historic species and planting patterns, or alternative native species that are suitable to the site. In less visible locations, plantation management is driven by site conditions to encourage conifer regeneration on suitable sites or to favor regeneration of native species on other sites (NPS 2006a).

Various silvicultural practices are used to achieve these goals. Uneven-aged management is used in mixed forest stands to promote diversity of age classes and vertical structure. Management is limited in natural areas of special management concern, which include wetlands and steep slopes. Legacy trees are retained as long as possible. New legacy trees are to be selected and allowed to grow large to enrich the cultural landscape and provide for wildlife habitat. Hayfields and pastures are retained by cultivating perennial grasses through annual mowing or grazing and nutrient management to maintain the landscape mosaic. Existing or historic vistas are maintained through mowing or thinning. Wildlife habitat is enhanced by increasing large diameter trees, snags, coarse woody debris, and slash, where appropriate. Under this management approach, the Mount Tom forest should retain key features valued for historic or ecological reasons, but these features will not exist exactly or in the same place as they do now or did historically. This approach is designed to maintain the cultural landscape while working with ecological change. The Mount Tom Forest is certified by the Forest Stewardship Council (FSC) to verify the use of responsible forest practices (NPS 2006a).

The park operates under a policy of wildland fire suppression, to protect cultural and historical resources within the park and the neighboring community. No prescribed fire is used at this park (NPS 2005). In addition, NPS is mandated to protect native species while controlling invasive species (NPS 2006b). MABI manages known populations of prioritized invasive exotic species using a variety of mechanical and chemical treatments consistent with Integrated Pest Management (IPM), with the assistance of Redstart Forestry, Inc. and park interns (Currie 2006, Wheeler and Miller 2013).

Status of Supporting Science

MABI is part of the Northeast Temperate Network (NETN) of the NPS Inventory and Monitoring Program (I&M). As part of this program, twelve baseline inventories have been completed (Water quality, Base cartography, Air quality data, Air quality related values, Climate, Geologic resources, Soil resources, Water body location and classification, Vegetation map, Species lists, Species occurrence and distribution, and Natural resource bibliography); six Vital Sign Inventories have been completed (Breeding birds, Amphibians and reptiles, Terrestrial mammals, Vegetation classification and mapping, Fish, and Land cover); and monitoring is underway for six monitoring protocols (Air quality, Breeding landbird, Invasive species – Early detection, Forest health, Phenology, and Lakes, ponds & streams). These and many other data sources are summarized in Table 2.5.

Table 2.5. Datasets available for assessing natural resource condition at Marsh-Billings-Rockefeller National Historical Park. GIS indicates spatial data are available.

Natural Resource or Issue	Data type	Year(s) collected	Source
Air quality	Air quality assessment Deposition sensitivity assessment Ozone sensitivity assessment Dry deposition monitoring	1999-present, ongoing Ongoing	NPS ARD 2013 Sullivan et al. 2011a, 2011b NPS 2004a CASTNET (www.epa.gov/castnet)
Contaminants	Hg in litterfall and upper soil horizons Hg and MeHg conc. in vernal pools Monitoring Hg in dragonfly nymphs Hg wet deposition monitoring	2009 2010-2011 2010-2011, ongoing 2004-presesnt, ongoing	Juillerat et al. 2012 Davis 2013 Nelson and Flanagan 2013 Mercury Deposition Network (nadp.sws.uiuc.edu/mdn)
Climate & Phenology	Climate inventory Status and trends assessment Phenology monitoring (GIS)	2006 2011 2010-present, ongoing	Davey et al. 2006 Morris et al. 2011 NETN
Forest soil	Soil chemistry monitoring (GIS) Soil chemistry study Soil carbon, other quality indicators	2006-present, ongoing 2004, ongoing? 2009, ongoing?	NETN (Miller et al. 2013) Schroth et al. 2007 Donald Ross at UVM, www.uvm.edu/~soilcrbn/
Water quantity and quality	Baseline report Monitoring (GIS)	1998-1999 2006-present, ongoing	Farris and Chapman 2000 NETN (Gawley 2013)
Streams-macroinvertebrates	None	N/A	N/A
Invasive species – early detection	Invasive plant inventory Invasive aquatic plant detection and monitoring Invasive species early detection (ISED) HWA risk assessment Forest invasive plant monitoring (GIS) Invasive plant detection, assessment and management Occurrence tracking and assessment (GIS)	2003 2007-present, ongoing 2010-present, ongoing 2004 2006-present, ongoing 2008-present, ongoing 2006-present, ongoing	Shriver et al. 2004 NETN (Gawley 2013) NETN (Wheeler and Miller 2013) Machin et al. 2005 NETN (Miller et al. 2013) Vellia and Zamaria 2010 MABI (in WIMS database)
Wetland vegetation	Town-wide inventory Forested wetland monitoring (GIS)	2003 2006-present, ongoing	Arrowwood Environmental 2004 NETN (Miller et al. 2013)
Forest vegetation and plantations	Monitoring (GIS) Monitoring (GIS) Silvicultural inventory Silvicultural inventory (GIS) Annual stand surveys	2006-present, ongoing 2001-2003 2004 2006 – present, ongoing 2010-present, ongoing	NETN (Miller et al. 2013) Keeton 2005 NPS 2004c Restart Forestry 2006 Ruddell and Machin 2011

Natural Resource or Issue	Data type	Year(s) collected	Source
	Forest management and inventory		Wiggin 1993
White-tailed deer herbivory	Spotlight counts (GIS) WMU population estimates Herbivory impacts monitoring (GIS)	2011-2012, ongoing 2000-present, ongoing 2006-present, ongoing	NETN VFW 2012a, VFW 2012b NETN (Miller et al. 2013)
Breeding birds	Inventory Monitoring (GIS) Monitoring	2001-2002 2006-present, ongoing	Faccio 2003 NETN (Faccio and Mitchell 2013) eBird (ebird.org)
Amphibians and reptiles	Inventory Salamander tracking Monitoring (GIS) Acoustic monitoring	1999-2000 2000 2009-2011 2010	Faccio 2001a Faccio 2001b Faccio 2011 Brauer 2012
Fish	Inventory	1999-2001	Mather et al. 2003
Legacy trees	Inventory (GIS)	2001-2003	Keeton 2005
Bats	Inventory Resampling	2001 2011	Reynolds and McFarland 2001 McFarland 2011
Terrestrial mammals	Inventory	2004	Gilbert et al. 2008
Terrestrial invertebrates	None	N/A	N/A
Visitor usage	Automated counters and visitor sign-in	1998-present, ongoing	NPS 2013
Forest management	Annual management audit	2005-present, ongoing	Rainforest Alliance 2013
Vegetation classification and mapping	Natural community assessment (GIS) Classification and mapping (GIS)	2002 2011	Lautzenheiser 2002 Gawler and Engstrom 2011
Landcover / ecosystem cover	Landcover change Landcover and land use Population and housing density	1973-2002 2005-2006 Various	Wang and Nugranad-Marzilli 2009 NPS 2014b NPS 2014b
Land Use	Land use history	Various	Foulds et al. 1994
Surrounding landscape / connectivity	Assessment	2007	Allen et al. 2007
Cultural landscape	Archaeological assessment Cultural landscape inventory Cultural landscape report - Grounds Cultural landscape report - Forest	2007 2004 Various Various	Kenny and Crock 2007 NPS 2004b Auwaerter and Curry 2005a,b,c Wilcke et al. 2000
Soundscape	Model predictions	N/A	NPS Natural Sounds & Night Skies Division (NSNSD)
Lightscape	Model predictions	N/A	NPS NSNSD

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Chapter 3. Study Scoping and Design

Preliminary Scoping

A scoping meeting was held in September 2012 at MABI and was attended by Kyle Jones (MABI Resource Manager), Christina Marts (MABI Assistant Superintendent), Brian Mitchell (NETN Inventory and Monitoring Program Manager), Adam Kozlowski (NETN Data Manager), Peter Sharpe (NPS), and Geri Tierney (SUNY ESF). During the scoping session, Peter Sharpe described the NRCA process and outlined the expectations of NPS for content and format, as well as park participation in choosing a study design, indicators and reporting format. Geri Tierney presented the NETN Vital Sign framework (Mitchell et al. 2006) as a possible framework to guide selection and reporting of indicators for this NRCA, and the Natural Resource Condition Assessment for the Roosevelt-Vanderbilt National Historic Sites (ROVA; Cole et al. 2012) as a possible reporting format for this NRCA. An alternative indicator framework and reporting format with greater focus on pictorial schematics and numerical “roll-ups” of condition within indicator categories (as in Carruthers et al. 2011) were also discussed. Following discussion of framework and reporting format, the group brainstormed to identify all useful data products available from Park sources, the NETN, NPS, collaborators and other regional sources. Most of these are available online via the NPS Integration of Resource Management Applications (IRMA) portal. The group briefly discussed whether Park representatives wished to see management recommendations included within the NRCA, but a decision was not reached.

Study Design

Indicator Framework, Focal Study Resources and Indicators

The scoping group decided to use the NETN Vital Signs framework (Mitchell et al. 2006) to guide selection and reporting of indicators for this NRCA. Starting from the list of 19 vital signs selected for MABI (Mitchell et al. 2006), the scoping group deselected 1 Vital Sign (Fishes) of low importance at MABI, combined 2 related Vital Signs (Climate & Phenology), and added 7 additional indicators of interest to NPS staff (Wetland vegetation, Legacy trees, Bats, Mammals, Terrestrial invertebrates, Soundscape and Lightscape) for a total of 24 Vital Signs or other indicators to be reported herein (Table 3.1). After review of an interim product in November 2013, Christina Marts requested the addition of ‘Forest management’ and ‘Historical cultural landscapes’ as additional Vital Signs. Forest management was included in subsequent drafts, bringing the total number of Vital Signs to 25, while consideration of historical cultural landscapes was included within existing Vital Signs (Legacy trees and Landcover /ecosystem cover /connectivity). One or more metrics are used to describe the condition of each Vital Sign or other indicator selected for inclusion.

Reporting Areas

MABI is a small park comprised of naturally regenerating forest stands interspersed with plantations. The scoping group decided to assess plantations separately, and using different criteria, from naturally regenerating forest.

Table 3.1. NPS Vital Signs assessed as indicators of natural resource condition at Marsh-Billings-Rockefeller National Historical Park.

Category	**Vital Sign**	**Metrics**
Air and Climate	Ozone	Ozone concentration, injury to sensitive species
	Acidic deposition & stress	Total N and S wet deposition rates, dry deposition rates
	Contaminants	Hg concentration in wet deposition
	Climate & phenology	Monthly temperature and precipitation, phenophase dates, snow cover duration and depth
Geology and Soils	Forest soil condition	Nutrient ratios, base saturation
Water	Water quantity (Pond/Stream)	Pond water level, stream discharge
	Water chemistry (Pond/Stream)	Temperature, pH, DO, specific conductance, N, P, ANC
	Streams-macroinvertebrates	Density, species richness, index of sensitive taxa, etc.
Biological Integrity	Invasive exotic plants	Presence and relative abundance of key species
	Invasive exotic animals	Detections of key pests
	Wetland vegetation	Extent, width and condition of buffer, % cover of invasive plants, qualitative assessment of disturbance and alteration
	Forest vegetation	Forest structural stage, snag abundance, coarse woody debris, tree regeneration, tree condition and forest pests, tree growth and mortality rates
	White-tailed deer herbivory	Deer population density, browse vegetation impacts
	Breeding birds	Guild species richness, population trend
	Amphibians and reptiles	Amphibian index of biotic integrity, population trend
	Legacy trees	Number of legacy trees
	Bats	Species richness, population index
	Mammals	Species richness, population trend
	Terrestrial invertebrates	Species richness, population trend
Human Use	Visitor usage	Number of visitors by location and activity, visual assessment of trampling
	Forest management	FSC certification
Landscapes	Landcover / ecosystem cover / connectivity	Land cover change, forest patch size distribution
	Land use	Anthropogenic land use, nearby housing density
	Soundscape	Anthropogenic sound pressure level
	Lightscape	Anthropogenic light ratio

General Approach and Methods

Assessment points are used to distinguish expected or acceptable condition from undesired conditions that warrant concern, further evaluation or management action (Bennetts et al. 2007). Assessment points were drawn from knowledge of ecological integrity, as well as from regulatory or program standards, park management goals, historical data, data from relatively undisturbed sites, predictive models, or expert opinion. When warranted by available information from one or more of these categories, an additional assessment point was set to attempt to distinguish conditions that warrant "moderate" from "significant" concern. For example, the scientific literature on white-tailed deer browsing impacts on native vegetation in the eastern U.S. suggests that negative impacts on vegetation may be measurable at deer density levels as low as 8 deer/km^2, but that severe impacts are documented at deer densities at or above 20 deer/km^2 (section 4.4.5). In this case, two assessment points were used.

In a National Historical Park such as MABI, expected or acceptable condition for ecological integrity will sometimes conflict with desired condition for preservation or interpretation of a historical landscape; this potential conflict is evident in Vital Signs such as Landcover and Forest vegetation. In these cases, assessment of ecological integrity benchmarks is valuable because it provides a deeper understanding of park condition, as well as a consistent baseline to assess management goals. Where possible, we have also considered park management goals. Additional condition reporting based on park management goals may become possible as NETN and park staff progress in development of scorecards that track progress towards park resource management goals.

Trend in condition was determined by a statistical test of significance if sufficient data were available. Unless otherwise specified, an alpha value of 0.10 was used to determine statistical significance.

Confidence in condition status was assigned by considering the quality and depth of the available data, as well as the justification for the assessment points used to determine condition. High confidence was assigned to assessments based on abundant, quantitative data from multiple sites reflecting the range of variation in the park resource, and which relied on well-justified assessment points. Medium confidence was assigned to assessments based on sufficient, quantitative or qualitative data from at least one representative site in or near the park, and which relied on well-justified assessment points. Low confidence was assigned to assessments based on preliminary or incomplete data, or preliminary or incomplete assessment points. Confidence in trend was based on the length and quality of the dataset and the level of significance of the trend. High confidence in trend was reserved for datasets containing at least 10 years of quantitative data, while moderate confidence in trend required a dataset at least 5 years.

NPS stoplight reporting categories and symbology (Table 3.2) are used to report condition status, trend, and confidence in a report card format (Appendix A). For cases in which confidence in condition status differed from confidence in trend, confidence in condition status was presented in the report card symbol.

Table 3.2: NPS symbology for reporting resource condition, trend and confidence in assessment.

Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in Good Condition		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Warrants Significant Concern		Condition is Deteriorating		Low

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Chapter 4. Natural Resource Conditions

Air and Climate

Ozone

Description and Relevance

Ground level ozone is a hazard to human health and to vegetation, particularly to ozone-sensitive species. Ozone is produced by a chemical reaction of nitrogen oxides and volatile organic compounds, from industrial and automobile emissions, in the presence of sunlight during hot summer months. MABI is located in an ozone attainment region, indicating that ozone levels do not exceed the U.S. Environmental Protection Agency (EPA)'s National Ambient Air Quality Standards (NAAQS) for ozone (U.S. EPA 2012). A network risk assessment of ozone injury for MABI determined low risk due to low regional ozone exposure levels, but noted several ozone-sensitive species onsite and soil moisture conditions favorable to ozone uptake (NPS 2004). Twenty ozone-sensitive species have been identified at MABI, including white ash (Table 4.1). Sensitive species may experience foliar injury due to ozone exposure levels below assessment points targeted at protecting human health (NPS ARD 2011).

Table 4.1. Ozone-sensitive plant species at MABI (NPS 2006).

Common name	Latin name	Common name	Latin name
Groundnut	*Apios americana*	Green ash[1]	*Fraxinus pennsylvanica*
Hemp dogbane	*Apocynum cannabinum*	Virginia creeper	*Parthenocissus quinquefolia*
Spreading dogbane	*Apocynum*	American sycamore	*Platanus occidentalis*
Swamp milkweed	*Asclepias incarnata*	Quaking aspen	*Populus tremuloides*
Common milkweed	*Asclepias syriaca*	Black cherry	*Prunus serotina*
Whorled aster	*Aster acuminatus*	Chokecherry	*Prunus virginiana*
Big-leaf aster	*Aster macrophyllus*	Black locust	*Robinia pseudoacacia*
Devil's darning needles	*Clematis virginiana*	Allegheny blackberry	*Rubus allegheniensis*
White snakeroot	*Ageratina altissima*	American elder	*Sambucus canadensis*
White ash	*Fraxinus americana*	Red elderberry	*Sambucus racemosa*

[1]Green ash (*Fraxinus americana*) may not be present in natural habitats in the park, but it was planted in the parking lots (K. Jones, personal communication, 26 March 2014).

Data and Methods

NPS Air Resources Division (ARD) has calculated annual statistics estimating ozone values at all national park units using data from a national network of ozone monitoring stations, and has calculated ten-year trend in ozone condition at a subset of park units. ARD condition estimates are five-year averages based on available data from ozone monitoring stations across the country, and are interpolated for parks without onsite ozone monitoring stations. The closest ozone monitoring station to MABI is 56 km (35 miles) away in Sullivan County, NH.

In addition, the Vermont Department of Forests, Parks and Recreation (DFPR) has conducted annual ozone biomonitoring in MABI since 2005 to monitor ozone effects on sensitive vegetation, as part of the USFS FIA program (NPS Investigator Annual Reports 2005-2010).

Assessment Points

NPS ARD has used the U.S. EPA's NAAQS's ozone standard to assess ozone condition in national park units (NPS ARD 2013). This standard, based on protecting human health, assesses the multi-year average of the annual fourth-highest daily maximum 8-hour average ozone concentrations (ppb) as shown in Table 4.2. The U.S. EPA standard specifies a three-year average; NPS calculates five-year averages (NPS ARD 2011). However, ARD recognizes that effects on vegetation should also be considered in ozone condition ratings for national park units. For that reason, NPS has developed ozone condition ratings based on cumulative exposure over the growing season using W126 and SUM06 (Table 4.2; NPS ARD 2011). W126 is calculated as the "sum of hourly weighted ozone concentrations summed over daylight hours for each 3-month period during the local ozone season, with higher concentrations weighted more heavily. The annual maximum 3-month period is then averaged over 5-years" (NPS ARD 2012). SUM06 is calculated as the "sum of hourly ozone values equaling or exceeding 0.060 ppm summed over daylight hours for each 3-month period during the growing season. The annual maximum 3-month period is then averaged over 5-years" (NPS ARD 2012). This W126 rating is thought to be protective for growth of tree seedlings in natural ecosystems (NPS ARD 2011). An ozone risk assessment for NETN suggested a W126 assessment point of 5.9 ppm-hr to protect highly sensitive species in the network (NPS 2004), which is slightly lower than the current ARD recommendation.

Table 4.2. Ozone condition rating developed by NPS ARD (2011).

Condition rating	4th highest 8-hr (ppb)	W126 (ppm-hrs)	SUM06 (ppm-hrs)
Good condition	<= 60	< 7	< 8
Moderate concern	61 - 75	7 - 13	8 - 15
Significant concern	>= 76	> 13	>15

Condition and Trend

ARD interpolated a 5-yr average (2006-2010) ozone estimate for 4th highest 8-hour concentration of 67.9 ppb for MABI, a value which warrants moderate concern, and 5-year averages of both W126 and SUM06 to be 5.1 ppm-hrs (NPS ARD 2012), indicating good condition. ARD did not determine trend for MABI; ten-year trends in ozone condition at national park units in neighboring states (NY and MA) range from unchanging to significant improving trend (Figure 4.1; NPS ARD 2013).

DFPR reports ozone injury was suspected or confirmed to white ash seedlings and/or saplings at MABI in 2005, 2006, and 2009. No injury was detected to other monitored species, and no injury to any species was detected in 2007, 2008 or 2010 (NPS Investigator Annual Reports 2005-2010).

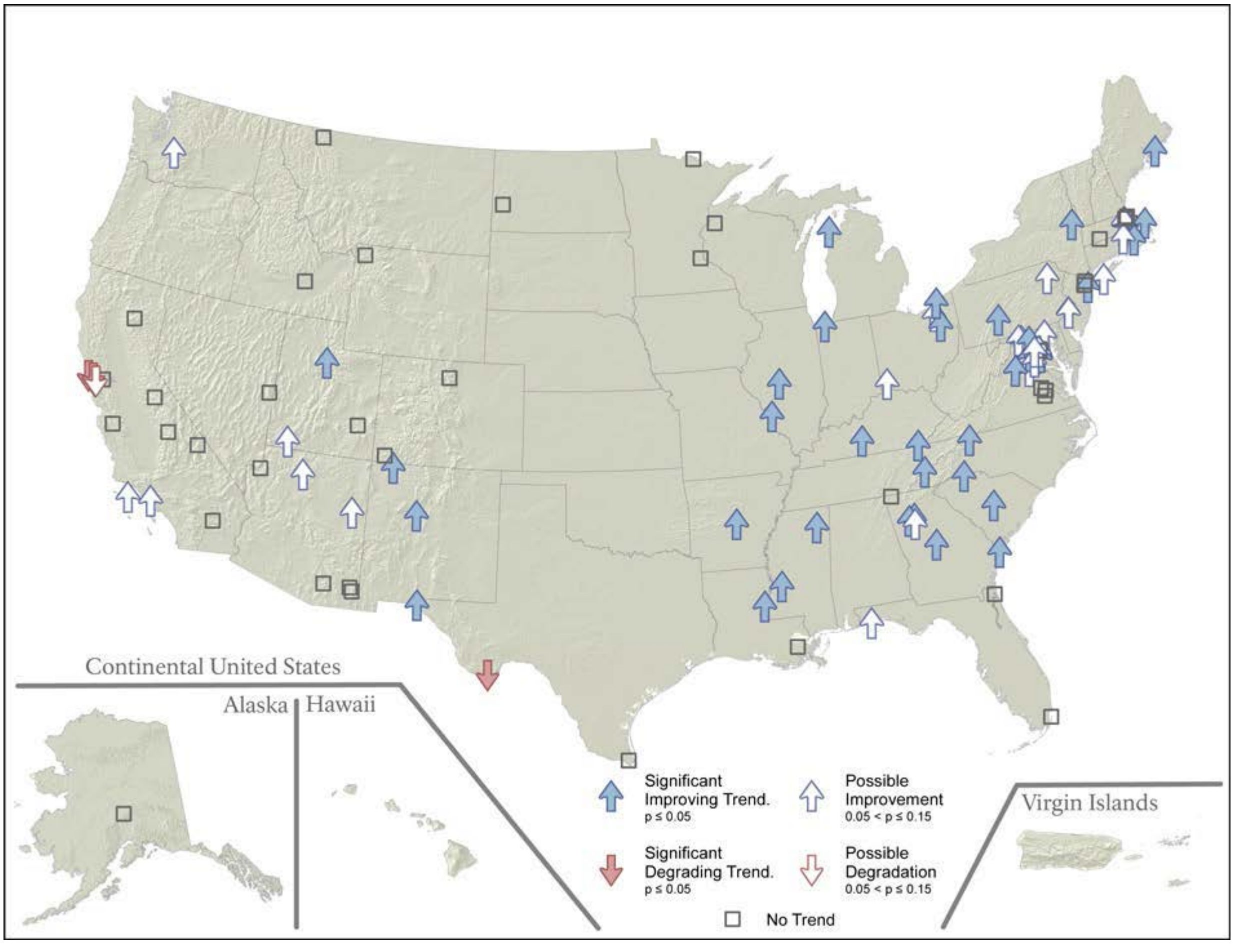

Figure 4.1. National trends in annual 4th-highest daily maximum 8-hour average ozone concentration (ppb/yr), 2000–2009 (excerpted from NPS ARD 2013).

Data Gaps and Level of Confidence

Confidence in status assessment is medium. Ozone condition was interpolated from multi-year quantitative data collected at least 56 km (35 miles) away, and was supplemented by qualitative data from onsite monitoring of ozone-sensitive species. Trend was not assessed due to insufficient data.

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Acidic Deposition & Stress

Description and Relevance

Emissions of sulfur (S) and nitrogen (N) from power plants, factories, automobiles and other sources have dramatically altered precipitation chemistry in many regions, particularly the northeastern U.S. (Driscoll et al. 2001). Atmospheric deposition of S and N has contributed to acidification of soils and surface waters, export of nutrient cations (Ca, Mg, etc.), and mobilization of aluminum (Al; a toxin) in soils (Likens et al. 1996, Reuss and Johnson 1985). In addition, sulfur deposition can stimulate microbes to methylate mercury (Hg) into a toxic, bioavailable form (U.S. EPA 2008). Nitrogen (N) is a limiting nutrient necessary for plant growth that has historically been retained within northeastern forested ecosystems. As atmospheric deposition has increased N inputs by five- or 10-fold in the northeastern U.S., concern has arisen that excess N may “saturate” forested ecosystems, causing excess nitrification and N leaching which in turn would exacerbate the effects of acidification (Aber et al. 1998).

Broad-scale patterns of wet deposition across the northeast are well characterized and are most substantial at high elevations and in the southern and western parts of the northeast region, diminishing to the northeast (U.S. EPA 2008). Substantial additional acidity can result from dry and occult deposition, and these patterns of deposition are not well characterized (NPS ARD 2013). Since passage of the 1990 Clean Air Act Amendments, wet deposition of S has decreased 35% or more across the eastern US, while wet deposition of N changed little in the 1990s, but generally has decreased since 2000 (U.S. EPA 2008).

Sullivan et al. (2011a) assessed ecosystem sensitivity to acidification for I&M park units based on vegetation, lakes and streams within the park. MABI was found to have very high ecosystem sensitivity, moderate pollutant exposure and moderate park protection yielding an overall high risk from acidic deposition. Sugar maple, a widespread species at MABI, is known to be acid-sensitive due to the species’ high need for calcium (Sullivan et al. 2013). Sullivan et al. (2011b) also assessed sensitivity to nutrient N enrichment for I&M park units based on sensitive vegetation and lakes. MABI was found to have very low ecosystem sensitivity and an overall very low risk from N enrichment. However, Miller et al. (2012) reported low C:N ratios at MABI, indicating a risk of N enrichment at this park.

Data and Methods

NPS ARD has assessed condition in sulfur and nitrogen wet deposition from National Atmospheric Deposition Program (NADP) data as an indicator of acidic deposition and stress on natural ecosystems in national park units across the nation, including MABI (NPS ARD 2012). NADP collects wet deposition data from a national network of monitoring stations. Condition is calculated using normalized 30-year precipitation values in order to reduce the influence of yearly variations in precipitation on results. For parks without onsite monitoring stations, park values are interpolated from nearby stations. The closest NADP sites for monitoring wet deposition are located at least 89 km (55 miles) from MABI at Hubbard Brook, NH and Bennington VT. ARD has determined trend in sulfur and nitrogen wet deposition for a subset of park units.

ARD has not assessed dry deposition since data availability is more limited (NPS ARD 2013). The closest Clean Air Status and Trends Network (CASTNET) monitoring sites for monitoring dry deposition are located about 89 km (55 miles) from MABI at Hubbard Brook, NH and Lye Brook, VT.

Assessment Points

ARD has set condition assessment points for N and S wet deposition as shown in Table 4.3. However, if park ecosystems are ranked very high in sensitivity to acidification or nutrient enrichment, wet deposition condition ratings are adjusted up to the next worse category (NPS ARD 2013). MABI was found to have very high ecosystem sensitivity to acidification (Sullivan et al. 2011a), thus this ranking shift applies to MABI.

Table 4.3. Wet deposition condition assessment points and rating developed by NPS ARD (2013).

Condition rating	Total N wet deposition (kg/ha/yr)	Total S wet deposition (kg/ha/yr)
Good condition	< 1	< 1
Moderate concern	1-3	1-3
Significant concern	> 3	> 3

Condition and Trend

ARD interpolated 5-yr average (2006-2010) wet deposition rates for MABI are shown in Table 4.4. Both total N and total S rates exceed benchmarks which warrant significant concern. ARD did not determine trend in wet deposition for MABI. Ten-year trends in sulfate and nitrogen (combined nitrate and ammonium) wet deposition for other park units of the northeastern US show significantly improving trends (Figures 4.2 and 4.3; NPS ARD 2013) and this regional trend is likely to be representative of MABI.

Table 4.4. Five-year (2006-2010) average wet deposition rates for MABI in kg/ha/yr (NPS ARD 2012).

NH_4	NO_3	SO_4	Total-N	Total-S
2.0	8.6	10.6	3.5	3.5

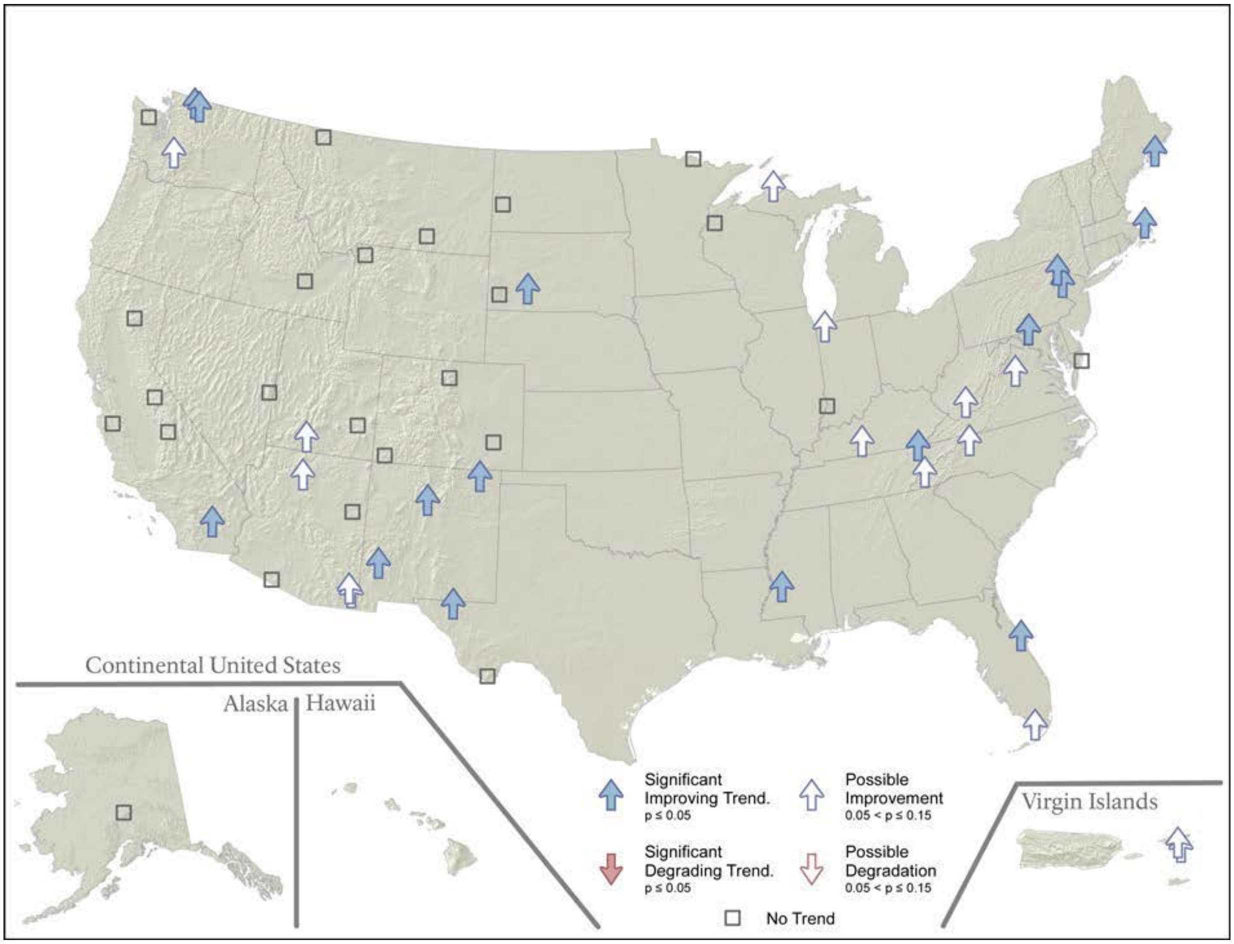

Figure 4.2. National trends in sulfate concentrations in precipitation (µeq/L/yr), 2000–2009 (excerpted from NPS ARD 2013).

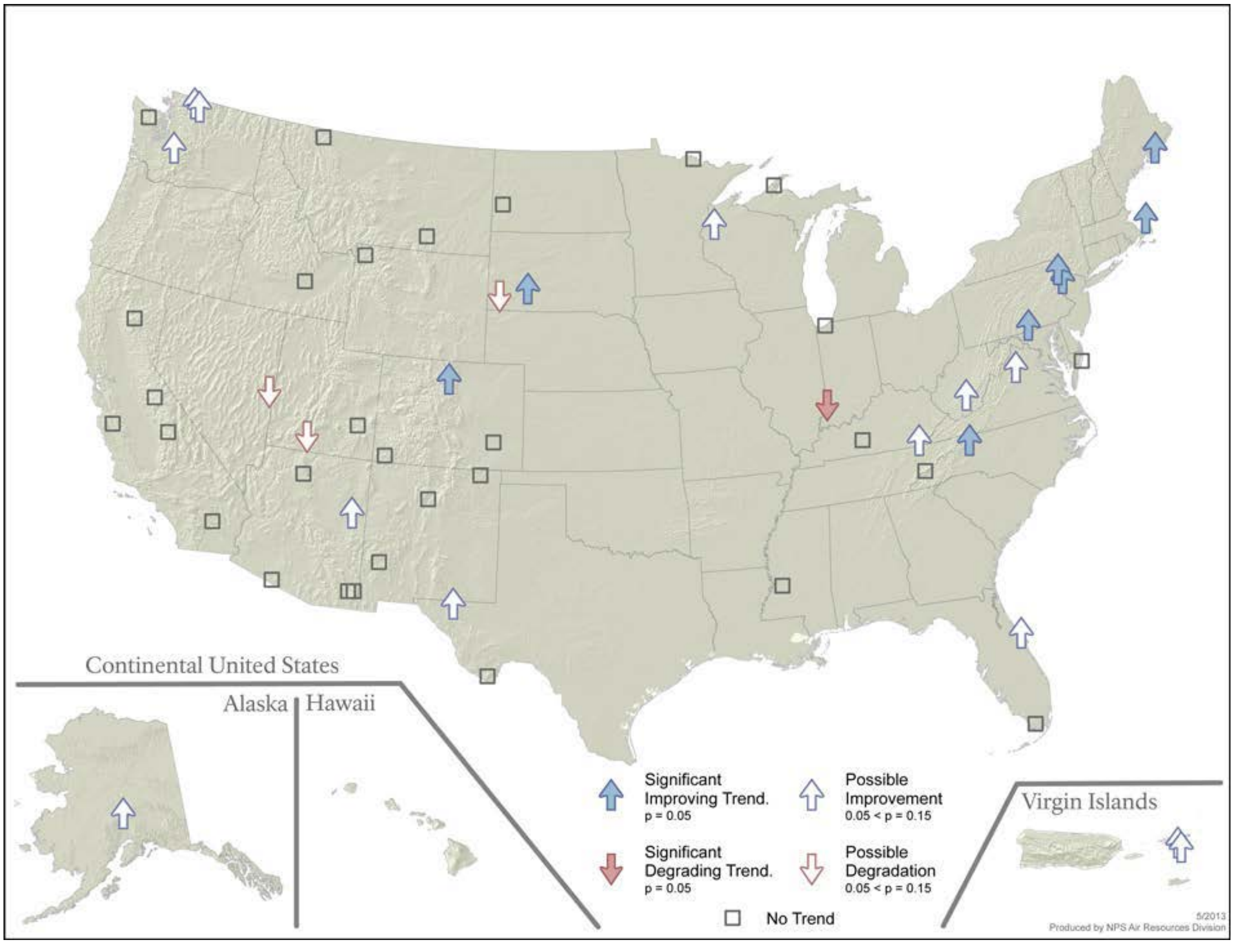

Figure 4.3. National trends in nitrogen concentrations in precipitation (μeq/L/yr), 2000–2009 (excerpted from ARD 2013).

Data Gaps and Level of Confidence

Confidence in status assessment is medium. Data was interpolated from sites at least 89 km (55 miles) away, and complements onsite forest soil, pond and stream water sampling to increase understanding of acidic deposition stress at MABI. Confidence in regional trends is high.

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Contaminants

Description and Relevance

Deposition of heavy metal contaminants was identified as a Vital Sign for NETN parks (Mitchell et al. 2006). Of particular interest is mercury (Hg), an environmental contaminant of concern in aquatic and, more recently, terrestrial ecosystems (Evers et al. 2005, Rimmer et al. 2009). Hg is emitted by coal-burning power plants and solid waste incineration and other sources. Typically deposited in an inorganic form by wet, dry or occult deposition, Hg is transformed by microorganisms in wetland sediments or forest soil into an organic form (methyl mercury, MeHg), a process which can be stimulated by S deposition (U.S. EPA 2008). MeHg is a neurotoxin which bioaccumulates up the food chain.

Data and Methods

The Mercury Deposition Network (MDN), part of the NADP, monitors wet deposition of mercury at a network of sites across the nation. The nearest MDN site to MABI is located approximately 100 km (62 mi) NW in Underhill VT (site VT 99), where mercury wet deposition has been monitored since August 2004. Using MDN data, NPS ARD has determined the 10-year trend in mercury deposition at a subset of national park units which did not include MABI. Condition and trend in deposition for MABI were determined herein from the wet deposition dataset collected at the Underhill VT station.

Examining Hg in litterfall and upper soil horizons at 15 forest sites across Vermont, including a sugar maple site at MABI, Juillerat et al. (2012) found that measured total Hg deposition flux in litterfall at MABI (28.5 micrograms/m^2/year) was substantially higher (67%) than modeled deposition rates. Flux at MABI was the highest of the 15 sites measured by this study.

Davis (2013) studied mercury methylation rates in four vernal pools within MABI from 2010-2011. Mean total-Hg concentrations in vernal pool water samples at MABI ranged from 0.53 ng/L to 2.98 ng/L, while mean MeHg concentrations ranged from 0.24 ng/L to 1.41 ng/L, corresponding to methylation efficiencies (or the proportion of total Hg available as MeHg) ranging from 43% to 58%. It has been suggested that methylation efficiencies >10% result in elevated Hg levels in biota (Krabbenhoft et al. 1999).

NPS has developed a citizen scientist monitoring program to study mercury levels in dragonfly larvae in national park units. Dragonfly larvae are useful indicators of mercury contamination for two reasons: they bioaccumulate mercury from their prey, and they are an important food source for many species of fish. Dragonfly samples have been collected from the Pogue at MABI annually in the fall from 2010 through the present, and analyzed for Hg concentration (Figure 4.4; Nelson and Flanagan 2013).

Assessment Points

ARD has not yet established condition ratings for mercury deposition. An assessment point of 2 ng/L mercury in precipitation is suggested by ecological modeling indicating that this level of deposition corresponds to a level of 0.5 MeHg mg/kg in freshwater fish tissue (Meili et al. 2003). The U.S. EPA has established an assessment point of 0.3 MeHg mg/kg in fish tissue for human consumption to protect human health (U.S. EPA 2001).

Condition and Trend

Five-year (2008-2012) average concentration of Hg in wet deposition monitored in Underhill VT is 7.45 ng/L +/- 0.34 SE), a level more than three times higher than the 2 ng/L assessment level suggested by Meili et al. (2003). This level warrants significant concern. Inter-annual eight-year trend (August 2004-August 2012) at this site is unchanging (Figure 4.5). Ten-year trends in Hg concentration in precipitation are possibly improving at assessed national park units in the northeastern US (Figure 4.6, NPS ARD 2013).

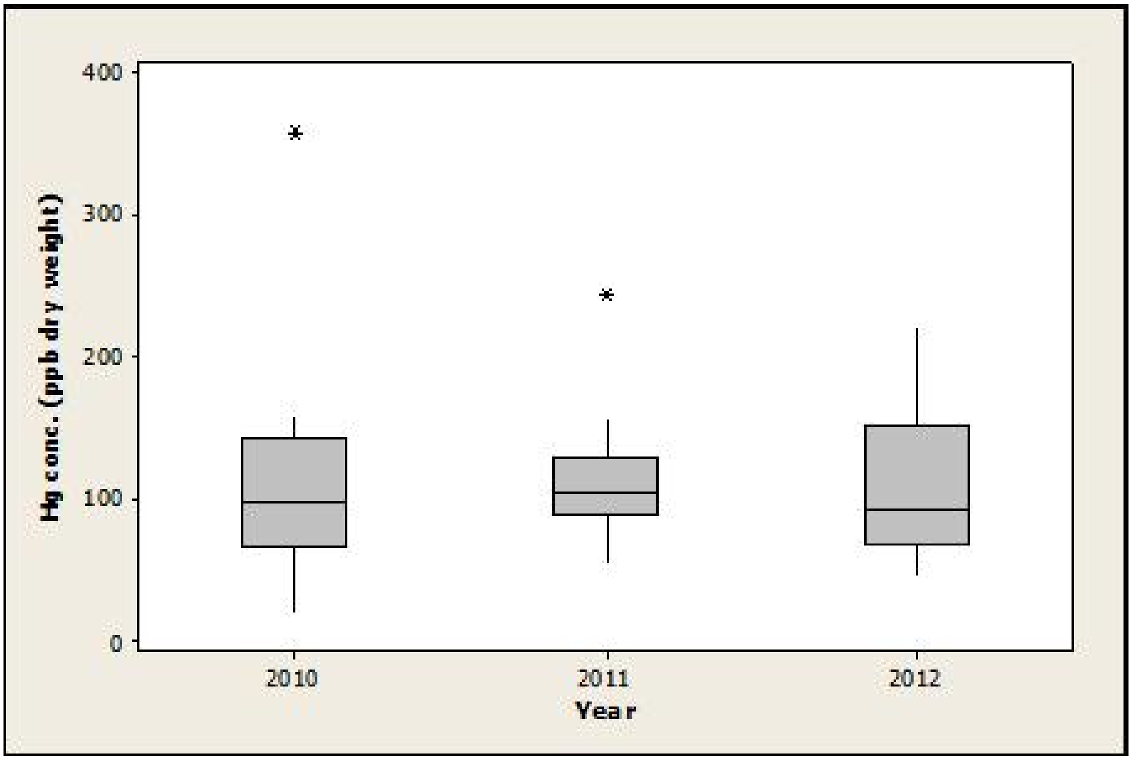

Figure 4.4: Box plot of mercury concentration in dragonfly larvae collected from the Pogue in Marsh-Billings-Rockefeller National Historical Park. The box shows the middle 50% of the data with a line across the box marking the median. Lines extend above and below the box to show the range of the data, with extreme values designated *.

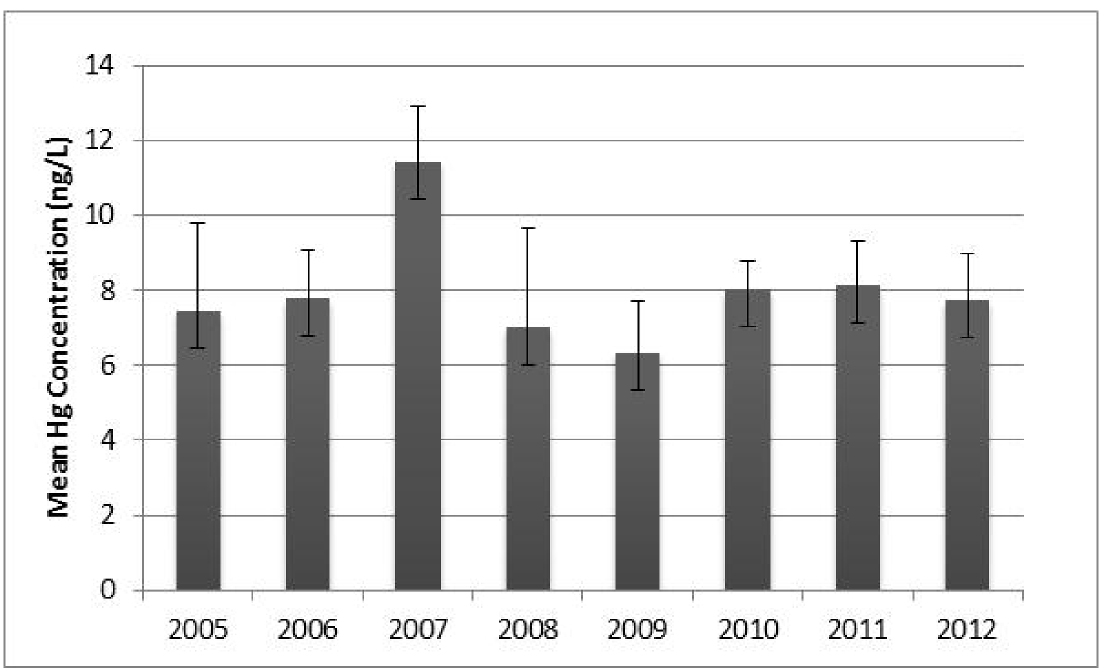

Figure 4.5. Mean concentration of mercury in wet deposition recorded from 2005-2012 at station VT99 in Underhill VT. Bars represent standard error.

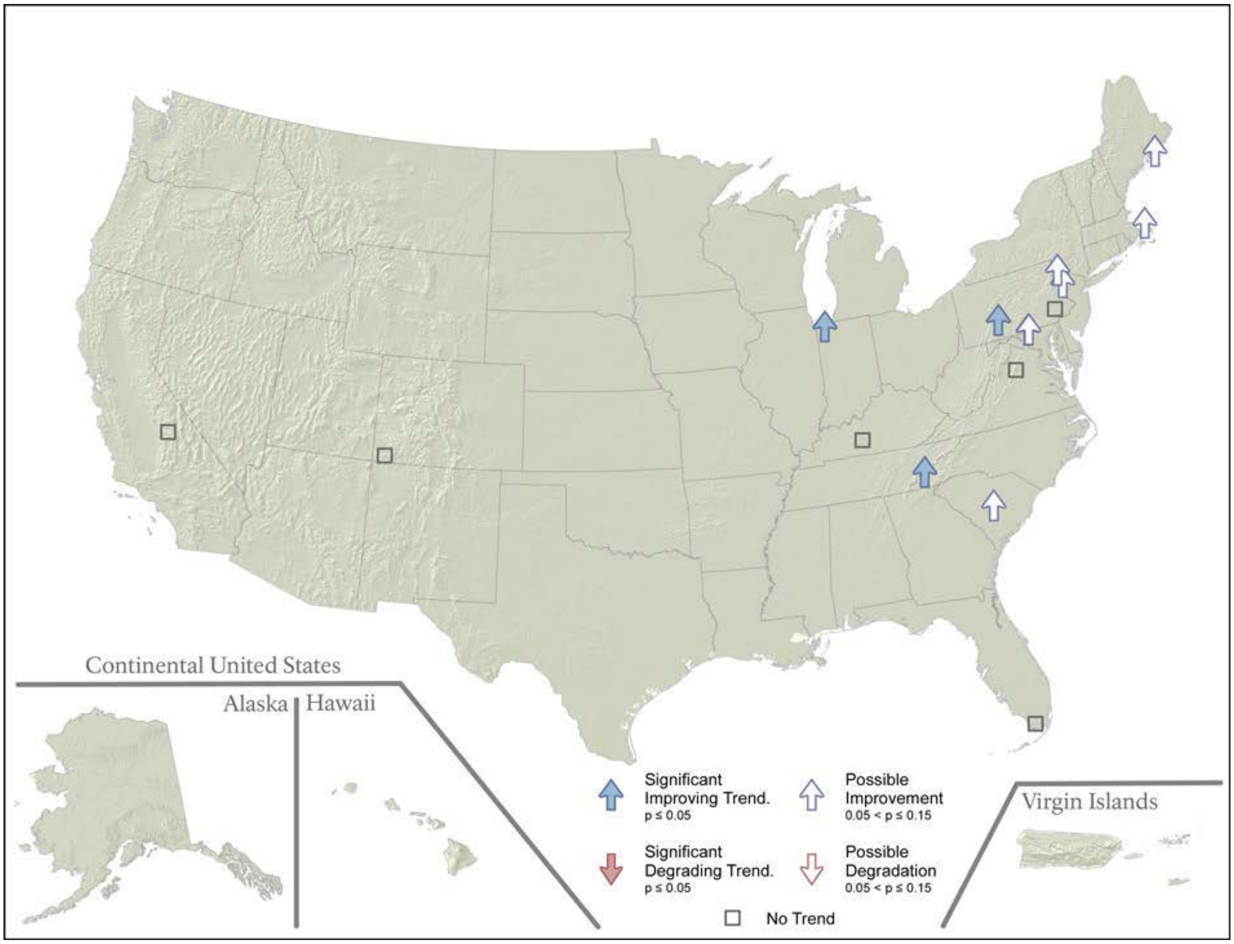

Figure 4.6. National trends in mercury concentrations in precipitation (ng/liter/yr), 2000–2009 (excerpted from NPS ARD 2013).

Data Gaps and Level of Confidence

Confidence in status assessment is low. Condition was based on multi-year quantitative data from a single site 100 km (62 mi) from MABI which may be representative of the Park. Suggested assessment points for mercury based on ecological effects need refinement. Level of confidence in unchanging seven-year trend at the Underhill site is medium.

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Climate & Phenology

Description and Relevance

Climate is a dominant driver of ecological structure, composition and functional relationships. Anthropogenic climate change is expected to cause “major changes in ecosystem structure and function, species’ ecological interactions, and species’ geographical ranges, with predominantly negative consequences for biodiversity” (IPCC 2007). Many observed physical and biological changes have already been linked to human-induced warming, including the rise in global average temperature and changes in phenology of many species (Parmesan and Yohe 2003, IPCC 2007). Phenology is the study of the timing of recurrent biological events, such as flowering, leaf-out, migration, and hibernation, and provides a simple and straightforward process in which to track changes in the ecology of species in response to climate change (Denny et al. 2014).

Data and Methods

Parameter-elevation Regressions on Independent Slopes Model (PRISM) data were obtained for MABI in order to compare recent temperature and precipitation data to long-term climate trends for the standard 30-year average (1971-2000) and a historical 71-year average (1895-1965; Morris et al. 2011). PRISM data are high-quality, uninterrupted, spatial climate data interpolated from records collected at weather stations across the nation. Trends over the historical record were assessed by linear regression (Morris et al. 2011). This park data is complemented by a state-wide assessment of climate and phenology trends across Vermont from four Vermont weather stations (Betts 2011) and a regional assessment of climate change impacts on forests of the northeastern US and Canada (Rustad et al. 2012).

Phenology data for selected species has been collected at two sites in the park since 2010 using the methods outlined in the NETN Phenology Protocol (Tierney et al. 2013). Park phenology data is uploaded to and stored in the USA National Phenology Network (USA NPN) interface, Nature's Notebook. One species (sugar maple, *Acer saccharum*) has been observed regularly since 2010 (Table 4.5). In addition, the phenology of lilac bushes (*Syringa chinensis* and *Syringa vulgaris*) has been monitored as an indicator of climate at stations across the nation, and lilacs have been monitored at more than twenty stations across Vermont since the 1960's (Schwartz et al. 2006).

Table 4.5. Species observed for phenophase status and abundance at MABI.

Species observed	Species common name	Observation site	Years observed
Acer pensylvanicum	striped maple	4875	2010
Acer rubrum	red maple	5668	2012
Acer saccharum	sugar maple	4875	2010
Acer saccharum	sugar maple	5668	2011-2013
Arisaema triphyllum	jack in the pulpit	4875	2010
Betula alleghaniensis	yellow birch	4875	2010
Eurybia divaricata	white wood aster	5668	2011, 2013
Fagus grandifolia	American beech	4875	2010
Fraxinus americana	white ash	4875	2010
Poecile atricapillus	black-capped chickadee	4875	2010
Populus tremuloides	quaking aspen	4875	2010
Quercus rubra	northern red oak	4875	2010
Tamias striatus	eastern chipmunk	4875	2010
Trillium undulatum	painted trillium	5668	2011
Tsuga canadensis	eastern hemlock	4875	2010
Turdus migratorius	American robin	4875	2010

Assessment Points
Assessment points for climate condition have not been determined

Condition and Trend
Examination of PRISM data for MABI indicates that recent 5-year and 10-year average monthly temperatures at MABI were warmer than both the standard and historical averages in all months of the year (Figure 4.7). Temperature at MABI showed an overall warming trend from 1895 to 2011, which explained from 20-36% of the variation in the three temperature indicators shown in Figure 4.8. These findings concur with regional assessment showing that surface air temperatures in the northeast U.S. have warmed by an average of 0.8 °C over the last century (Rustad et al 2012). Betts (2011) found that the frost-free growing season in Vermont increased by 2 weeks in the past 40 years, and that winter temperatures increased twice as much as summer temperatures (2.5° C and 1.1° C respectively) from 1960 to 2008. Projections indicate future summer temperature increases may exceed winter increases (Hayhoe et al. 2007).

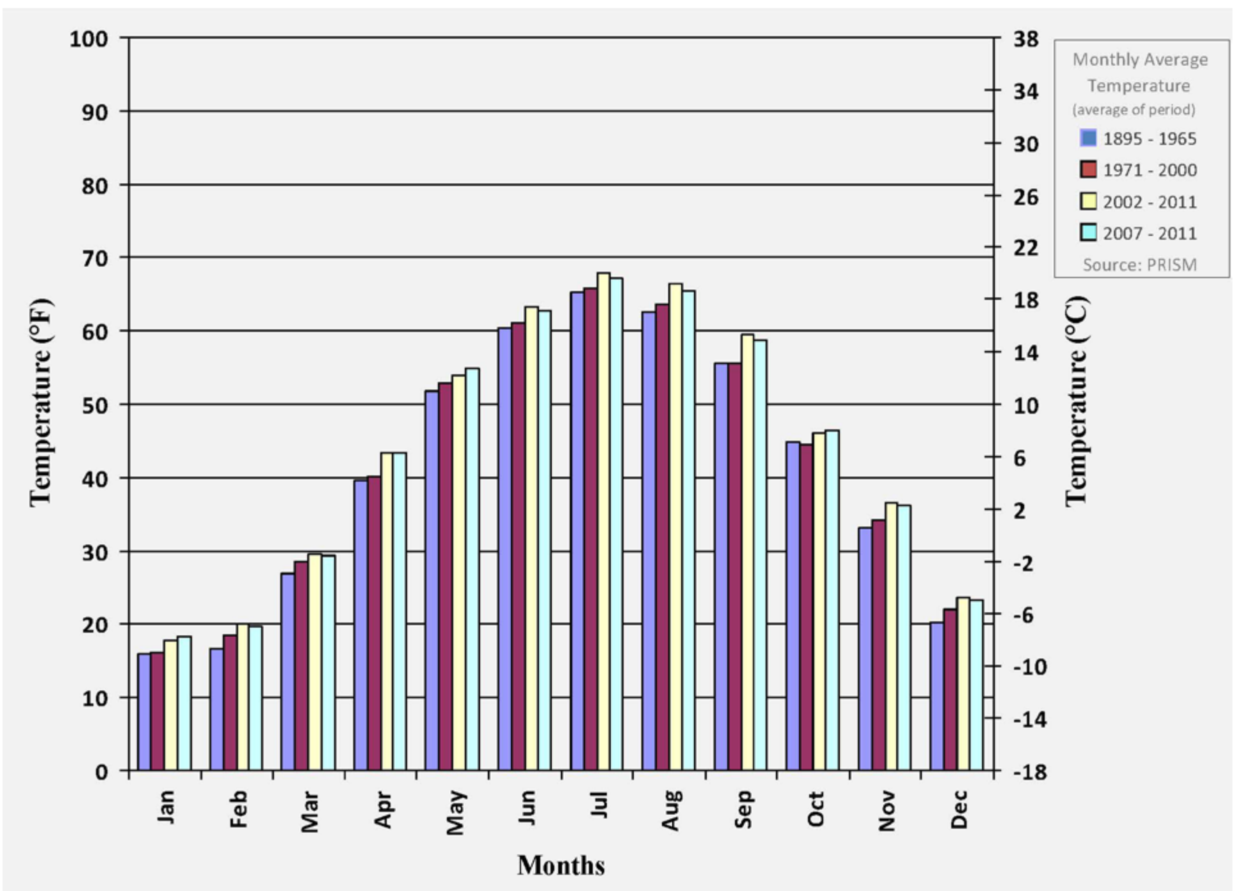

Figure 4.7. Comparison of PRISM monthly average temperature values at MABI during four periods (excerpted from Morris et al. 2011).

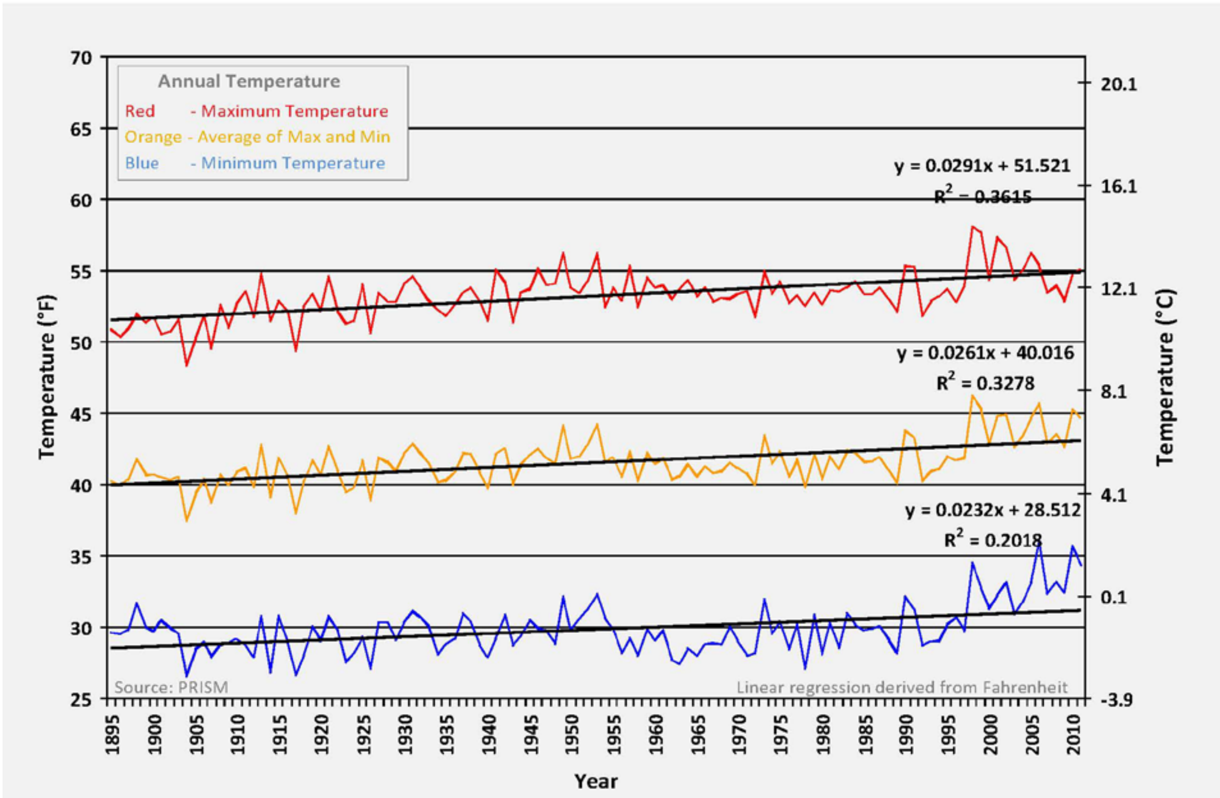

Figure 4.8. PRISM-derived annual temperature and linear regression fit for MABI from 1895 to 2011 (excerpted from Morris et al. 2011).

Looking at lilac phenology data from six Vermont sites from 1965-2008, Betts (2011) found that first leaf dates have advanced more quickly than first bloom dates (2.9 ± 0.8 and 1.6 ± 0.6 days $decade^{-1}$, respectively). Lilac first leaf date is well correlated with monthly mean temperatures for February–April, increasing by 5 ± 0.5 days for every 1°C.

Recent 5-year and 10-year average monthly precipitation values at MABI were higher than both the standard and historical averages during most months of the year (Figure 4.9). Precipitation at MABI showed an overall increasing trend from 1895 to 2011, which explained roughly 24% of the variation in annual precipitation (Figure 4.10). Regional assessment shows that precipitation has increased across New England by about 9% over the last century, and has increased most notably in spring and fall (Huntington et al. 2009, Hayhoe et al. 2007). Across the region, large precipitation events have increased in frequency (Spierre and Wake 2010). Some data indicate summer conditions in the northeast U.S. have become drier due to longer intervals between rain events and a longer growing season (Rustad et al. 2012).

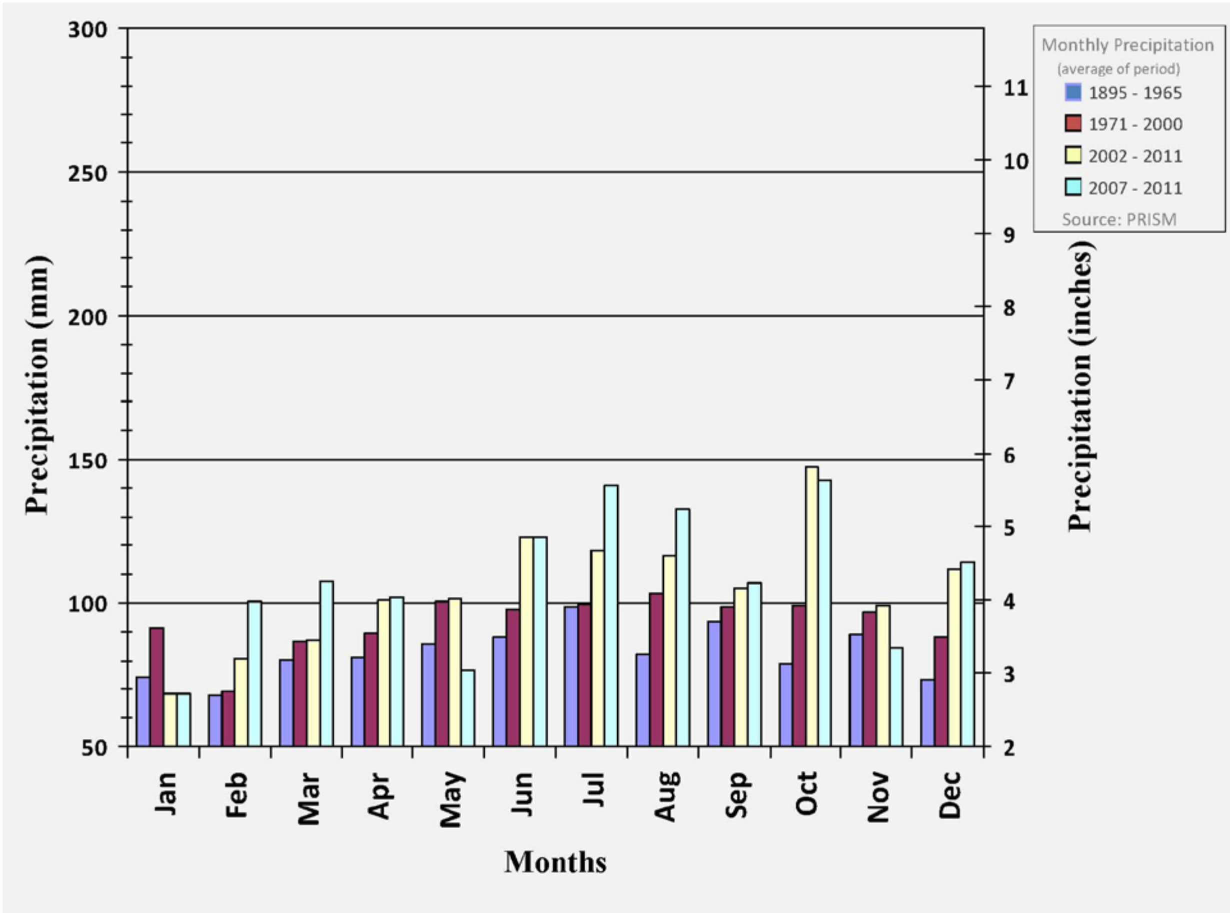

Figure 4.9. Comparison of PRISM monthly average precipitation values at MABI during four periods (excerpted from Morris et al. 2011).

Although assessment points for climate condition have not yet been determined, the extent and magnitude of ecosystem impacts expected over the next century under current warming projections warrant significant concern (IPCC 2007, Rustad et al. 2012).

Data Gaps and Level of Confidence

Confidence in status assessment is low because understanding of ecosystem changes in response to climate change is poor and because assessment points have not been established. Continued monitoring of species phenology in the park will be informative, as would park monitoring of snowpack and drought conditions. Level of confidence in regional trends in temperature and precipitation is high.

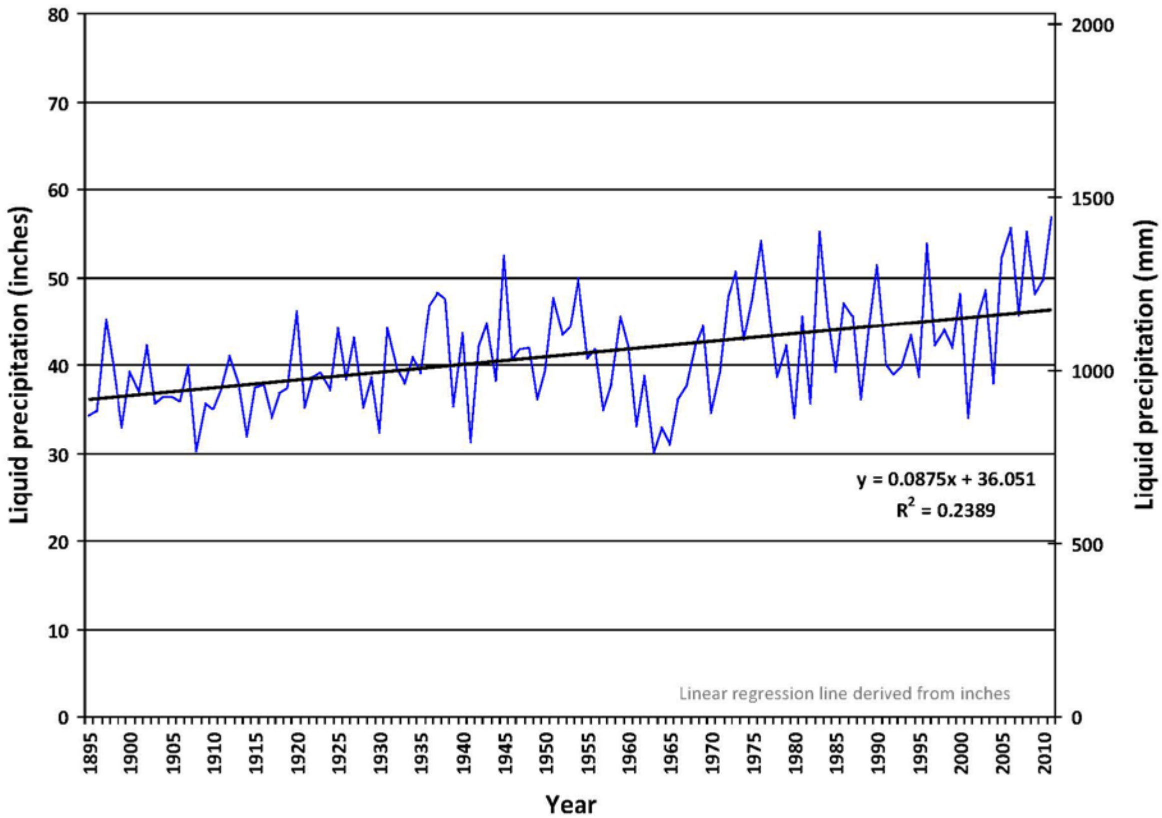

Figure 4.10. PRISM-derived annual precipitation and linear regression fit for MABI from 1895 to 2011 (excerpted from Morris et al. 2011).

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Geology & Soils

Forest Soil Condition

Description and Relevance

Soil provides the foundation upon which forest ecosystems exist, providing physical structure for anchorage and fine root growth, and nutrients and water for tree growth and maintenance. Forest soil condition is affected by physical disturbance from timber harvest, fire, or trampling, as well as by atmospheric deposition of acidic inputs and other contaminants (Driscoll et al. 2001, Aber et al. 2003). Soil nutrient cycling is also affected by prior land use, weathering of parent material, and by tree species growing on the site, and by interaction of these factors (Schroth et al. 2007). Tree species vary in their influence in soil nutrient cycling, particularly with respect to nitrogen (N) cycling and sugar maple has been identified as a species associated with increased N cycling and nitrification (Finzi et al. 1998, Lovett and Mitchell 2004). The impacts of atmospheric deposition on forest soil condition are of particular concern in the northeastern US.

Data and Methods

Since 2006, NETN has collected composite soil samples from 24 permanent forest plots. Half the plots are monitored during each biennial collection, yielding two cycles of data (2006-2008; 2010-2012) separated by a 4-year revisit interval. Soil samples were separated by horizon (O and A) if possible, dried and analyzed for pH, organic matter (as loss on ignition; % LOI), percent total N (% TN) and total carbon (% TC) by combustion, exchangeable acidity in potassium chloride, and exchangeable cations in ammonium chloride (see Miller et al. [2012] for detailed methods). Percent base saturation (% BS) herein was calculated from milliequivalent levels of base cations and acidity. NETN also records visual assessment of earthworm presence or absence at each plot.

MABI soils are poorly developed with little horizonation, and samples of the O horizon were not reliably collected. Analysis herein focuses on the A horizon. Statistical analysis showed no significant difference between NETN A horizon samples collected from naturally regenerating forest versus plantations for any soil chemistry parameters except sodium (Na), so NETN data are presented herein for all plots combined. Condition was determined from the recent data cycle (2010-2012) and trend was determined by comparing the initial and recent data cycles using a paired t-test or a Wilcoxon test (for variables which could not be transformed to normality).

Schroth et al. (2007) examined macronutrient depletion and redistribution along soils profiles in triplicate soil pits beneath paired plantation (red pine, Norway spruce and white pine) and northern hardwood sites at MABI. That study found plantation surface soils to be more acidic and depleted in base cations than northern hardwood sites at MABI, presumably due to different patterns of fine root exudation and decomposition among species. However, deeper soils were more acidic and sometimes cation-depleted under northern hardwood than conifer forests, which may be related to deeper root networks of northern hardwood species. The study noted that soils sampled at MABI were more alkaline than soils developed on similar glacial till in surrounding areas, suggesting that the till substrate at MABI has higher acid-buffering capacity than elsewhere in Vermont and New Hampshire (Schroth et al. 2007).

Assessment Points

NETN rated soil chemistry based on the ratio of exchangeable Ca to Al (Ca:Al), developed as an indicator of acid stress on forest soils (Cronan and Grigal 1995), and the ratio of total C to total N (C:N), a primary indicator of nitrogen status (Aber et al. 2003) as shown in Table 4.6 (Miller et al. 2013). Percent base saturation (%BS) is considered here as a complementary indicator of acid stress (Cronan and Schofield 1990). The USFS has developed a detailed Soil Quality Index (SQI) that integrates 19 physical and chemical properties of forest soils for use in interpreting USFS Forest Inventory and Analysis (FIA) data (Amacher et al. 2007). SQI assessment points were considered to interpret MABI forest soil condition (Table 4.7).

Table 4.6. Assessment points for forest soil condition at MABI. See text for description.

Condition rating	Ca:Al	C:N	% BS
Good condition	> 4	> 25	>15%
Moderate concern	1 - 4	20 - 25	10-15%
Significant concern	< 1	< 20	<10%

Condition and Trend

Analysis of soil pH showed that most forest plots have moderately acid soil which could affect growth of acid-intolerant plants (Table 4.7). TN is adequate for plant nutrition, and TC is adequate to excellent. Low C:N ratio indicates forest soils at MABI warrants significant concern for vulnerability to N saturation, though N deposition rates at MABI (reported in section 4.1.2 herein) fell below threshold rates for predicted onset of N saturation (5-18 kg N/ha/yr; Aber et al. 2003). Base cation status is adequate or good at most plots except for potassium (K) which may be deficient. Aluminum (Al) toxicity may be a problem to sensitive vegetation at most plots, and to a wider range of plants at plots with the highest Al values. Ca:Al ratio indicate good condition at most plots due to high soil Ca levels, but plots at the lower end of the range may experience Al toxicity. About half of NETN forested plots were invaded with earthworms in the current data cycle. Statistical analysis showed no significant trend between the first and second data cycles in pH, Ca, Al, Ca:Al ratio, C:N ratio and % BS.

Table 4.7. A-horizon soil chemistry data from 23 permanent forested NETN plots at MABI sampled 2010-2012. Interpretation follows the USFS Soil Quality Index (Amacher et al. 2007), unless otherwise cited. Soil parameters are described in text. Cation values are g/kg sample.

	Min	Q1	Median	Q3	Max	Interpretation
% LOI	5.8%	7.5%	9.6%	12.5%	31.0%	
soil pH	4.5	4.8	5.2	5.7	6.6	Moderately acid (4-5.5) to slightly acid (5.51-6.8)
% TN	0.1%	0.2%	0.3%	0.4%	0.8%	Most plots have adequate levels (0.1-0.5%)
% TC	3.1%	3.8%	4.9%	6.3%	13.1%	Adequate levels (1-5%) to excellent buildup (>5%)
Ca	139.5	494.8	841.4	1,831.6	4,662.0	Adequate levels (100-1,000) to excellent buildup (>1,000)
K	26.2	48.6	70.0	94.5	162.0	Most plots have possible deficiencies (<100)
Mg	9.0	50.5	80.8	105.1	170.7	Most plots have adequate levels (50-500)
Al	5.5	13.7	33.8	149.1	582.3	Sensitive plants likely to be affected (11-100) to adverse effects more likely (>100)
Na	1.0	1.0	3.0	5.0	11.8	Adverse effects unlikely (<=15)
Fe	1.5	3.2	4.6	7.5	59.3	Most plots have moderate levels (0.1-10)
Mn	10.7	27.6	65.0	92.1	181.4	Most plots have moderate levels, adverse effects or deficiencies less likely (10-100)
Zn	0.2	0.5	2.0	2.9	8.4	Most plots have moderate levels (1-10) but possible deficiencies in calcareous or sandy soils for some plots (<1)
C:N	13.1	14.4	15.1	17.7	23.0	Significant concern for vulnerability to N saturation (Aber et al. 2003)
Ca:Al	0.5	1.9	14.5	72.6	426.7	Most plots in good condition (>4) but Al toxicity possible in some plots (Cronan and Grigal 1995)
% BS	25%	55%	89%	97%	99%	Good condition (Cronan and Schofield 1990)

Data Gaps and Level of Confidence

Confidence in status assessment is medium. Confidence in unchanging trend is low due to the limited temporal span of sampling.

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Water

The only water body at MABI is a 4.5 ha. pond known as The Pogue, located in a depression near the summit of Mount Tom. The Pogue was enlarged from a peatland by dredging and a dam built about 1890. The Pogue's watershed lies entirely within the park; the pond is fed by submerged springs and two intermittent streams flowing from the west through forested parkland. The Park's only perennial stream, Pogue Stream, flows out from the Pogue into Barnard Brook.

Water Quantity

Description and Relevance

Climate is a primary driver of hydrology, and variation in the timing and magnitude of precipitation and snowmelt are important drivers of change in water quantity at MABI. Low streamflows can create adverse conditions for aquatic life (high temperatures and low DO). Both temperature and precipitation at MABI have increased over the last 50 years (section 4.1.4 herein). An irrigation pipe draws water from the Pogue for lawn and garden irrigation (Farris and Chapman 2000). The Park has considered a micro-hydro electrical generator that would feed from the Pogue. Installation of a micro-hydro electrical generator or changes in park land use or forest management could affect water quantity.

Data and Methods

NETN monitors pond water level at a sampling location in The Pogue, and stream discharge at a location along Pogue Stream (Figure 4.11). Water quantity has been monitored monthly (May to October) since 2006 with some missed values. Measurements were made using a folding ruler (height of water in The Pogue) and current meter (stream flow) (Lombard et al. 2006, Gawley et al. 2014). Seven-year trend (2006-2012) was assessed for average late summer (July 15 – September 15) pond height and stream discharge using linear regression analysis.

Assessment Points

Assessment points for water quantity at MABI have not been set. Minimum values for pond water height and stream discharge may be set in comparison to mean values measured onsite after more data is collected, but should also consider ecological functioning.

Condition and Trend

Water levels in the Pogue are typically lowest in September, and reached their lowest levels on record in September 2007 (Figure 4.12). Data from 2012 (the most recent year reported herein) fall within the range of values previously recorded. Stream discharges in Pogue stream are typically lowest in late summer (Figure 4.13). The highest discharge measured was in May 2006 (2.5 cubic feet second^{-1}; cfs). The minimum discharges recorded (0.02 cfs) occurred in August 2007 and September 2012. Data from 2012 fall within the range of values previously recorded.

Water quantity condition is unknown due to the lack of established assessment points. Regression analysis showed no significant interannual trend in water quantity at either site.

Data Gaps and Level of Confidence

Assessment of condition will become possible by determination of appropriate assessment points. Level of confidence in unchanging seven-year trend is medium.

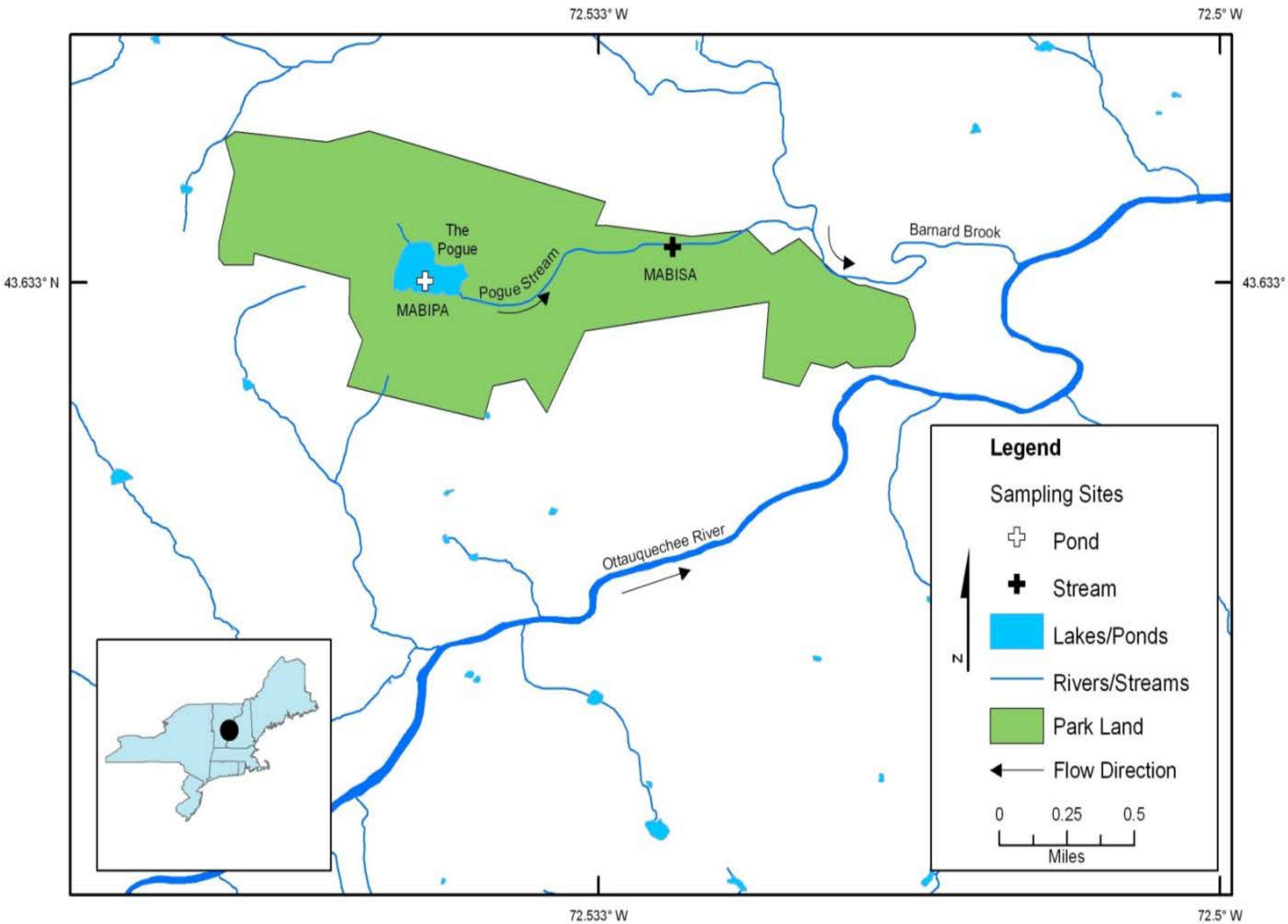

Figure 4.11. NETN water monitoring sites at Marsh-Billings-Rockefeller NHP (excerpted from Gawley 2013).

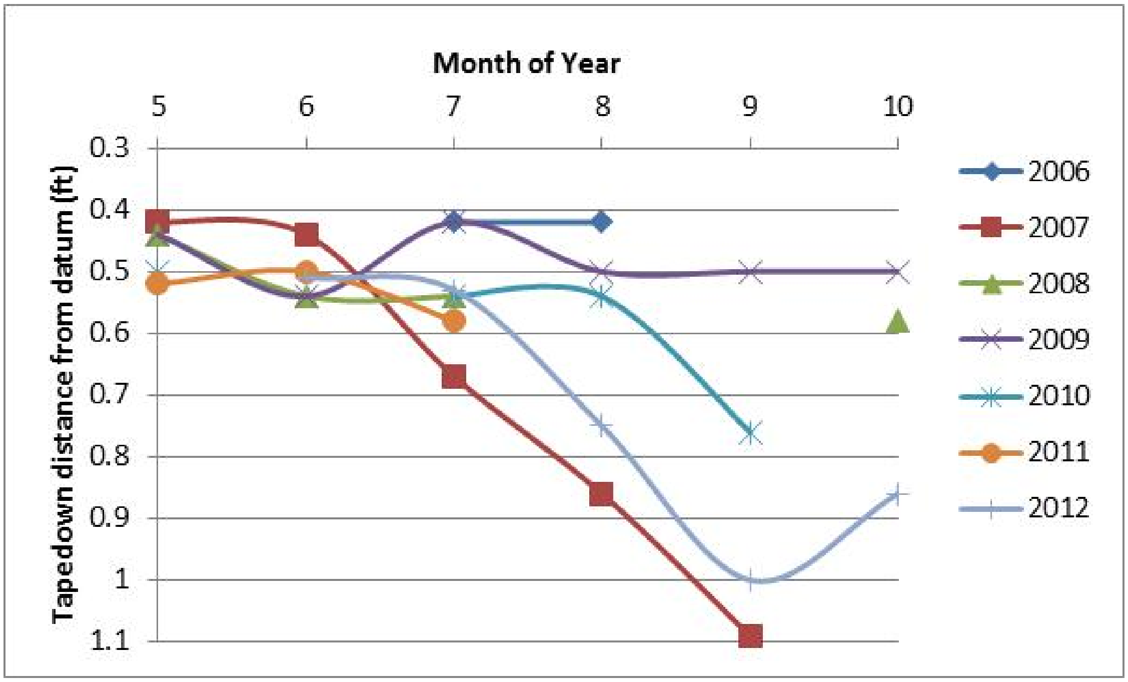

Figure 4.12. Monthly water height measured from a standard datum in the Pogue at MABI. Data are from Gawley (2012) and Gawley (2013).

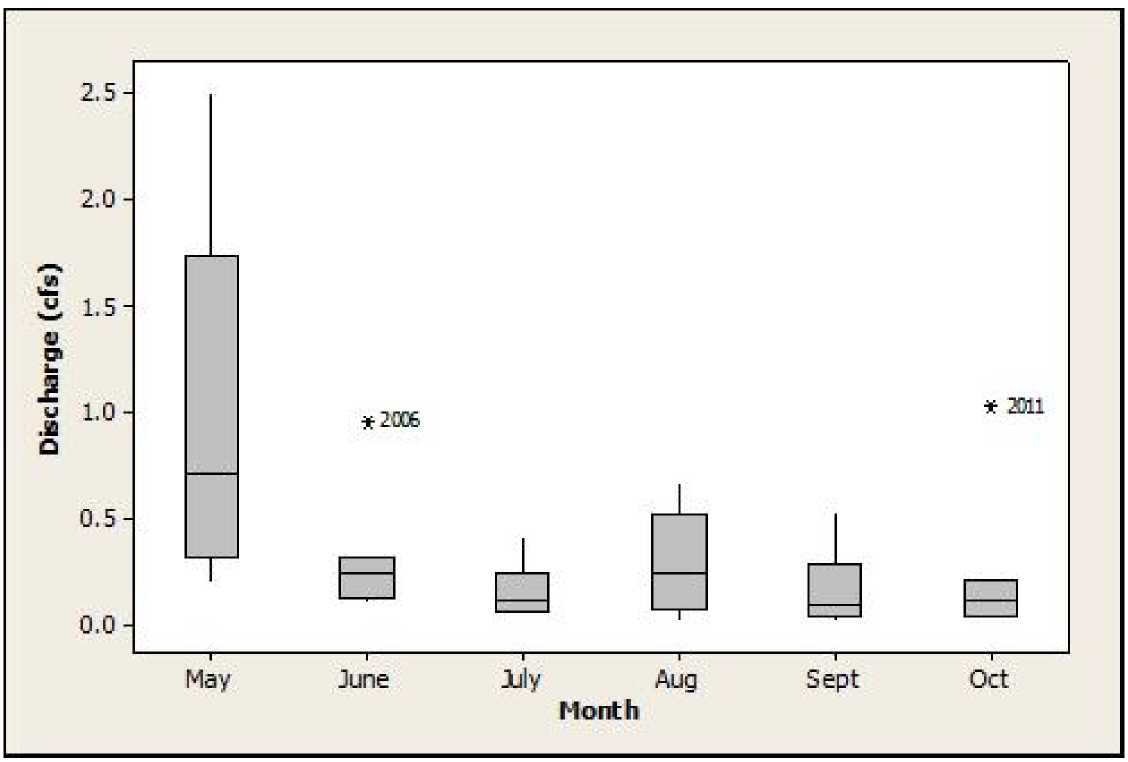

Figure 4.13. Boxplots of monthly stream discharge measured at a permanent sampling location on Pogue stream for 2006-2012. Data are from Gawley (2012) and Gawley (2013). The box shows the middle 50% of the data with a line across the box marking the median. Lines extend above and below the box to show the range of the data, with extreme values designated *.

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Water Chemistry

Description and Relevance

Water chemistry is an essential indicator for determining condition of aquatic resources, providing fundamental information about the quality of the resource and its ability to support aquatic life. A lightly-used cow pasture adjacent to Pogue Stream is separated from Pogue stream by a fenced buffer (K. Jones, personal communication, 1 July 2014).

Data and Methods

NETN has monitored water chemistry at a single location in the Pogue and a single location along the Pogue Stream approximately monthly May through October since 2006 (Figure 4.11). Sampling includes in-situ water quality measures like pH, specific conductance, temperature, and dissolved oxygen. Temperature affects water chemistry and biology, and temperature is inversely correlated with dissolved oxygen (DO). DO is a critical indicator of water quality because low oxygen levels can kill or stress most aquatic life. A marked increase in specific conductance (a measure of the level of dissolved ions in water) can be an indicator of pollution. Naturally occurring values cover a wide range (less than 20 to more than 1,000 microsiemens per centimeter; μS/cm). At each site, acid neutralizing capacity (ANC) and nutrients are monitored twice yearly, once in May or June (i.e., late spring) and once in August (late summer). Measurement of total nitrogen (TN) includes all forms of nitrogen (organic and inorganic). Nitrogen is an essential plant element and is often the limiting nutrient in terrestrial systems and marine waters, though it can also be limiting in some freshwater systems. Phosphorus (P) is a major plant nutrient which is typically limiting to plant growth in streams and ponds. Beginning in 2012, fractions of water samples were also analyzed for chlorophyll *a* and other metrics. Detailed methods can be found in Lombard et al. (2006) and Gawley et al. (2014).

Water quality condition was assessed from the most recent data year (2012). Seven-year trend in average late summer (July 15 – September 15) water quality values and spring ANC were assessed using regression analysis.

Assessment Points

Gawley (2013) assessed MABI water quality using water quality assessment points from the State of Vermont and the U.S. EPA (Table 4.8). Vermont standards are set with the goals of limiting eutrophication and protecting aquatic biota, wildlife, and aquatic habitat uses (State of Vermont Water Resources Board 2011). EPA criteria provide assessment points developed specifically for Ecoregion 8 (VT, NH and Maine) and represent nutrient conditions that are minimally impacted by human activities (U.S. EPA 2000a, U.S. EPA 2000b). The EPA criteria are not regulatory values; they were established based on the lower 25th percentile of lakes greater than 4 ha (10 ac) and with mean residence time >= 14 days assessed by EPA, and thus represent the most undisturbed lakes for which data was available.

Table 4.8. Water quality assessment points for MABI from the state of Vermont (DO, pH, and TN-VT), and U.S. EPA criteria (TN-EPA, TP, and chlorophyll a). Min ANC is from Stoddard et al. (2003).

Water body	Min DO (mg/L)	pH range	Max TN – VT (mg/L)	Max TN- EPA (mg/L)	Max TP(µg/L)	Chlorophyll *a* (µg/L)	Min ANC (µeq/L)
Stream	6-7	6.5-8.5	2	0.38	10	0.63	100
Pond	--	6.5-8.5	5	0.24	8	2.43	100

Condition and Trend

In The Pogue, water temperature, pH, dissolved oxygen and specific conductance varied seasonally (Figure 4.14); seasonal variation was also evident in Pogue stream (Figure 4.15). Water temperatures in 2012 fell within the range of variability recorded at these sites since 2006. The pH values from both sites were moderately basic and, with one exception at the Pogue in August 2012, fell within Vermont water quality standards (6.5 – 8.5). All DO measurements in Pogue stream and most values in Pogue Pond in 2012 fell above the state DO standard (7 mg/L). The exceptions were values measured at the lowest depth sampled (> 2.0 m) which regularly fell below this level (data not shown) as expected due to biological activity in pond sediment. An extreme high DO level in Pogue stream in October 2012 corresponded to one of the lowest recorded temperatures (Gawley 2013). Specific conductance values from both the pond and stream sites were within an expected range for moderate to high ionic strength waters. Specific conductance values for the Pogue Stream were the highest recorded in August through October 2012, while values for The Pogue were among the lowest recorded during the same period.

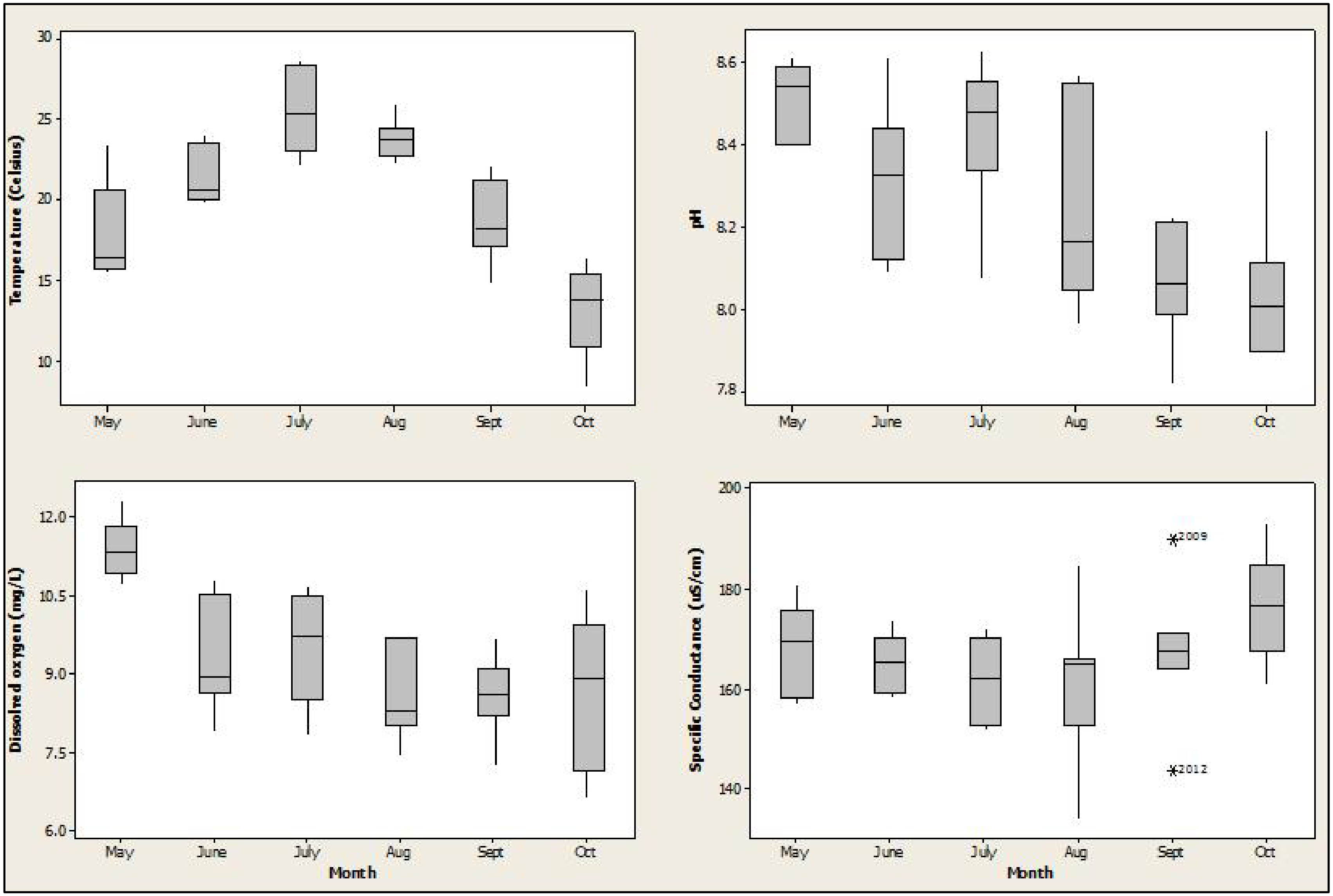

Figure 4.14. Boxplots of monthly temperature, pH, DO, and specific conductance at 1-m depth at a sampling site on the Pogue in MABI from 2006-2012. Data are from Gawley (2012) and Gawley (2013).

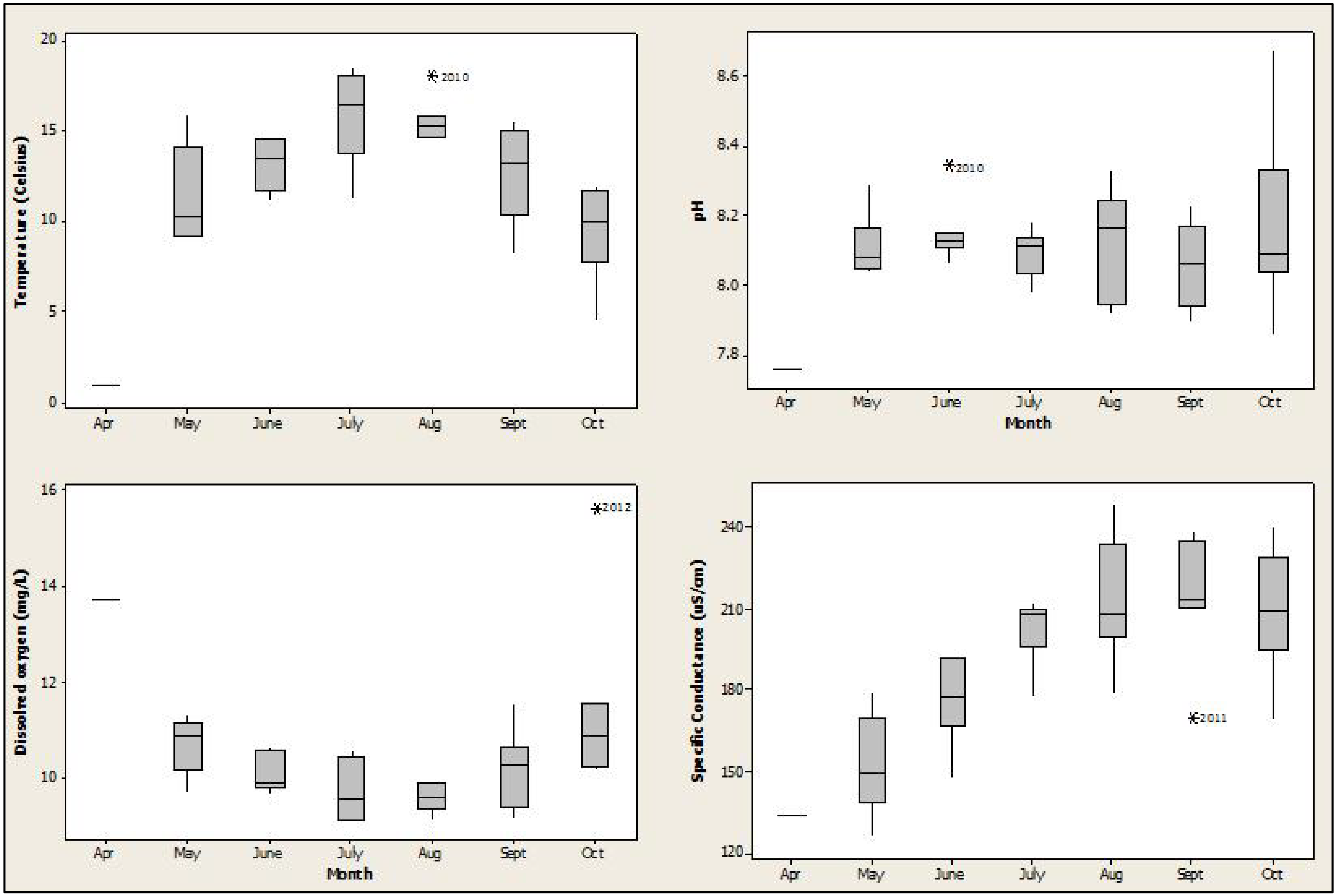

Figure 4.15. Boxplots of monthly temperature, pH, DO, and specific conductance in stream water from 2006-2012 at a sampling site on Pogue stream in MABI. Data are from Gawley (2012) and Gawley (2013).

Analysis for ANC showed that both sites were well buffered, with all measurements falling well above the 100 μeq/L assessment point (Figure 4.16). In the Pogue stream, ANC was far lower in the spring than the summer, due to the acidic influence of snowmelt and runoff. ANC in The Pogue did not display a seasonal trend, although the summer 2012 value was the lowest value yet recorded (1,210 μeq/L).

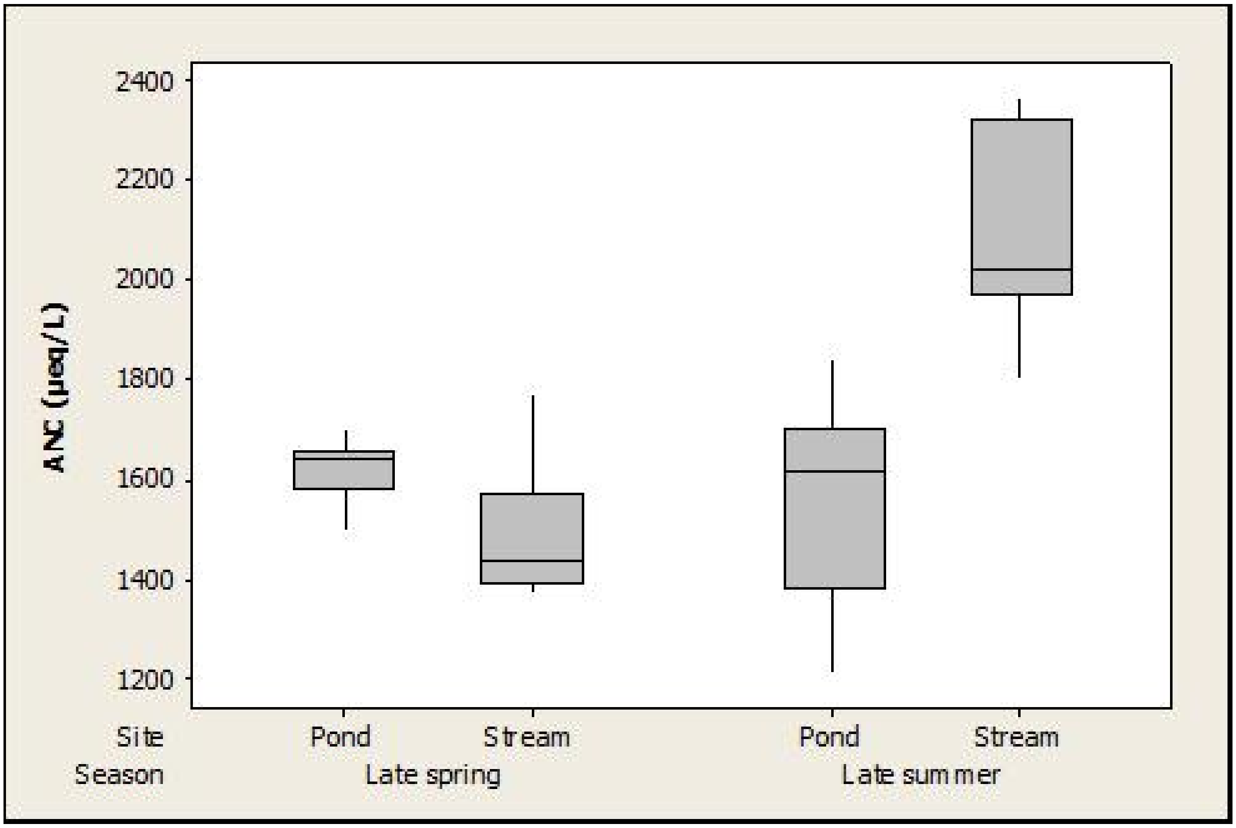

Figure 4.16. Box plot of acid neutralizing capacity (ANC) in water samples collected twice annually from 2006-2012 from a pond site and a stream site in MABI. Data are from Gawley (2012) and Gawley (2013).

TN concentration in The Pogue varied seasonally, with higher values in the late summer, while TN in stream water did not vary seasonally (Figure 4.17). All TN measurements since 2006 were well below the state total nitrogen standard of 2.0 mg/L, and all stream TN values were below the EPA Region 8 criteria of 0.38 mg/L (corresponding to minimally-impacted condition). However all TN values in The Pogue exceeded the 0.24 mg/L EPA criteria.

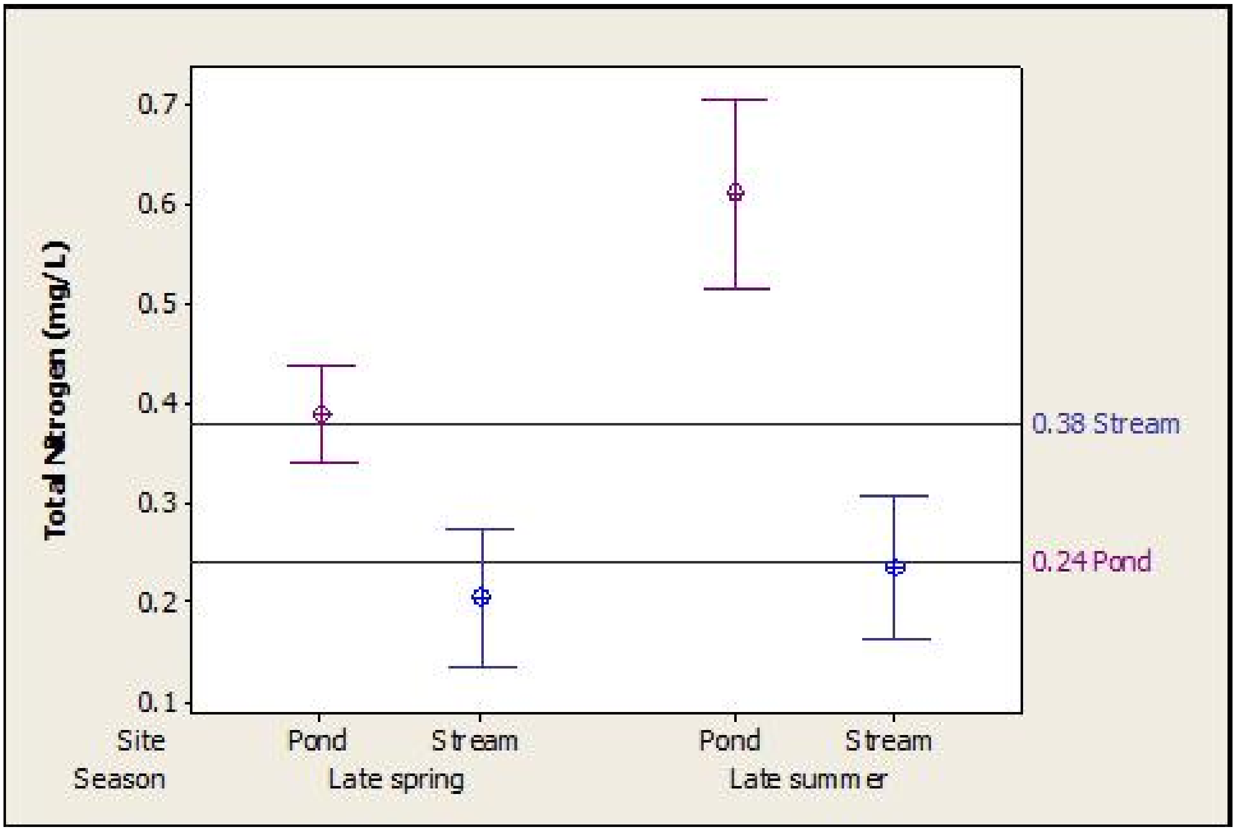

Figure 4.17. Interval plot of total nitrogen in water samples collected twice annually from 2006-2012 from a pond site and a stream site in MABI. Data are from Gawley (2012) and Gawley (2013).

Total phosphorus (TP) concentrations in stream water did not vary seasonally at MABI, while pond values were significantly higher in August than in late spring sampling (Figure 4.18). Both 2012 pond values exceeded the EPA Region 8 criteria of 8 mg/L, while both 2012 stream values fell at or below the EPA Region 8 criteria for streams (10 mg/L). Since 2006, all the pond values and most stream values have exceeded the EPA criteria (representing minimally-impacted condition). The EPA criteria do not have any regulatory meaning; there are no numeric Vermont water quality standards for phosphorus. Chlorophyll *a* was assessed in pond water samples in 2012 to better understand algal biomass. Values of 2.5 and 6.0 µg/L, respectively, in late spring and late summer samples both exceeded the EPA region 8 criteria of 2.43 µg/L.

Overall, water chemistry showed good condition for most metrics, though levels for total phosphorus, total nitrogen and chlorophyll *a* levels in the Pogue exceeded EPA criteria representing minimally-impacted condition. Regression analysis showed no significant inter-annual trend in any of the water quality metrics presented herein at either site.

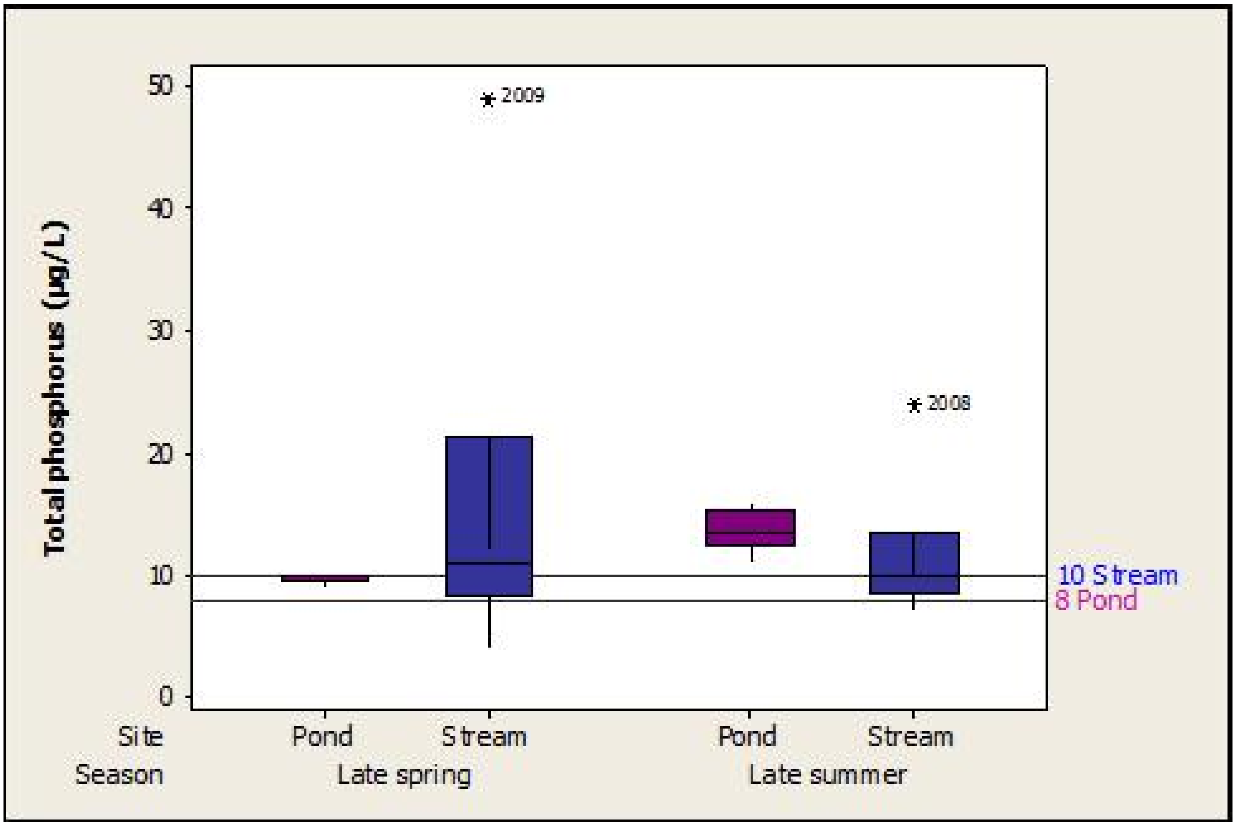

Figure 4.18. Box plot of total phosphorus in water samples collected twice annually from 2007-2012 from a pond site and a stream site in MABI. Data are from Gawley (2012) and Gawley (2013).

Data Gaps and Level of Confidence

Confidence in status assessment for Pogue stream is medium. However, confidence in status assessment of Pogue Pond is low because it was based in part on assessment points (EPA criteria) which may require further refinement for applicability to the Pogue. Confidence in unchanging seven-year trend is medium.

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Streams – Macroinvertebrates

Description and Relevance

Stream macroinvertebrates were identified as a Vital Sign that needs to be monitored in the future at MABI (Mitchell et al. 2006). The richness and composition of macroinvertebrate taxa in streams respond rapidly to changes in the physical and chemical environment, and provide a useful indicator of stream condition.

Data and Methods

No stream macroinvertebrate data have been collected at MABI.

Assessment Points

The Vermont Department of Environmental Conservation (VT DEC) has set reference condition for evaluating macroinvertebrate communities of three types of streams: small, high gradient streams, medium-size high gradient streams, and warm water medium gradient streams and rivers (VT DEC 2004). It may be possible to adapt these criteria for use in determining macroinvertebrate condition in Pogue stream.

Condition and Trend

Condition and trend cannot be assessed at this time due to the lack of data.

Data Gaps and Level of Confidence

This data gap could be filled if funding permits.

Literature Cited

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Biological Integrity

Invasive Exotic Plants

Description and Relevance

Invasive exotic species pose a serious threat to native biodiversity across the globe (Mooney et al. 2005). NPS is mandated to preserve native species and it is NPS policy to manage or eradicate invasive exotic species (NPS 2006). A systematic survey of the park in 2003 detected 12 species of exotic plants, with most detections occurring around old fields, parking areas, and a compost site; six exotic species not found in the systematic survey were noted present in the park (Table 4.9; Shriver et al. 2004). Additional exotic species have been detected subsequently by surveys and monitoring (Vellia and Zamaria 2010, Wheeler and Miller 2013). MABI manages known populations of prioritized invasive exotic species using a variety of mechanical and chemical treatments consistent with Integrated Pest Management (IPM), with the assistance of Redstart Forestry, Inc. and park interns (Currie 2006, Wheeler and Miller 2013).

Table 4.9. Exotic plant species detected in MABI since 2003. WIMS is the Park's Weeds Information Management System database.

Species common name	Latin name	Detection reference	ISED target list	NETN key species in forests
Norway maple	*Acer plantanoides*	Shriver et al. 2004	x	x
goutweed	*Aegopodium podagragia*	Shriver et al. 2004		
garlic mustard	*Alliaria petiolata*	Shriver et al. 2004	x	x
European alder	*Alnus glutinosa*	Wheeler and Miller 2013		
wild chervil	*Anthriscus sylvestris*	Shriver et al. 2004		
burdock	*Arctium minus*	Vellia and Zamaria 2010		
dutchman's pipe	*Aristolochia macrophylla (durior)*	Shriver et al. 2004		
Japanese barberry	*Berberis thunbergii*	Shriver et al. 2004		x

Species common name	Latin name	Detection reference	ISED target list	NETN key species in forests
common barberry	*Berberis vulgaris*	Wheeler and Miller 2013	x	x
oriental bittersweet	*Celastrus orbiculatus*	Shriver et al. 2004; Wheeler and Miller 2013	x	x
greater celandine	*Chelidonium majus*	Shriver et al. 2004		
swallow-wort	*Cynanchum louiseae/ C. rossicum*	Shriver et al. 2004; Wheeler and Miller 2013	x	x
daphne	*Daphne mezereum*	Vellia and Zamaria 2010		
autumn olive	*Elaeagnus umbellata*	Shriver et al. 2004; WIMS database	x	
winged euonymus	*Euonymus alatus*	Shriver et al. 2004	x	x
Dame's rocket	*Hesperis matronalis*	Vellia and Zamaria 2010		
bluets	*Houstonia (Hedyotis) caerulea*	Shriver et al. 2004		
purple dead nettle	*Lamium purpureum*	WIMS database		
honeysuckle	*Lonicera spp.(exotic)*	Shriver et al. 2004		x
creeping jenny	*Lysimachia nummularia*	WIMS database		
wall lettuce	*Mycelis muralis*	WIMS database		
phragmites	*Phragmites australis*	Wheeler and Miller 2013		
Japanese knotweed	*Polygonum cuspidatum*	Shriver et al. 2004	x	x
common buckthorn	*Rhamnus cathartica*	Vellia and Zamaria 2010		x
glossy buckthorn	*Rhamnus frangula*	Shriver et al. 2004	x	x
yellow/black locust	*Robinia pseudoacacia*	Shriver et al. 2004		
multiflora rose	*Rosa multiflora*	Vellia and Zamaria 2010	x	x
bittersweet nightshade	*Solanum dulcamara*	WIMS database		
Coltsfoot	*Tussilago farfara*	Vellia and Zamaria 2010		
common mullein	*Verbascum thapsus*	WIMS database		
periwinkle	*Vinca minor*	Shriver et al. 2004		

Data and Methods

Invasive exotic plants are surveyed regularly at MABI using four methods. First, the Pogue has been surveyed annually since 2007 for invasive aquatic plants on a high priority list which currently includes 11 species, and a secondary priority list of 13 species (Gawley 2013). The survey encompasses the entire shoreline and transects through the littoral zone (Lombard et al. 2006). Second, the NETN forest monitoring crew collects tree, shrub and understory plant data from 24 permanent forests plots at MABI on a four-year revisit interval (section 4.4.4 herein). These data are assessed for frequency and percent cover of 22 key exotic plant species known to be highly invasive in northeastern forest, woodland and successional habitats (Table 4.9, Miller et al. 2013). Third, the NETN Invasive Species Early Detection (ISED) program has relied on opportunistic surveys in MABI since 2010 in order to detect priority pests and exotic plants at early stages of establishment. This program provides park staff, cooperators and others with information describing priority species of concern, and procedures for reporting detections. The ISED target list for MABI includes 16 terrestrial plant species, five aquatic plants, and four forest insect pests (Wheeler and Miller 2013). ISED data provides useful information to park managers, but was not used herein to determine condition and trend due to the opportunistic nature of the sampling. Fourth, with the assistance of Redstart Forestry, Inc. and park interns, known occurrences of invasive plants are assessed and managed and new detections are recorded. Occurrences of invasive plants are tracked in a Park Weeds Information Management System (WIMS) database (Figure 4.19).

Condition was assessed herein using data from the annual aquatic surveys and the NETN forest crew. Trend was assessed using a Wilcoxon test to detect change in key exotic species occurrence in forest plots between the recent (2010-2012) and initial (2006-2008) forest monitoring cycles.

Assessment Points

NETN has established condition categories for key invasive exotic plant species as follows (Miller et al. 2013):

Good condition< 0.5 key species / plot
Moderate concern 0.5 to < 3.5 key species / plot
Significant concern 3.5 or more key species / plot

Condition and Trend

Annual surveys in the Pogue have detected no invasive aquatic plants of concern during annual surveys from 2007-2012 (Gawley 2013). This represents good condition. In forest plots, key invasive exotic species are infrequently found in naturally regenerating forest at MABI, and may be slightly more common in plantations (Table 4.10; Miller et al. 2013). Half the NETN forest plots had no detected key exotic species in the recent cycle, and the mean % cover by key exotic species was negligible. This finding is corroborated by Keeton (2005) who surveyed 16 forest stands at MABI from 2001-2003, and reported mean percent cover by exotic plants to be less than 1%. Five key exotic species have been found in NETN forest plots (Table 4.11). While detections in forest plots increased slightly in the recent (2010-2012) over initial (2006-2008) monitoring cycle, this difference did not represent a significant trend.

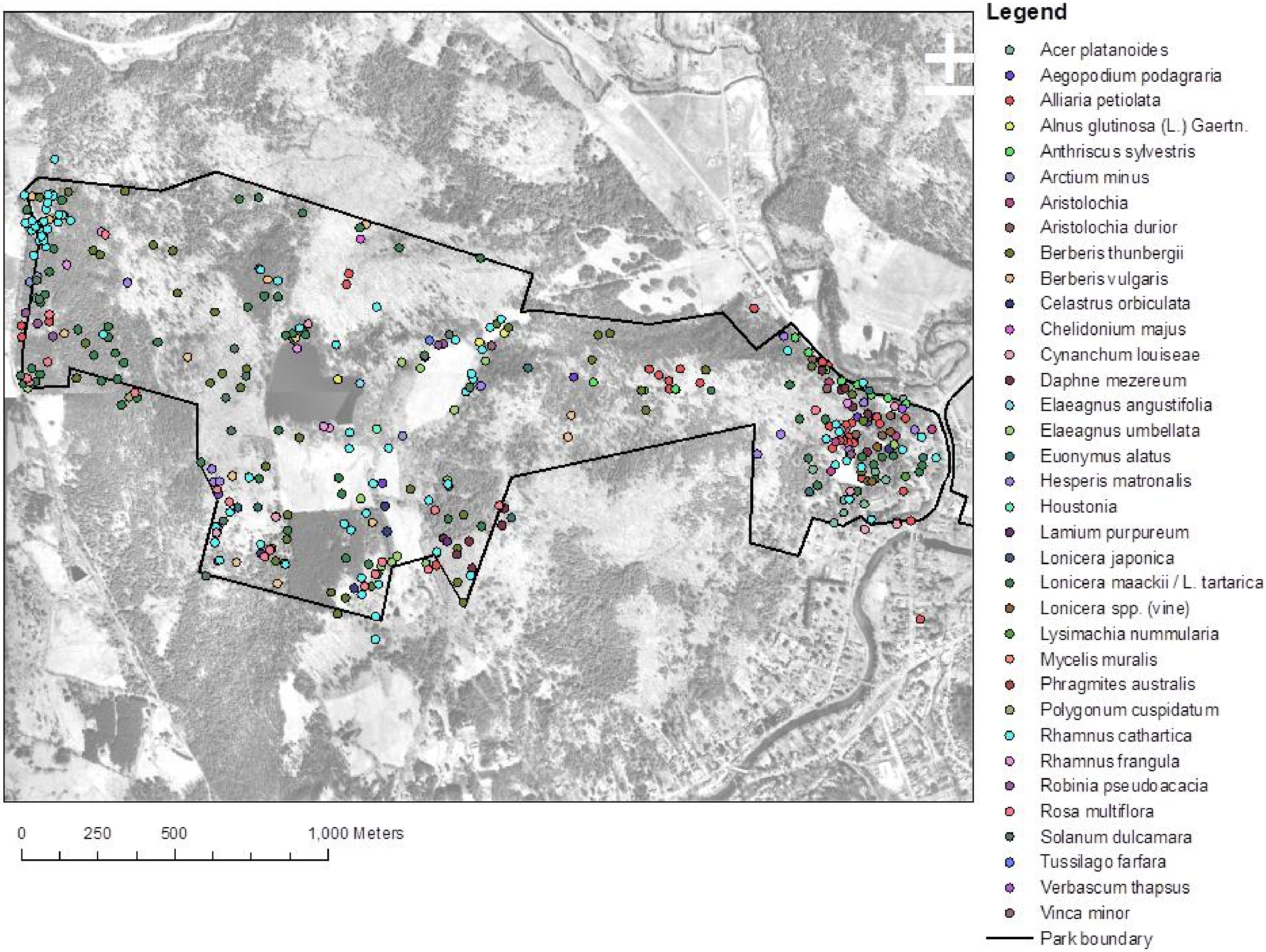

Figure 4.19. Map of exotic plant species occurrences documented in Marsh-Billings-Rockefeller National Historical Park since 2006.

Table 4.10. Mean detections and percent cover of key exotic plant species in NETN forest plots at MABI sampled 2010-2012 (Miller et al 2013).

Forest type	Plots	Mean detections per plot +/- SE	Mean % cover	Rating
Natural	13	0.46 +/- 0.18	0	Good condition
Plantation	11	1.00 +/- 0.27	<0.01%	Moderate concern

Table 4.11. Key exotic species of concern detected in NETN forest plots at MABI (Miller et al. 2013). *Berberis thunbergii* was detected in the initial data cycle only.

Latin name	Common name	Number of detections
Berberis vulgaris	European barberry	6
Lonicera spp. - Exotic	Exotic honeysuckle	6
Rhamnus cathartica	Common buckthorn	4
Celastrus orbiculata	Oriental bittersweet	1
Berberis thunbergii	Japanese barberry	1

Data Gaps and Level of Confidence

Confidence in status assessment is medium. Level of confidence in four-year unchanging trend in forest plots is low, while confidence in seven-year unchanging trend in the Pogue is medium.

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Invasive Exotic Animals

Description and Relevance

Several exotic forest pest species could cause dramatic changes in forest composition if they invade forests at MABI. The hemlock woolly adelgid (*Adelges tsugae*; HWA) has caused widespread and rapid mortality of hemlock across the eastern U.S. since introduction here in the 1950s, and threatens to rapidly and substantially reduce or eliminate eastern hemlock (*Tsuga canadensi*s) throughout much of its range (Orwig et al. 2002). HWA has been present in southern Vermont since 2006 and continues to approach the park with a new detection in Windham County in 2013 (VT DFPR 2014c). Eastern hemlock is an important and valued species; it is a significant component of three forest and two wetland associations which combined cover more than 30% of the park's 220 ha. (Gawler and Engstrom 2011). Machin et al. (2005) undertook a HWA risk assessment for MABI and determined that cold temperatures may limit the northward spread of this pest but that it still posed a serious threat to eastern hemlock in the Park; they recommended early detection and rapid response.

The Asian longhorned beetle (*Anoplophora glabripennis*; ALB) poses an enormous threat to maples (*Acer* spp.) and other species if it spreads from its current documented occurrences in Worcester, MA (2008) and Boston, MA (2010; VT DFPR 2014a). The emerald ash borer (*Agrilus planipennis*; EAB) is a destructive pest that quickly kills all native species of ash (*Fraxinus* spp.); it has been found in Canada (30 miles north of the Vermont border), Merrimack County, NH and Berkshire County, MA (VT DFPR 2014b). The Sirex woodwasp (*Sirex noctilio;* SIR) is an exotic wood-boring insect known to attack several pine species (*Pinus* spp.); this insect has been detected in a trap in Vermont but is not known to infest trees in the state (VT DFPR 2014d). Early detection of these species is crucial to management of impacts. The exotic scale insect (*Cryptococcus fagisuga*) that contributes to beech bark disease (BBD) has been established across Vermont since the 1960s.

Data and Methods

The NETN Invasive Species Early Detection (ISED) program serves as the front lines for early detection of exotic forest pests. Starting in 2010, ISED has maintained a list of high priority forest pests and provided support to park staff, cooperators and others working in the park to facilitate detection of priority pests and exotic plants at early stages of establishment. The ISED target list for MABI currently includes four forest insect pests: HWA, ALB, EAB, and SIR (Wheeler and Miller 2013). Exotic pest detections by county across the nation can be viewed at the National Agricultural Pest Information System (NAPIS) Pest Tracker (http://pest.ceris.purdue.edu/). State forest pest updates (available at http://www.vtfpr.org/protection/) provide complementary information regarding current geographic range of pests of concern in VT.

Assessment Points

Assessment points are suggested based on proximity of ISED high priority forest pests to MABI. Counties adjacent to Windsor Count VT are Windham, Bennington, Rutland, Addison, and Orange Counties in Vermont, and Grafton and Sullivan Counties in New Hampshire.

Good condition	No ISED high priority pests in Windsor County VT or adjacent counties.
Significant concern	Detection of ISED high priority pest in Windsor County VT or adjacent counties.

Condition and Trend

No ISED priority pests were detected at MABI during 2010-2012 (Wheeler and Miller 2013. However, HWA was detected in Windsor County, VT in 2014 (VT DFPR 2014c). ALB is not known to occur in VT or NH. EAB was detected in Merrimack County NH in 2013 (NAPIS Pest Tracker); this county is not adjacent to Windsor County, VT. SIR was detected in northern VT in 2013, but not in a county adjacent to Windsor County, VT (NAPIS Pest Tracker). The occurrence of HWA in Windsor County, VT warrants significant concern. Trend was not determined.

Data Gaps and Level of Confidence

Confidence in status assessment is low due to the qualitative dataset and preliminary assessment points. Trend was not determined.

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Wetland Vegetation

Description and Relevance

Freshwater wetlands provide many valuable ecosystem services including surface water detention, sediment retention, and nutrient transformation, in addition to providing critical habitat for many species of plants, insects, amphibians, fish and mammals. The Pogue is a Class II Wetland protected by State of Vermont Wetland Rules (VT DEC 2010). A complex of small wetlands and vernal pools lie north and east of the Pogue, and two small wetlands lie on the park's northern boundary (Faccio 2001, Two Rivers-Ottauquechee Regional Commission 2007). The Northern Hardwood-Hemlock Swamp, found in narrow basins within the forest at MABI, is considered to be of local importance for biodiversity (Gawler and Engstrom 2011).

Data and Methods

Key wetlands and vernal pools have been documented within MABI (Figure 4.20; Faccio 2001, Arrowwood Environmental 2004). However, wetland vegetation is not currently monitored at this park.

Assessment Points

One component of the U.S. EPA National Wetland Condition Assessment (NWCA) is the Rapid Assessment Method (USA-RAM) for rapid assessment of wetland condition and stress based on four components: buffer, hydrology, physical structure and biological structure (U.S. EPA 2011). NETN draws upon the RAM and other NWCA methods for assessment of wetland vegetation at Acadia National Park (Miller and Mitchell 2013). The RAM metrics could be used to assess the condition of wetland vegetation as suggested in Table 4.12.

Table 4.12. Suggested metrics and assessment points for determining condition of wetlands (adapted from US EPA 2011 and Faber-Langendoen 2009).

Metric	Good condition	Moderate concern	Significant concern
Percent of assessment area having a buffer	> 50 – 100%	25-49%	<25 %
Buffer width (average)	>= 100 m	50 – 99 m	< 50 m
Stress to buffer zone	No stressors affecting >= 1/3 of buffer	At least 1 stressor affecting >= 1/3 of buffer	At least 1 stressor affecting >= 2/3 buffer
Alterations to hydroperiod	Hydroperiod alterations are not severe	At least 1 moderately severe alteration impacting hydroperiod	At least 1 severe alteration impacting hydroperiod
Stress to water quality	Water quality stressors are not severe	At least 1 moderately severe stressor impacting condition	At least 1 severe stressor impacting condition
Habitat/substrate alterations	Substrate alterations are not severe	At least 1 moderately severe alteration impacting substrate	At least 1 severe alteration impacting substrate
Percent cover of invasive plants	0 %	< 5 % in any strata	>= 5 % in any strata
Vegetation disturbance	Vegetation disturbance are not severe	At least 1 moderately severe vegetation disturbance noted	At least 1 severe vegetation disturbance noted

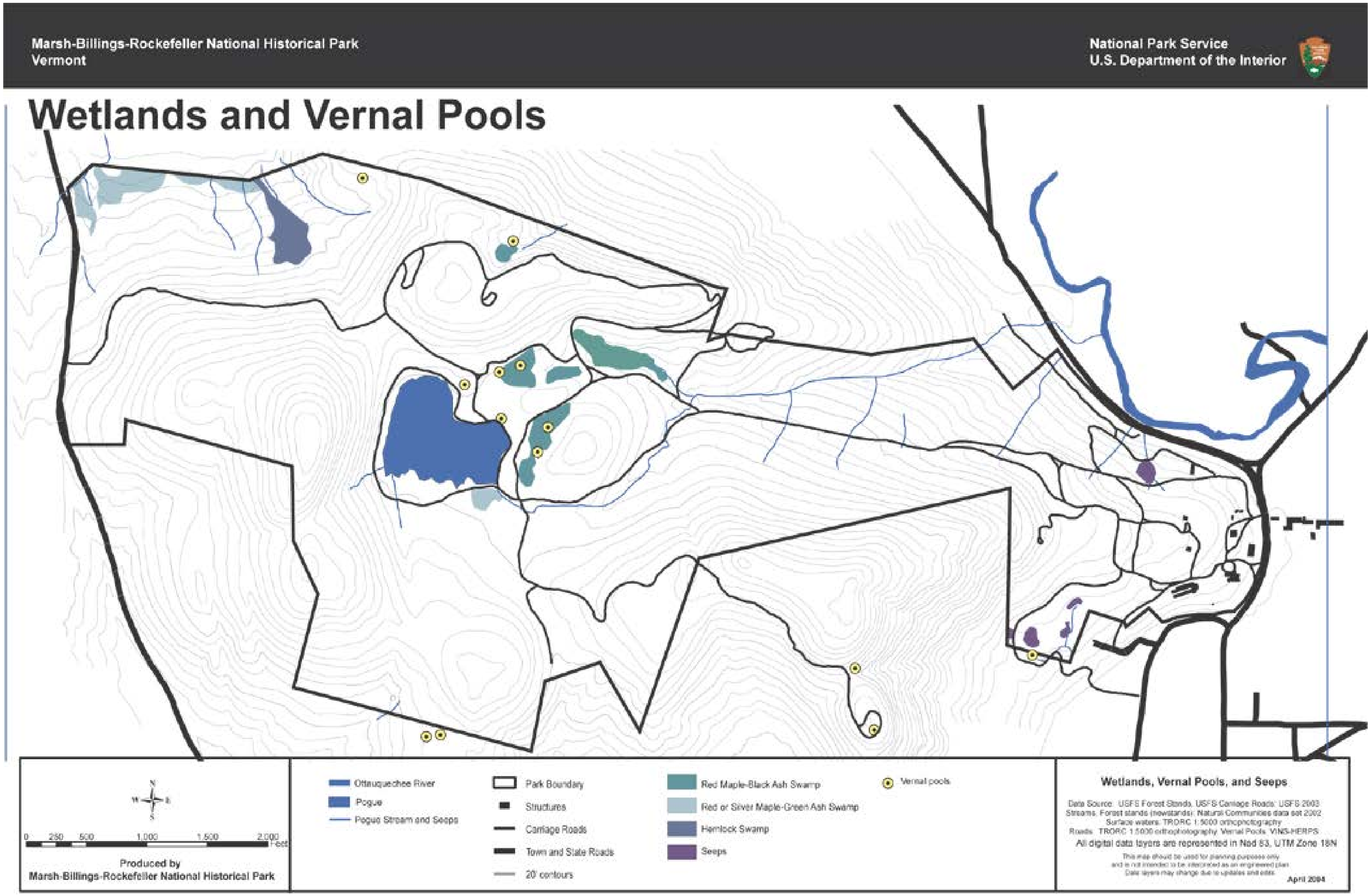

Figure 4.20. Wetlands, vernal pools, and seeps at Marsh-Billings-Rockefeller NHP (excerpted from NPS 2006).

Condition and Trend

Monitoring data is not available to determine status or trend.

Data Gaps and Level of Confidence

This is a data gap that could partially be filled by collecting rapid assessment data using USA-RAM (U.S. EPA 2011).

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Forest Vegetation

Description and Relevance

MABI is primarily a forested park, and the structure, composition and function of the forest resource determines the habitat for species which inhabit the park. The upland forest is dominated by Northern Hardwood Forest and Hemlock-Northern Hardwood Forest, with noted areas of Hemlock Forest, Rich Northern Hardwood Forest (including a Northern Hardwood Limestone Variant), two additional forest types, a woodland, and two successional forest types (Table 2.1 in section 2.2.2; Gawler and Engstrom 2011). None of the vegetation associations mapped at MABI are rare in Vermont or the New England region. However, the Northern Hardwood Limestone Forest, Rich Northern Hardwood Forest, and Red Oak-Northern Hardwood Woodland are less common in the region, and are thought to be of local importance for biodiversity (Gawler and Engstrom 2011). The 28 planted forest stands cover about 25% of the park and vary in age, species composition and management. Condition of these plantations must be assessed separately than naturally regenerating forest, using appropriate criteria. See section 2.2.2 herein for additional description of the upland vegetation associations.

MABI is unusual within the National Park System in that the forest is actively managed for interpretation of historic and progressive forest management. Forest management can create conditions contrary to some benchmarks used for ecological assessment of forest condition, particularly for forest structure. Alternatively, enlightened forest management can enhance some aspects of forest structure with high value to wildlife such as increasing abundance of snags and levels of coarse woody debris (Keeton 2006).

Data and Methods

Keeton (2005) installed 62 permanent monitoring plots within 16 forest stands (eight plantation and eight semi-natural stands) at MABI; these plots were monitored annually from 2001-2003 for a variety of structural and compositional metrics. This permanent plot network was incorporated into silvicultural inventories conducted in 2007 and repeated in 2012 (Redstart Forestry 2006). Redstart Forestry, Inc. sampled a total of 151 plots placed within the 45 forested stands at MABI to ascertain quality of growing stock, length and volume of forest products, insect and disease damage, tree regeneration and coarse woody debris.

Since 2006, NETN has monitored 24 permanent forest plots at MABI for a suite of stand, tree and understory metrics (Tierney et al. 2009). Half the plots are monitored during each biennial collection, yielding two cycles of data separated by a 4-year revisit interval. From this dataset, NETN assesses metrics of forest structure, composition and function, all but one of which have been assessed and rated on data collected through 2012 (Miller et al. 2013). Just over half these plots were placed in naturally regenerating forest stands, and the remainder were established in plantations. For the data reported herein, the initial dataset comprises data collected from 2006-2008, and the “recent dataset” comprises data collected 2010-2012. Tree growth rates and coarse woody debris were compared with regional mean rates from USFS Forest Inventory and Analysis (FIA) data collected from plots within the same ecoregional Subsection as MABI (M211Bb – Southern Piedmont).

For metrics with sufficient data, trend over the four-year return interval was assessed by comparing the recent with the initial dataset using a paired t-test for normally distributed data, or a Wilcoxon test for data which was not normally distributed.

Assessment of exotic plant species, deer browse impacts, and forest soil chemistry are considered, respectively, in sections 4.4.1 (Invasive exotic plants), 4.4.5 (White-tailed deer herbivory) and 4.2.1 (Forest soil condition). Biotic homogenization has not yet been assessed and is not reported herein. In addition to the plot measurements, NETN periodically calculates two landscape metrics associated with forest integrity (Forest patch size and Anthropogenic land use). These are reported herein in section 4.6.1 (Landcover / Ecosystem cover / Connectivity) and 4.6.2 (Land use).

<u>Assessment Points</u>

NETN has established assessment points for metrics of forest structure, composition and function as shown in Table 4.13 (adapted from Miller et al. 2013).

Table 4.13. Assessment points and ratings for six metrics of forest integrity for MABI (adapted from Miller et al. 2013). Medium to large (med-lg) trees are trees >= 30 cm diameter-at-breast-height (dbh).

Metric type	Metric	Good condition	Moderate concern	Significant concern
Forest structure	Structural stage	≥ 70% late successional structure	< 70% late successional structure	< 70% combined mature and late successional structure
	Snag abundance	≥ 10% standing trees are snags **and** ≥ 10% med-lg trees are snags	< 10% standing trees are snags **or** < 10% med-lg trees are snags	< 5 med-lg snags/ha
	Coarse woody debris ratio	> 15% live tree volume	5 - 15% live tree volume	< 5% live tree volume
Composition	Tree regeneration	Seedling ratio ≥ 0	Seedling ratio < 0	
	Tree condition and forest pests	Foliar problem < 10% **and** no Priority 1 or 2 pests **and** BBD ≤ 2	Foliar problem 10-50% **or** Priority 2 pest **or** BBD > 2	Foliar problem > 50% **or** Priority 1 pest
Function	Tree growth and mortality rates	Growth ≥ 60% regional mean **and** Mort ≤ 1.6%	Growth < 60% regional mean **or** Mort > 1.6%	

<u>Condition and Trend</u>

Recent NETN forest data found both naturally regenerating forests and plantations at MABI were comprised mostly of stands with late-successional and mature **forest structural stage** (Table 4.14). Both forest types fell below the desired 70% threshold for late-successional forest structure based on stand distributions under natural disturbance regimes for the Hemlock hardwoods forest type predominant at this park (Miller et al. 2013) and therefore warrants moderate concern. A paired t-test comparing the proportion of tree basal area comprised of large diameter trees (>= 46 cm dbh) recorded during the current versus initial datasets shows that the proportion of large trees (associated with late-successional structure) increased over the four-year revisit interval in both naturally regenerating forests and plantations at MABI ($p < 0.05$).

Table 4.14. Status of structural characteristics of forest integrity measured in NETN plots at MABI from 2010-2012 (adapted from Miller et al. 2013). Only 12 naturally regenerating stands were assessed for CWD.

	Number of plots	Stand structure		Snags		Coarse woody debris	
		% late succession structure	% mature Structure	All snags/ha	Med-large snags/ha	Volume (m^3/ha)	Volume (ft^3/ha)
Natural stands	13	61.5	30.8	38.5 +/- 13.5	7.7 +/- 3.3	31.3 +/- 13.0	447.4 +/- 186.3
Plantations	11	54.5	45.	47.7 5 +/- 12.8	0.0 +/- 0.0	39.2 +/- 9.1	560.5 +/- 130.2

Keeton (2005) found that dead trees (**snags**) in 16 forest stands at MABI (eight plantation and eight semi-natural stands) represented 1 to 16% of stand basal area, with all but 3 stands falling below 10%, and found a scarcity of large-sized snags. Looking at 45 of 47 forest stands at MABI, Redstart Forestry, Inc. found snags to range from 0 to 53% of trees overall, and that 76% of forest stands surveyed fell below desired levels of snag abundance equivalent to at least10% of standing trees (Redstart Forestry, Inc., unpublished data). NETN data also indicate that **snag levels** are lower than desired at MABI in both naturally regenerating forests and plantations, with plantations particularly lacking the medium-large snags which are of greatest value to wildlife (Table 4.14; Miller et al. 2013). The recent NETN data cycle shows snags comprised 7.4% of all standing trees in NETN permanent plots in naturally regenerating forest, and 5.6% of trees in medium-large size classes (>= 30 cm dbh). These values are less than the recommended 10% based on ecological integrity. In plantations, snags comprised 9.9% of all standing trees within NETN permanent plots; however none of these snags were in the medium-large size classes. Naturally regenerating forest had 7.7 (+/- 3.3 SE) medium-large sized snags/ha, which compares favorably to the desired level of 5 medium-large snags/ha based on wildlife needs. Thus naturally regenerating forests warrant moderate concern based on lower than desired snag levels, while plantations warrant significant concern based on the absence of medium-large snags. Comparing the current with the initial NETN datasets, no trend is suggested in snag density over all tree sizes. However, medium-large snag density doubled in naturally regenerating forest plots (from 2 to 4), but has decreased in plantations (from 1 to 0). In both types of stands, the sample size of medium-large snags was insufficient to determine trend.

Keeton (2005) reported mean stand **coarse woody debris** (CWD) volume in 16 forested stands at MABI to range from 5.9 to 235.0 m^3/ha, which corresponded to 2.3% to 4.0% of stand live tree volume; that study noted that CWD levels at MABI were low compared to mature and old-growth stands in the northeastern US. Recent NETN data report that CWD volume is lower than desired at MABI (Table 4.14). The recent NETN dataset reported CWD volume to be less than the desired 15%

of live tree volume in both natural stands (7.2% +/- 3.1%) and plantations (7.4% +/- 2.3%), warranting moderate concern for both forest types (Miller et al. 2013). This metric is sensitive to estimated tree height canopy, and differences between estimates presented herein are likely to be due in part to differences in tree height measurement and live tree volume calculation. Comparing MABI to data from USFS FIA plots in the surrounding region, Miller et al. (2013) reported that CWD volume in the park (35.1 +/- 7.9 m^3/ha) may be lower than in surrounding forest sampled by FIA (41.3 +/- 10.6 m^3/ha). Comparing recent CWD volume with the initial NETN dataset, no trend is suggested. Redstart Forestry, Inc., estimated CWD in 2012 to be slightly higher at MABI than NETN estimates indicate; using NETN calculation methods, Redstart estimated CWD values by stand for 44 of 47 forest stands to range from 8.7 to 157.8 m^3/ha, with an area-weighted mean value of 54.1 m^3/ha (Redstart Forestry, Inc., unpublished data).

Tree cavities are another forest structural element with high value to wildlife. In 2012, NETN sampling at MABI found modest numbers of large tree cavities (> 5 cm diameter) in dead trees (4.2 +/- 2.8 per hectare) and none in live trees (Miller et al. 2013). Keeton (2005) reported that 40% of wolf trees inventoried at MABI contained large cavities.

Most NETN plots in both forest types at MABI had negative seedling ratios, warranting moderate concern for **tree regeneration** (Miller et al. 2013). Naturally regenerating forest had a higher mean stocking index (87.8 +/- 40.5) than plantations (24.5 +/- 6.4), and more abundant larger seedlings (Figure 4.21). This pattern was expected, because even-aged plantations tend not to support an abundant understory. A Wilcoxon test of the difference in regeneration density between the initial and recent data cycles showed no significant change in larger seedling (>30 cm) or sapling density in either forest type. This analysis accounted for difference in the area sampled for regeneration between the 2006 survey and subsequent surveys.

Keeton (2005) assessed **tree condition** in sixteen forested stands at MABI using the FIA metrics crown density, foliage transparency and crown dieback and found significant levels of defoliation, decline, or physiological stress for six tree species: American beech (due to BBD), butternut (due to butternut canker, *Sirococcus clavigignenti-juglandacearum)*, green ash, white ash, red maple, and American basswood. Visual inspection of tree foliage condition in NETN forest plots showed that most plots had moderate leaf damage averaged across trees in the plot (10-50% of tree foliage affected) in the recent data cycle (Miller et al. 2013); this warrants moderate concern. Foliage condition appeared better in plantations than in naturally regenerating forest. There was no apparent trend in tree foliage condition between the first and second NETN data cycles. NETN used visual assessment of BBD severity to calculate a BBD index of 2.1 for the recent data cycle, in which a value of 2 corresponds to “scale insect present, some cracks in bark, 75% canopy remains” (Miller et al. 2013). Both the tree foliage condition and BBD severity index warrant moderate concern for tree condition.

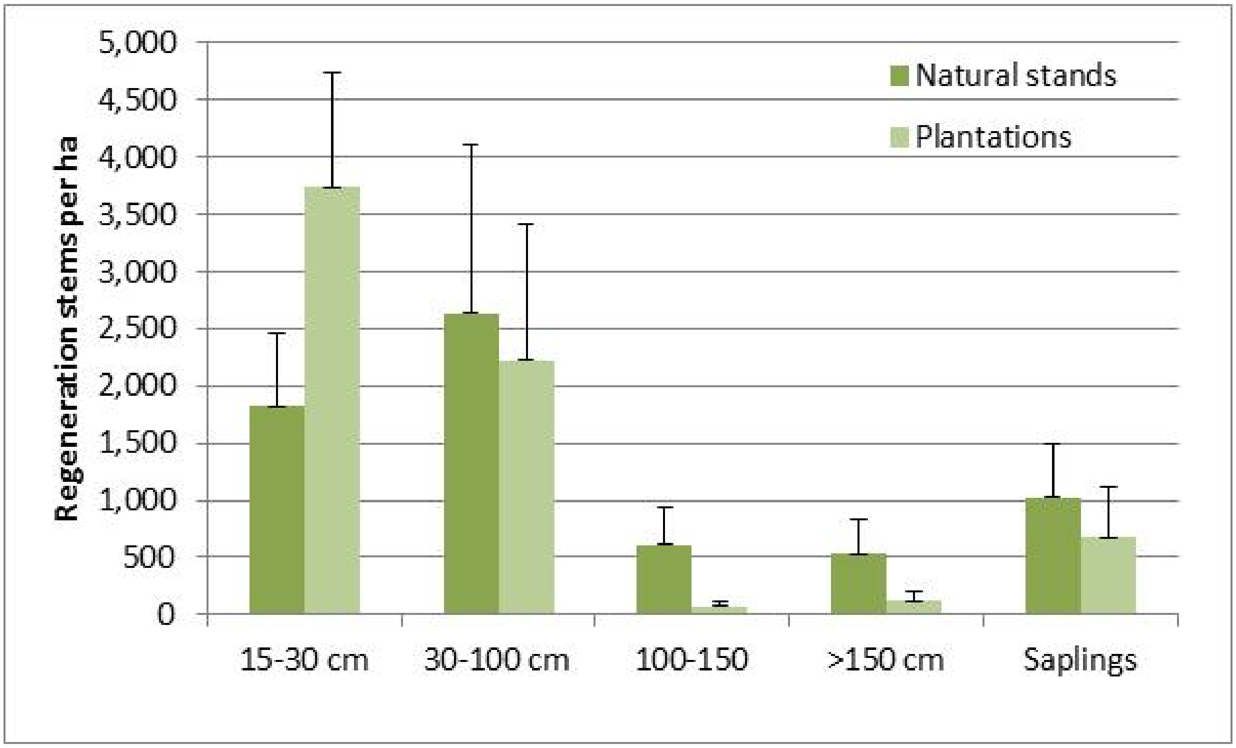

Figure 4.21. Tree regeneration measured in NETN forest plots at MABI from 2010-2012 (adapted from Miller et al. 2013).

Keeton (2005) assessed tree **growth rate** within 16 forest stands at MABI from 2001-2003, and reported mean annual growth rates of 2.2% +/- 0.2% for merchantable tree size classes, with no significant difference between naturally regenerating and plantation stands. Keeton found these growth rates to be satisfactory for moderate to highly productive sites, but did note that the sampling interval (2 years) was too short to obtain reliable estimates. NETN sampling found average annual canopy tree growth rates in mature and late-successional forest at MABI to be lower than those reported by Keeton, and substantially lower than those calculated from similar FIA plots in the region, particularly for American beech, white ash, and eastern hemlock (Table 4.15; Miller et al. 2013). The overall average MABI growth rate reported from NETN data was <60% of the FIA rate, warranting moderate concern. While the NETN analysis attempted to compare growth rates in plots of similar successional status, MABI has a higher proportion of late-successional stands than surrounding forest sampled by FIA, which may have influenced this comparison (Miller et al. 2013).

NETN sampling found average canopy tree **mortality rates** in mature or late-successional stands at MABI to average 0.8 +/- 0.3 in naturally regenerating forest (showing good condition) and 2.1 +/- 1.2 in plantations (warranting moderate concern). Mortality rates calculated by species show that rates for American beech, and red, white and Scotch pine were relatively high (Table 4.14). Beech bark disease has elevated mortality rates for American beech. There were insufficient data cycles to calculate trend in growth or mortality rates.

Table 4.15. Average annual growth (% basal area per year) and mortality rates (% stems per year) for canopy forest trees in mature or late successional stage forest plots, calculated by species and region, from 2006 – 2012 (adapted from Miller et al. 2013). The FIA column was calculated from USFS Forestry Inventory & Analysis (FIA) data from plots within the same ecological Subsection as MABI (M211Bb Southern Piedmont). NA indicates rate was not calculated due to low sample size (n<5).

Tree species	Growth rate		Mortality rate	
	MABI	FIA	MABI	FIA
Acer rubrum	1.6	2.1	0.0	0.6
Acer saccharum	1.4	2.4	1.2	0.1
Betula alleghaniensis	1.6	1.8	0.0	0.3
Fagus grandifolia	1.6	3.0	2.9	4.7
Fraxinus americana	1.6	6.3	0.9	0.1
Larix decidua	1.4	NA	0.0	NA
Picea abies	NA	NA	0.0	NA
Pinus resinosa	0.8	NA	3.0	NA
Pinus strobus	1.6	2.3	2.9	3.1
Pinus sylvestris	1.0	NA	3.6	NA
Quercus rubra	2.2	3.1	0.0	0.0
Tsuga canadensis	1.3	2.8	0.0	0.0
Overall	1.4	2.6	1.4	1.0

Data Gaps and Level of Confidence

Confidence in status assessment is medium. Level of confidence in trend is low but will increase over time with continued sampling.

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White-tailed Deer Herbivory

Description and Relevance

White-tailed deer are a "keystone" species in the northeastern US, having a profound effect on the composition, structure and function of the ecosystems they inhabit. Sustained, selective browsing by a historically high population of white-tailed deer is currently impacting understory species composition and tree regeneration in parts of the northeast US (Russell et al. 2001, Rooney and Waller 2003, Cote et al. 2004, Kain et al. 2011).

Data and Methods

Local deer population size determines browse pressure on vegetation. Data on status and trend in white-tailed deer population size come from two sources. First, the Vermont Fish and Wildlife Department releases annual deer density estimates at several scales (state-wide, regional and within Wildlife Management Units or WMUs) using data from surveys of deer sightings by hunters, deer catch per unit effort, and road-kill, and population estimation models (VFW 2009). Second, in 2011 MABI and NETN began spotlight counts to estimate trend in the size of the park deer population size (Mitchell and Kozlowski, in prep.). Spotlight surveys were conducted in the fall along roads and carriage roads throughout the park.

In addition, data on browsing impacts has been collected by NETN as part of the Long-term Forest Monitoring Program (see section 4.4.4 herein). Sustained browsing pressure can result in population reduction or loss of species preferred by deer (such as native perennial forbs) and increases in browse-resistant or non-preferred species (such as grasses and sedges, ferns, and exotic species; Augustine and deCalesta 2003, Balgooyen and Waller 1995, Rooney 2009). NETN has monitored frequency of deer-browse indicator species since 2008 in eight 1-m^2 quadrats within 24 permanent forest plots (12 of which were resampled in 2012); the NETN forest crew also recorded a qualitative assessment of deer browse impacts at each plot visited since 2010 (Miller et al. 2013). In addition, Keeton visually assessed deer browse marks on saplings at MABI from 2001-2003, to determine browse preference and intensity.

Assessment Points

Historical densities of white-tailed deer in the eastern US are estimated at 3-4 deer per km^2 (McCabe and McCabe 1997). Negative browse impacts have been documented where deer densities exceed 8 per km^2 for 10 or more years, and severe impacts have been observed with deer densities ≥ 20 per km^2 (Horsley et al. 2003, Augustine and deCalesta 2003). The Vermont Department of Fish and Wildlife Department (VFW) seeks to manage the state-wide deer population to maximize sustainable yield while minimizing negative impacts on vegetation occurring at deer densities at or above 8 deer per km^2 (20 per mi^2; VFW 2009). The VFW has established a population objective to maintain the state-wide deer herd at 102,000 – 141,000 individuals, corresponding to an average state-wide deer density of 5 – 7 deer per km^2 (13 – 18 per mi^2; VFW 2009). Within the Eastern Foothills region of southeastern VT in which MABI is situated, the VFW has set a slightly lower population objective of roughly 4 – 6 deer per km^2 (10 – 15 per mi^2; VFW 2009). The Eastern Foothills is comprised of five WMUs (M1, M2, O1, O2 and Q) which lie east of State Route 100 and extend from the Massachusetts border north to State Route 107 and US Route 4.

Accordingly, these conditions ratings for deer population density are applicable at MABI:

Good condition	< 8 deer per km^2
Moderate concern	8-20 deer per km^2
Significant concern	>= 20 deer per km^2

For assessing deer browse impacts on vegetation, NETN assigns ratings based on change over time in browse-sensitive and browse-avoided species as follows (Miller et al. 2013):

Good condition	No decrease in frequency of most browse-sensitive species
Moderate concern	Decrease in frequency of most browsed species **or** increase in frequency of browse-avoided species
Significant concern	Decrease in frequency of most browsed species **and** increase in frequency of browse-avoided species

Condition and Trend

State-wide, the pre-hunt deer herd in 2013 was estimated to be about 130,000 individuals and about 4% larger than the equivalent time in 2012 (VFW 2013). This level roughly corresponds to a density of 6 deer per km^2. Two consecutive mild winters in Vermont have likely precipitated this increase in the deer population (VFW 2013).

Within the Eastern Foothills Region, deer density has been estimated to vary over the last 13 years from a high of almost 8 deer per km^2 in 2007 to a low of about 4 deer per km^2 in 2011 and in 2013 (Figure 4.22; VFW 2103). These deer density estimates show good condition.

After three years of deer spotlight counts in MABI, park data are insufficient to generate an estimate of deer abundance, but long-term data collection may be useful for calculating an index to detect trend. Surveying an area of approximately 58 ha (143 acres) along a total route length of 8.4 km (5.2 miles), an average of 3.7 (+/- 1.7 SE) deer were detected in 2011, 1.0 (+/- 0.3 SE) in 2012, and 8.0 (+/- 1.3 SE) in 2013.

Preliminary assessment of deer-browse indicator species at MABI indicates deer-browse pressure may be affecting vegetation. In 12 plots revisited in 2012 after a 4-yr interval, 40% of browse-preferred species had decreased in abundance, and 1/3 of browse-avoided species had increased in abundance. While this shows good condition, it warrants continued monitoring. Qualitative assessment of deer browse impacts in 24 plots monitored since 2010 averaged 2.45 +/- 0.12 SE, which is equivalent to low/moderate impacts.

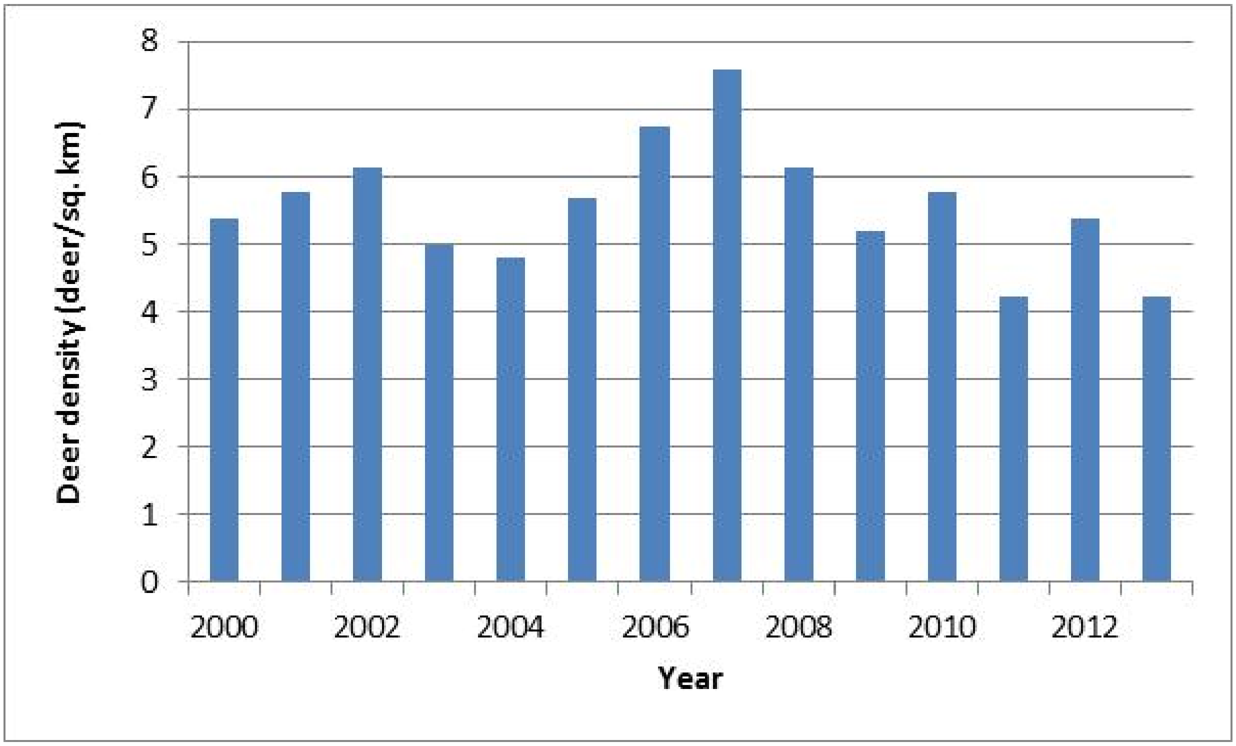

Figure 4.22. Estimated deer density within the Eastern Foothills region of Vermont (adapted from VFW 2013).

Keeton (2005) reported the percentage of tree saplings by species in MABI that had been browsed. In conifer stands, the highest browse-percentages were for American beech (57% of saplings browsed), northern red oak (50%), black cherry (35%), sugar maple (32%), and white ash (31%); while in hardwood stands the top five browsed species were white ash (67%), hophornbeam (60%), striped maple (50%), American beech (49%), and sugar maple (48%).

There is insufficient data to infer trend in park population or in vegetation impacts. State and regional data for the period from 2000 to present indicate that the deer population size fluctuates in response to winter severity, management through hunting regulation, and other factors, but data do not indicate an overall trend across the time period.

Data Gaps and Level of Confidence

Confidence in status assessment is medium. Trend was not assessed.

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Breeding Birds

<u>Description and Relevance</u>

Birds are a visible and charismatic faunal group that generate high public interest. They are also useful indicators of habitat fragmentation and anthropogenic change (Robinson et al. 1995, Rosenberg et al. 1999). Birds were selected as a high priority vital sign for monitoring in NETN parks, and the NETN bird monitoring program works collaboratively with volunteers from the local bird community near each park (Mitchell et al. 2006, Faccio and Mitchell 2013).

Data and Methods

Since 2006, NETN has relied on volunteer monitors to detect birds at three forested sites in the Park at least once per year between late May and June (Faccio et al. 2011). Two of these sites (Northwest and East) consist of 10 point count stations each, and one site (South) consists of five point count stations. Volunteers record the species of each individual bird detected during 10-minute point counts. Second surveys occurred in 2007, 2011 and 2012; while data from second surveys was included in the guild-based ecological integrity assessment, these data were excluded from summaries and trend analysis to facilitate comparison across years. At this park, volunteer monitors were all trained biologists (S. Faccio, personal communication, 23 June 2014).

Assessment Points

To assess and interpret condition, NETN has developed an avian ecological integrity assessment consisting of 13 guilds in three ecological integrity categories: compositional, functional, and structural (Table 4.16; Faccio et al. 2011, Faccio and Mitchell 2013). Each guild is broadly categorized as “generalist” or “specialist” (i.e., comprised of species with a narrow range of habitat tolerances, or a low intrinsic rate of population growth). In general, the presence of specialist guilds is indicative of high ecological integrity, while generalist guilds indicate low ecological integrity. Bird species from five groups (perching birds or passerines, woodpeckers, cuckoos, swifts and hummingbirds, and doves) were assigned to one or more guilds based on their life history traits, and the proportional species richness of each guild was calculated by dividing the number of guild members detected by the total number of species detected (Faccio et al. 2011, Faccio and Mitchell 2013). Condition was determined using the assessment points shown in Table 4.15. Since some guild members are likely missed during an annual survey, the condition assessment was based on the full seven-year dataset.

Condition and Trend

A total of 58 bird species have been recorded at MABI from 2006-2012; Ovenbird and Red-eyed Vireo have consistently been the most abundant species detected (Faccio and Mitchell 2013). Twenty-three of the detected bird species at MABI are Partners in Flight (PIF) Species of Concern, Stewardship Species or are Common Bird in Steep Decline (CBSD) species (Table 2.4). The park-wide forest avian ecological integrity assessment for all years combined at MABI resulted in seven of thirteen categories showing good condition, and the remainder warranting moderate concern, with four of the latter missing a good rating by a slim margin (Table 4.17). The two guilds which fell solidly in the middle category (Moderate concern) were High Canopy Forager and Single-Brooded. Bird relative abundance and species richness at MABI declined in 2012 (Figure 4.23 and 4.24); however regression analysis showed no significant inter-annual trend in relative abundance or species richness.

Table 4.16. Forest Avian Ecological Integrity thresholds for 13 response guilds (from Faccio and Mitchell 2013). Percentages are proportional species richness.

Biotic Integrity Element	Response Guild Metric	Ratings (% Species Richness)		
		Good Condition	Moderate Concern	Significant Concern
Compositional	Exotic Species	0%	0.5 -7%	> 7%
	Nest Predator/Brood Parasite	< 10%	10 - 15%	> 15%
	Resident	< 28%	28 - 41%	> 41%
	Single-Brooded	> 68%	50 - 68%	< 50%
Functional	Bark Prober	> 11%	4 - 11%	< 4%
	Ground Gleaner	> 9%	4 - 9%	< 4%
	High Canopy Forager	> 12%	7 - 12%	< 7%
	Low Canopy Forager	> 22%	14 - 22%	< 14%
	Omnivore	< 30%	30 - 50%	> 50%
Structural	Canopy Nester	> 35%	29 - 35%	< 29%
	Forest-ground Nester	> 18%	5 - 18%	< 5%
	Interior Forest Obligate	> 35%	10 - 35%	< 10%
	Shrub Nester	< 18%	18 - 24%	> 24%

Table 4.17. Park-wide Forest Avian Ecological Integrity Assessment for Marsh-Billings-Rockefeller National Historical Park, 2006-2012 (adapted from Faccio and Mitchell 2013).

Biotic Integrity Element	Response Guild Metric	Percentage	Rating
Compositional	Exotic Species	0%	Good condition
	Nest Predator/Brood Parasite	7%	Good condition
	Resident	28%	Good condition
	Single-Brooded	61%	Moderate concern
Functional	Bark Prober	15%	Good condition
	Ground Gleaner	9%	Good condition
	High Canopy Forager	7%	Moderate concern
	Low Canopy Forager	19%	Moderate concern
	Omnivore	33%	Moderate concern
Structural	Canopy Nester	35%	Good condition
	Forest-ground Nester	15%	Moderate concern
	Interior Forest Obligate	35%	Good condition
	Shrub Nester	19%	Moderate concern

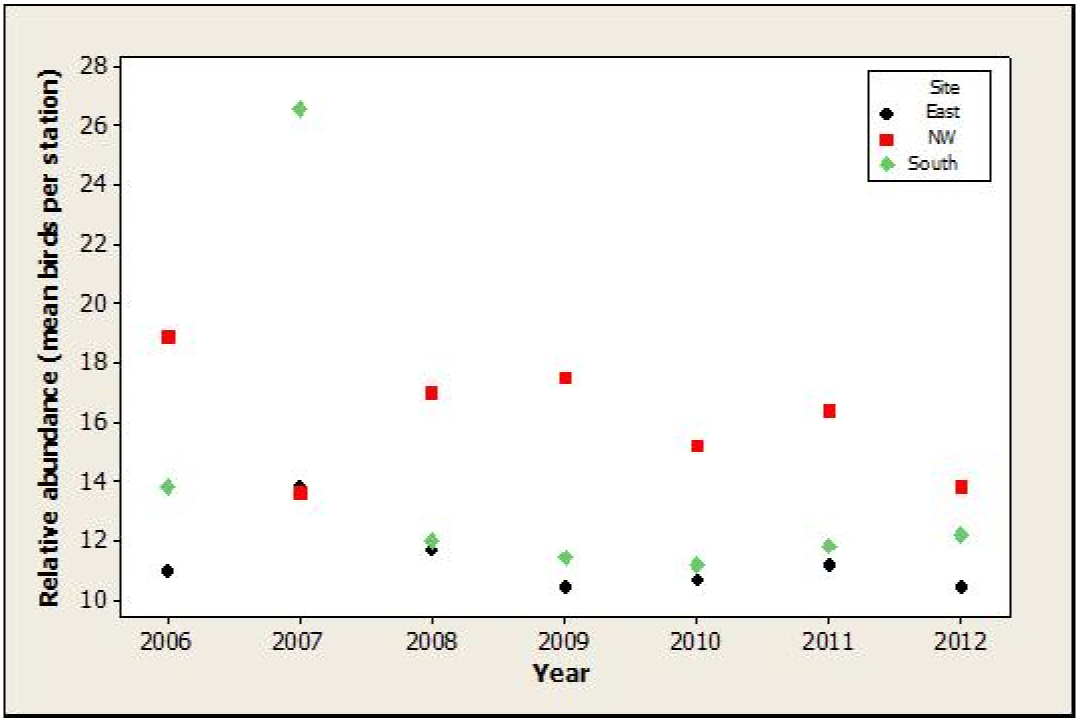

Figure 4.23 Relative abundance of birds detected during first annual surveys at three forest sites in MABI (data from Faccio and Mitchell 2013).

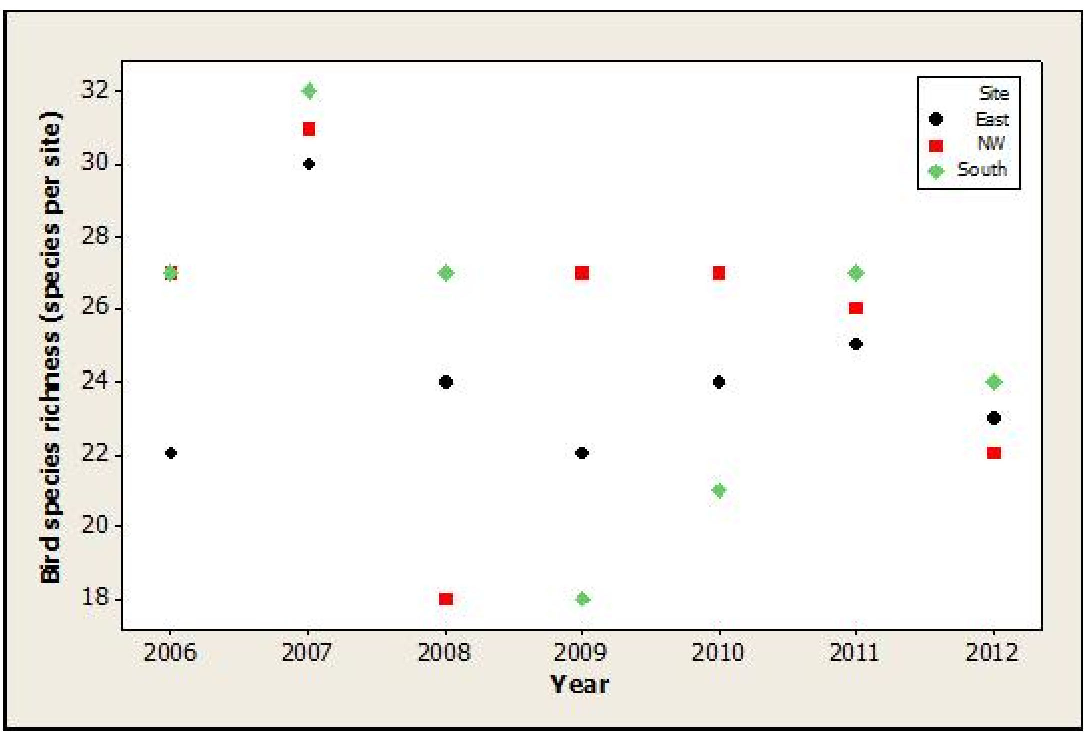

Figure 4.24. Bird species richness detected during first annual surveys at three forest sites in MABI (data from Faccio and Mitchell 2013).

Data Gaps and Level of Confidence

Confidence in status assessment from the multi-year dataset is medium. The Avian Ecological Integrity Assessment continues to be evaluated and assessment points may be adjusted over time (Faccio and Mitchell 2013). Trend in condition was not determined.

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Amphibians and Reptiles

Description and Relevance

Amphibians and reptiles are valued park resources that also may serve as useful bioindicators of environmental stress from changes in water quantity and quality, atmospheric deposition, climatic change, habitat degradation and habitat loss. Forest management practices at MABI can affect the condition of amphibian populations; thus the status and trend in key amphibian and reptile populations can provide useful information guiding park management (Faccio 2001, Faccio 2011).

Data and Methods

An inventory of amphibians and reptiles conducted from 1999 to 2000 documented a total of 13 amphibian species (6 salamanders, 7 frogs) and 5 reptiles species (2 turtles, 3 snakes) in MABI, though one anuran (Northern leopard frog, *Lithobates pipiens*) was documented only as a single unconfirmed call (Faccio 2001). Eleven of the thirteen amphibian species (6 salamanders, 5 frogs) were confirmed to have breeding populations in the Park; this group included Jefferson Salamander (*Ambystoma jeffersonianum*), a Species of Greatest Conservation Need (SGCN) in Vermont. All the reptiles are suspected, but not confirmed, to breed within the Park. Red-backed salamanders (*Plethodon cinereus*) were the most widely distributed amphibian species found in the Park. Two species that were expected to occur in MABI but were not documented during the inventory are gray treefrog (*Hyla versicolor*) and smooth green snake (*Opheodrys vernalis*); the former has subsequently been reported in the park (K. Jones, personal communication, 1 July 2014).

Faccio (2011) conducted twice annual egg mass counts in seven vernal pools in or near MABI from 2009 to 2011 to monitor productivity and estimate population size of three amphibian species (*Lithobates sylvatica*, *Ambystoma maculatum*, and *A. jeffersonianum*). Size for each breeding population was estimated from annual egg mass counts adjusted for detection probability, reported average egg masses laid per female for each species, and the previously measured sex ratios of each species at this site. Hydrology and water chemistry data were collected to better understand condition of breeding habitat. Water chemistry and hydrology were similar between pools, and the number of eggs present was positively correlated to pool size for all three species. The cluster of four vernal pools just north of the Pogue (POPO, PRPO, FWNO and FWSO in Figure 4.25) was the most important vernal pool breeding habitat studied; this cluster supported 90% of the study area's Wood Frog population, 81% of the Spotted Salamander population, and 58% of the Jefferson Salamander population.

Brauer (2012) undertook periodic anuran call surveys and collected automated recordings at MABI from May 1 – July 1 2010 to study audio detection methods for four Anuran species (*Hyla versicolor, Pseudacris crucifer, Anaxyrus americanus,* and *Lithobates clamitans*).

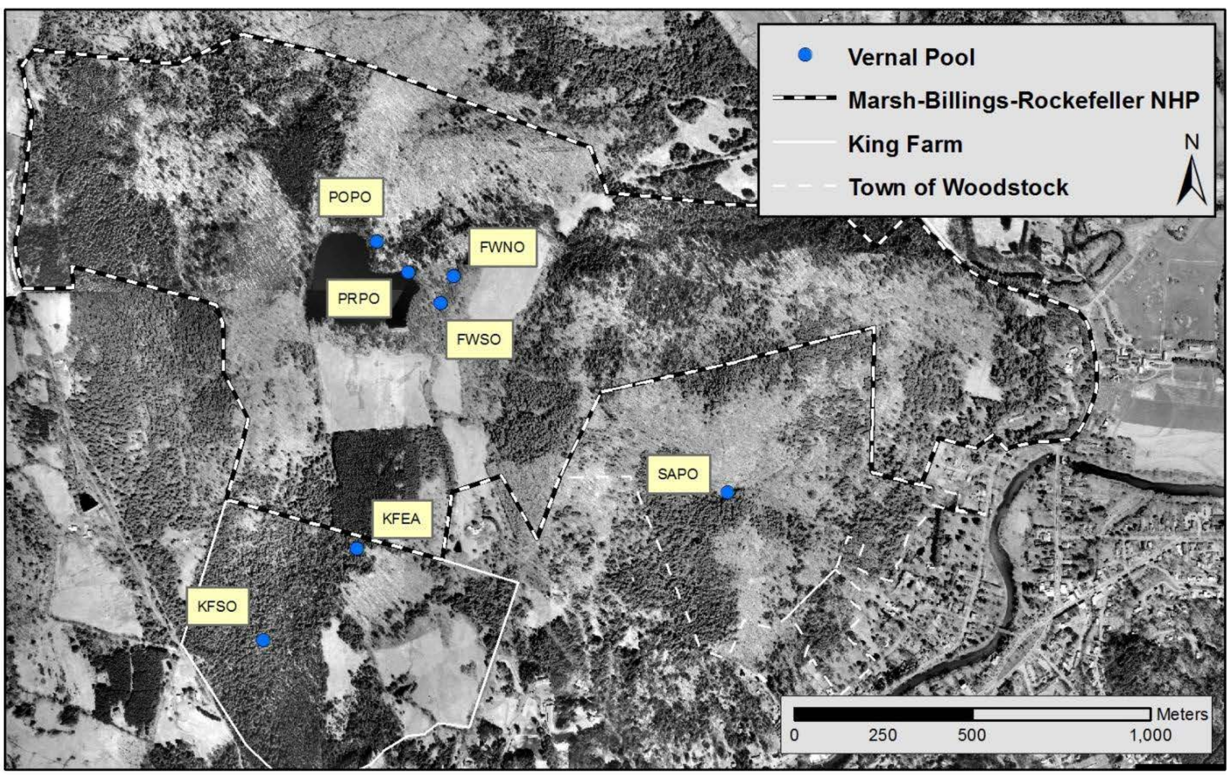


Figure 4.25. Vernal pools in and near Marsh-Billings-Rockefeller NHP (excerpted from Faccio 2011).

Assessment Points

The Ohio Environmental Protection Agency has developed an Amphibian Index of Biotic Integrity (AmphIBI) to assess the quality of forested and shrub wetlands, based on characteristics of the amphibian community (Micacchion 2004). This index provides a tool to assess amphibian community condition (Wagner et al. 2014). AmphIBI assesses condition based on five metrics of amphibian community composition: three metrics assess the relative abundance of sensitive and tolerant amphibian species, one metric assesses the number of pond-breeding salamanders, and one metric assesses the presence or absence of spotted salamanders or wood frogs (vernal pool breeding species correlated with the availability of forested cover). Species sensitivity to disturbance is estimated using a coefficient of conservatism (C of C) ranging from 1 to 10, with higher numbers assigned to sensitive species. A maximum of 10 points is awarded for each metric, which are summed to yield a maximum total index score of 50 points. Micacchion (2011) identified index scores >= 30 as Superior wetland habitat, while scores below 20 are considered Restorable wetland habitat (10-19) or Limited wetland habitat (<10). Accordingly, we suggest assessment points for amphibian community condition as shown in Table 4.18.

Table 4.18. Suggested assessment points for rating amphibian community condition at MABI (adapted from Micacchion 2011).

Condition rating	AmphIBI score
Good condition	30 – 50
Moderate concern	20 - 29
Significant concern	< 20

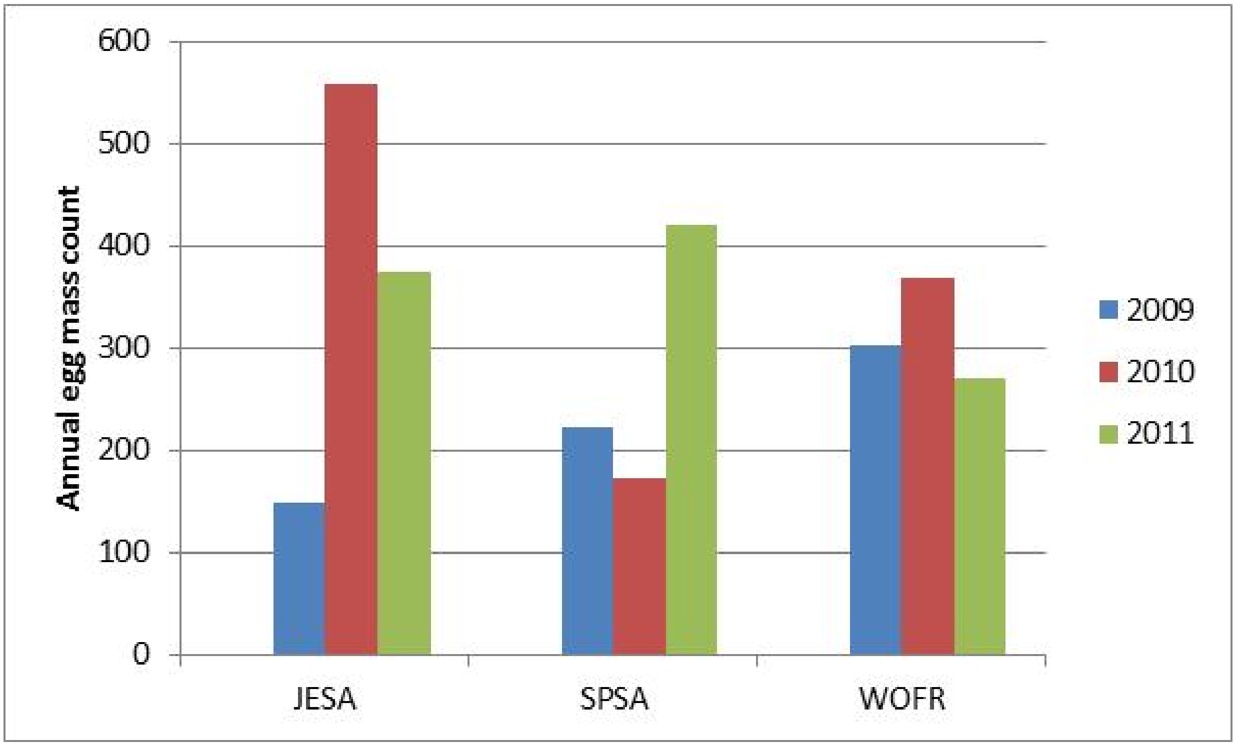
Condition and Trend

Pooling all data from the park Amphibian and Reptile Inventory (Faccio 2001a), MABI achieved an overall AmphIBI score of 38, showing good condition, with all five AmphIBI metrics receiving high scores (>=7 out of 10). Thus amphibian species sensitive to disturbance and pond-breeding salamanders are well-represented in the amphibian community at MABI, and vernal-pool breeding species associated with forest cover are present.

Three-year annual egg mass counts and associated population estimates for three species (*Lithobates sylvatica*, *Ambystoma maculatum*, and *A. jeffersonianum*) at MABI showed considerable variation among years (Figure 4.26 adapted from Faccio 2011). Trend in community condition and species population estimates were not assessed due to the limited available data.

Data Gaps and Level of Confidence

Confidence in status assessment is low due to limited data, and use of an assessment tool (AmphIBI) that was developed for assessing the wetlands of Ohio. Trend was not assessed.



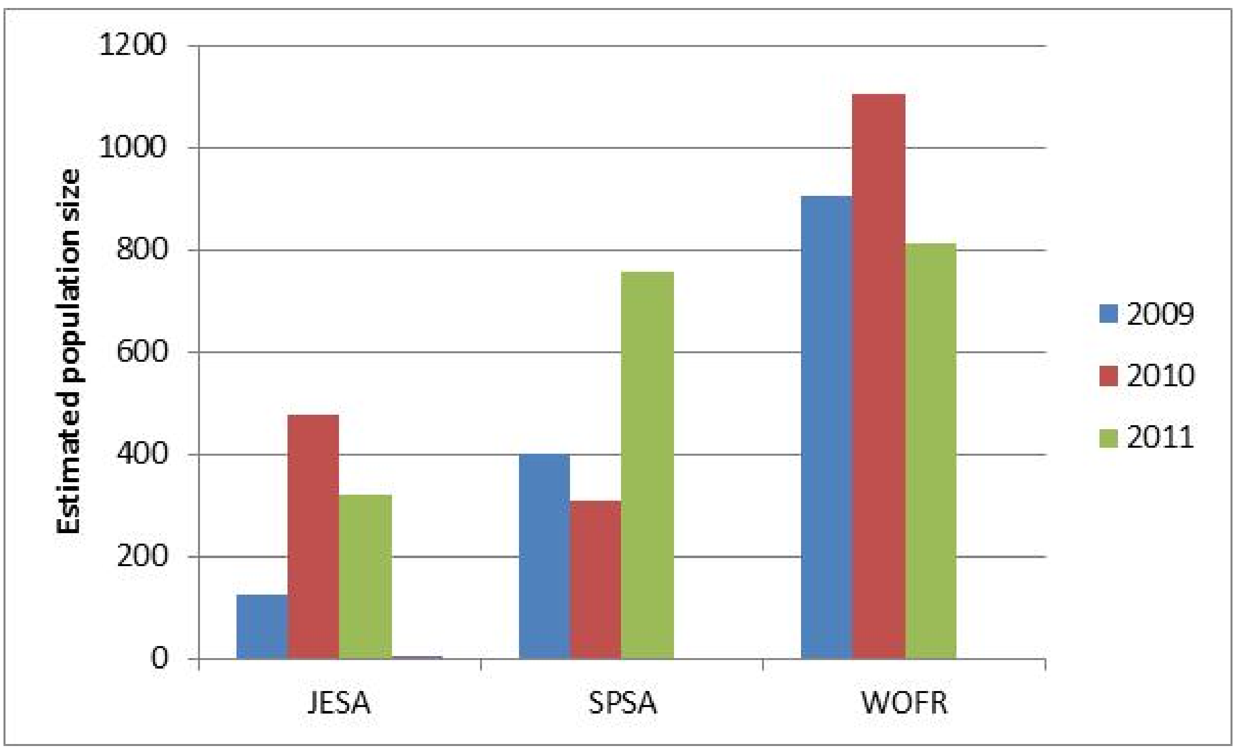


Figure 4.26. Three-year annual egg mass counts and associated population estimates for three species at MABI (adapted from Faccio 2011). JESA is Jefferson salamander (*Ambystoma jeffersonianum)*, SPSA is Spotted salamander (*A. maculatum*) and WOFR is wood frog (*Lithobates sylvatica*).

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Legacy Trees

Description and Relevance

Legacy trees provide a valued cultural and ecological resource due to their large size or old age. Some of the Park’s legacy trees were planted historically to line carriage roads and other landscape features; others are large, open-grown “wolf” trees which grew up in open fields or along field edges; and some are ancient hemlock which are found near The Pogue and associated wetlands. These trees enhance the historic and aesthetic appeal of the Park by providing a grand and historic landscape feature. These trees also are a valuable ecological resource which provides structural diversity and wildlife habitat for a variety of species. Dead legacy trees continue to provide this ecological service for many years, as the decaying bole provides nesting, roosting, foraging and den sites for a variety of bird, small mammal, and amphibian species.

Data and Methods

In the early 2000’s, legacy trees were sighted from eleven survey transects running east-west across the park (Figure 4.27, Keeton 2005). The study did not define the criteria used to identify trees as legacy trees for inclusion and mapping, but classified trees as remnant old-growth or wolf trees. This survey identified 97 legacy trees (87 alive, 8 dead, and 2 dying) within or directly adjacent to MABI. Seventy-five percent of these were wolf trees and the remainder were remnant old-growth. The trees ranged in size from 48.5 to 152.5 cm diameter-at-breast-height (dbh) and were primarily sugar maple and eastern hemlock trees (Figure 4.22). While many wolf trees had cankers and large cavities, Keeton reported that most had little crown dieback and remained vigorous.

Legacy trees are not monitored currently as a resource at MABI. However, large trees and snags which occur within NETN forest plots are monitored on a 4-year revisit interval (see section 4.4.4 herein). The initial forest survey (2006-2008) recorded 53 large trees (>= 46 cm dbh) occurring within the 24 permanent forest plots, one of which was standing dead. Each plot is 20 m x 20 m. The total area of 24 plots is approximately 1 hectare. The trees were primarily eastern hemlock, sugar maple, and eastern white pine trees (Figure 4.28), and ranged in size up to 131 cm dbh. Four years later, remeasurement recorded 56 large trees in these plots (one of which was standing dead). During this interval, 7 large trees grew into this size class, one died and broke, and three were cut and removed during forestry operations. Two cut trees were eastern white pine and the third was Scots pine.

In addition, the condition of legacy trees in key, highly visible locations (such as historic Norway spruce which line carriage roads) is informally observed by park staff to assess hazards that might affect visitor safety. Hazardous trees may be pruned, topped, or removed if deemed necessary, and several trees have been topped to mitigate the hazard but retain a snag (K. Jones, personal communication, 26 March 2014).

Assessment Points

The Forest Management Plan at MABI specifies that existing legacy trees be retained as long as possible, and that new legacy trees be recruited in plantations and hardwood and mixed forest stands to increase the overall number of legacy trees (NPS 2006).

Good condition	Net gain of legacy trees since enactment of FMP in 2006
Moderate concern	No net change in number of legacy trees since 2006
Significant concern	Net loss of legacy trees since 2006

Condition and trend

Data from NETN forest monitoring report a 6% net gain in large trees (>=46 cm dbh) within permanent plots between initial measurement (2006-08) and remeasurement (2010-12), which indicates good condition. NETN forest monitoring was not designed to monitor legacy trees, and the limited dataset for large trees from the 24 permanent forest plots is insufficient to determine condition or trend of legacy trees across the park.

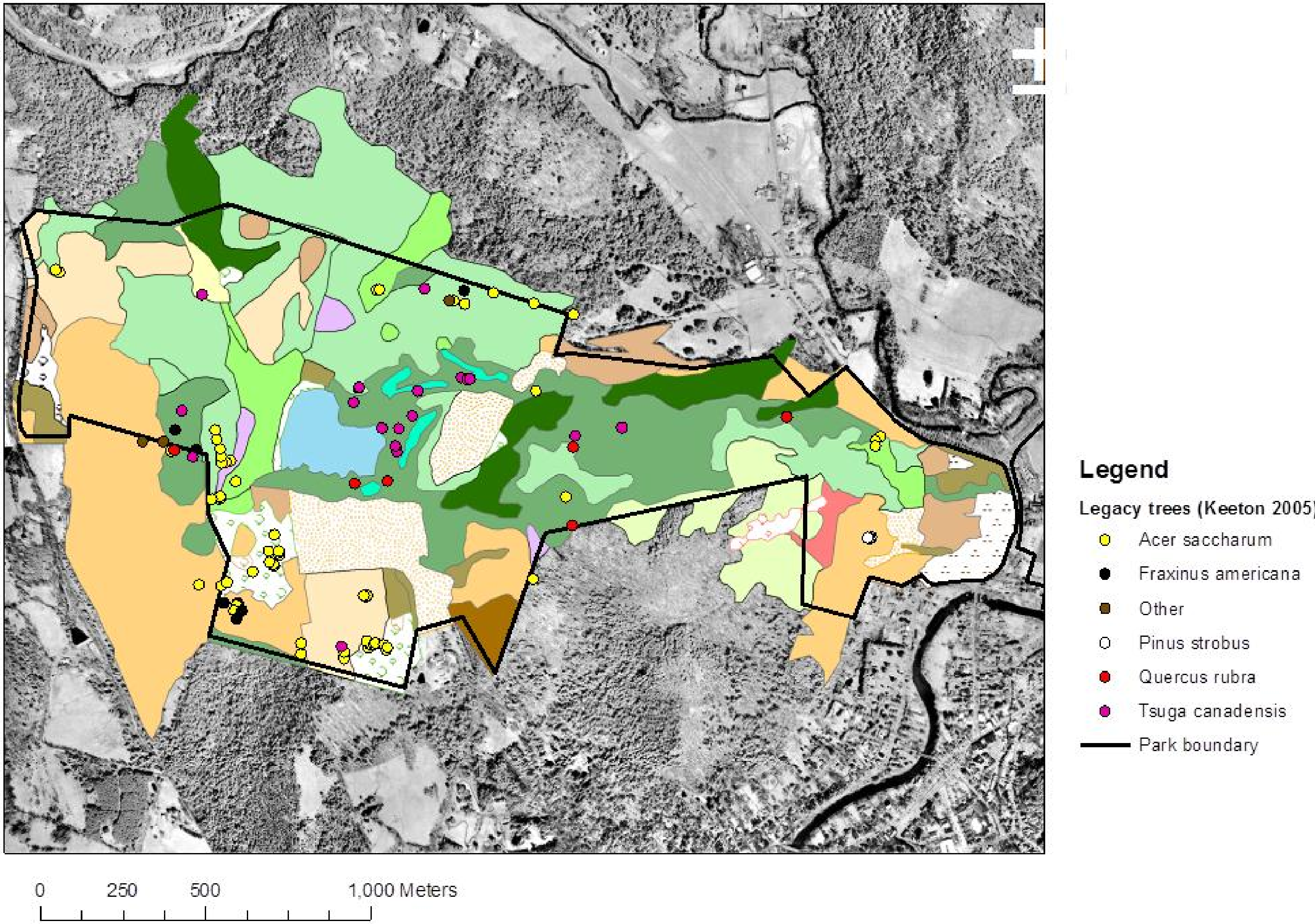

Figure 4.27. Map of legacy trees inventoried along eleven transects in Marsh-Billings-Rockefeller National Historical Park (Keeton 2005).

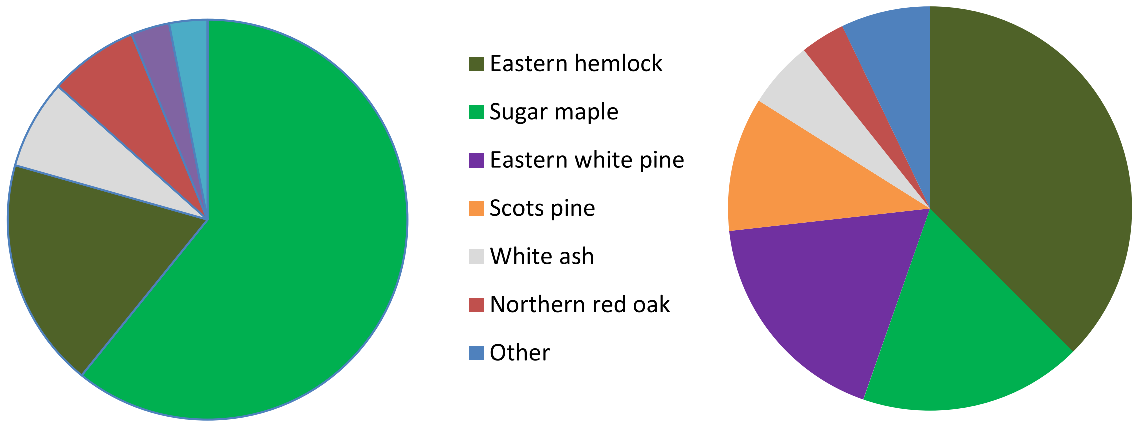

Figure 4.28. Species distributions of a) 97 “legacy trees” in or near MABI surveyed by Keeton 2005; and b) 56 large trees (>= 46 cm dbh) monitored in NETN permanent forest plots.

Data Gaps and Level of Confidence

Legacy trees are not explicitly monitored, thus confidence in this assessment is low. Legacy trees are a cultural resource as well as an ecological resource. As such, legacy trees in some highly visible or historically important locations may have higher value than legacy trees in other locations. Large trees of undesired species may not qualify as legacy trees. Park managers may wish to explicitly define the legacy tree population at the park, and set up a monitoring program at key locations to ensure proper stewardship of this resource. Monitoring could include photographic documentation of the aesthetic impact of key legacy trees.

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Bats

Description and Relevance

Since 2006, white-nose syndrome (WNS) has spread across the eastern US and Canada causing major mortality in populations of several species of cave bats (Ingersoll et al. 2013). Four of these species are now listed as endangered in the state of Vermont (including the federally endangered Indiana bat, *Myotis sodalis*; see Table 4.19). The formerly common little brown bat (*Myotis lucifugus*) may be at risk of rapid extinction (Frick et al. 2010). WNS is considered to be among the worst wildlife health crises in recent history.

The federally endangered Indiana bat (*Myotis sodalis*) has not been confirmed present in the park (Table 4.17) but may use roosts within 40 km (25 miles) of the park (Britzke et al. 2006).

Table 4.19. State conservation status and detection status of bat species in MABI. SGCN is a Species of Greatest Conservation Need in Vermont (VNHI 2012). Detection status was reported by Reynolds and McFarland (2001) and McFarland (2011). "Unknown" detection status indicates audio detection software was not specific enough to determine whether calls from that species were present.

Common name	Scientific name	VT Conservation Status	Detected in MABI 2001	Detected in MABI 2011
Little brown myotis	*Myotis lucifugus*	Endangered	Mist nets, recorded calls	Recorded calls
Eastern small-footed myotis	*M. leibii*	Threatened	Unknown	Single recorded call
Northern long-eared myotis	*M. septentrionalis*	Endangered	Mist nets, recorded calls	Single recorded call
Indiana bat	*M. sodalis*	Endangered[1]	Unknown	Unconfirmed recorded calls
Big brown bat	*Eptesicus fuscus*		Recorded calls	Single recorded call
Eastern pipistrelle bat (Tri-colored bat)	*Perimyotis subflavus*	Endangered	Recorded calls	Single recorded call
Eastern red bat	*Lasiurus borealis*		Single recorded call	Recorded calls
Hoary bat	*Lasiurus cinereus*	SGCN	Recorded calls	Recorded calls
Silver-haired bat	*Lasionycteris noctivagans*	SGCN	Recorded calls	Recorded calls

[1] M. sodalis is listed as a federal endangered species.

Data and Methods

A Park bat inventory conducted in July-August 2001 documented two species of bats in mist nets, and recorded calls from an additional five bat species using acoustic monitoring (Table 4.19). Bat activity centered around The Pogue and in fields. The little brown bat (*M. lucifugus*) was the most common species in the park, accounting for 75% of mist-met captures (Reynolds and McFarland 2001).

Resampling in 2011 using an Anabat bioacoustic monitoring system deployed on the Pogue shoreline showed a dramatic drop in bat activity compared to the 2001 survey (Table 4.20; McFarland 2011). Both the overall rate of bat calls per hour and the rate of Myotis bat calls per hour detected by acoustic sampling in 2011 were below 5% of the rate sampled in 2001. Bat species richness detected by acoustic monitoring in 2011 was similar to 2001 (Table 4.17).

Table 4.20. Comparison of bat activity (calls/hour) recorded in MABI during bat inventory (Reynolds and McFarland 2001) and resampling (McFarland 2011).

Year	Site	Sampling Days	Hours Sampled	Total Calls	Myotis Calls	Calls/hour	Myotis Calls/hour
2001	Pogue East and Pogue West	3	19.5	1247	1238	63.9	63.5
2011	Pogue East	5	45	100	64	2.2	1.4

Assessment Points

Using recorded calls per hour as an index of bat activity, the following assessment points were used to interpret Bat condition:

Good condition	>= 80% of bat activity and species pool (7 species) recorded in 2001 inventory
Moderate concern	50% to 80% of bat activity OR species pool recorded in 2001 inventory
Significant concern	< 50% of bat activity OR species pool recorded in 2001 inventory

Condition and Trend

The rate of bat calls per hour detected by acoustic sampling in 2011 was < 50% the rate sampled in 2001. While the surveys are insufficient for statistical trend analysis, trend in bat activity appears to have deteriorated substantially since 2001 warranting significant concern.

Data Gaps and Level of Confidence

The dramatic drop in bat activity indicated by resampling data at this park mirrors well-documented declines in at least four species across the region (Frick et al. 2010, Ingersoll et al. 2013). Thus confidence in both status assessment and regional trend is high despite the limited park dataset.

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Mammals

Description and Relevance

National park units provide important habitat for native mammal species, which in turn play important roles in park ecosystems as consumers of park vegetation and as predators. Data describing the status and trend in key mammal populations can provide useful information to park managers. The Park lies within a larger matrix of protected lands adjacent to important bear habitat (NPS 2006, Allen et al. 2007).

Data and Methods

In 2004, mammals were surveyed at 26 sampling points (12 traps and 14 indirect measure such as camera or trackplate) within seven community types in the Park (conifer, riparian, wetland, deciduous, field, rich northern hardwood, and mixed deciduous-conifer; Gilbert et al. 2008). Of 58 species that were considered possibly present in the Park based on park habitat and mammal geographic distributions, Gilbert detected 23 species (Table 4.21). Fisher (*Martex pennanti*) was the most commonly detected species during the mammal survey, followed by raccoon (*Procyon lotor*), and deer mouse (*Peromyscus maniculatus*) was the most commonly captured species. Six of the species detected by this inventory do not occur on the NPS certified species list of mammals present or probably present in the Park (Table 4.19; NPS 2014). A domestic dog also was detected by automatic camera during the inventory (Gilbert et al. 2008). During the Park herptile inventory in 2001, eight species of small mammals were captured in pitfall traps in forested wetlands east of the Pogue including three species not detected during the mammal inventory (Table 4.19); masked shrew (*Sorex cinereus*) was the mammal most frequently detected during that inventory (Faccio 2001). Bat sampling has detected at least seven bat species in the Park (Table 4.19; see also section 4.4.9). Eight additional species occur on the certified species list of 33 mammals present or probably present in the Park (Table 4.19; NPS 2014). In addition to these certified and detected species, Virginia opossum (*Didelphis virginiana*) has been sighted and photographed in the park; and two river otter (*Lutra canadensis*) sightings were reported in 2010 (Jones 2011). No federally protected mammal species have been detected in the park; the only state protected mammal species documented in the park are bats (see section 4.4.9). One species (*Mustela frenata*) documented in MABI by Gilbert et al. (2008) is a Species of Greatest Conservation Need (SGCN) in Vermont (VNHI 2012).

Table 4.21. Mammal species present or possibly present within MABI.

Common name	Latin name	Abundance	Source	NPS Certified List
Moose	*Alces alces*[1]	Rare		x
White-tailed deer	*Odocoileus virginianus*	Common	Gilbert et al. 2008	x
Coyote	*Canis latrans*	Uncommon	Gilbert et al. 2008	x
Gray fox	*Urocyon cinereoargenteus*	Uncommon	Gilbert et al. 2008	x
Red fox	*Vulpes vulpes*	Occasional	Gilbert et al. 2008	x
Bobcat	*Lynx rufus*		Jones 2011	x
Striped skunk	*Mephitis mephitis*	Occasional	Jones 2011	x
Fisher	*Martes pennanti*	Rare	Gilbert et al. 2008	x
Ermine	*Mustela erminea*		Gilbert et al. 2008	
Long-tailed weasel	*Mustela frenata*		Gilbert et al. 2008	
Mink	*Mustela vison*		Gilbert et al. 2008	x
Raccoon	*Procyon lotor*	Occasional	Gilbert et al. 2008	x
Black bear	*Ursus americanus*	Uncommon	Jones 2011	x
Big Brown bat	*Eptesicus fuscus*		Reynolds and McFarland 2001, McFarland 2011	x
Silver-haired bat	*Lasionycteris noctivagans*		Reynolds and McFarland 2001, McFarland 2011	x
Red bat	*Lasiurus borealis*		Reynolds and McFarland 2001, McFarland 2011	x
Hoary bat	*Lasiurus cinereus*		Reynolds and McFarland 2001, McFarland 2011	x
Little brown myotis	*Myotis lucifugus*		Reynolds and McFarland 2001, McFarland 2011	x
Northern long-eared myotis	*Myotis septentrionalis*		Reynolds and McFarland 2001, McFarland 2011	x
Eastern pipistrelle	*Pipistrellus subflavus*		Reynolds and McFarland 2001, McFarland 2011	x
Virginia opposum	*Didelphis virginiana*		Jones 2011	
Clethrionomys gapperi	*Red-backed vole*		Gilbert et al. 2008	
White-footed mouse	*Peromyscus leucopus*	Common	Gilbert et al. 2008	
Deer mouse	*Peromyscus maniculatus*	Common	Gilbert et al. 2008	
Woodland jumping mouse	*Napaeozapus insignis*		Faccio 2001	x
Porcupine	*Erethizon dorsatum*		Gilbert et al. 2008	x
Meadow vole	*Microtus*	Common	Faccio 2001, Gilbert et	x

Common name	Latin name	Abundance	Source	NPS Certified List
	pennsylvanicus		al. 2008	
House mouse	*Mus musculus*			x
Muskrat	*Ondatra zibethicus*		Jones 2011	x
Northern Flying Squirrel	*Glaucomys sabrinus*[2]			x
Southern flying squirrel	*Glaucomys volans*		Gilbert et al. 2008	
Woodchuck	*Marmota monax*[3]			x
Gray Squirrel	*Sciurus carolinensis*		Gilbert et al. 2008	x
Eastern Chipmunk	*Tamias striatus*	Common	Gilbert et al. 2008	x
Red squirrel	*Tamiasciurus hudsonicus*	Common	Gilbert et al. 2008	x
Short-tailed shrew	*Blarina brevicauda*	Common	Faccio 2001, Gilbert et al. 2008	x
Masked shrew	*Sorex cinereus*	Common	Faccio 2001, Gilbert et al. 2008	x
Smokey shrew	*Sorex fumeus*	Common	Faccio 2001	x
Star-nosed mole	*Condylura cristata*	Occasional	Faccio 2001	x
Hairy-tailed mole	*Parascalops breweri*	Occasional	Faccio 2001, Gilbert et al. 2008	x

[1] This species is very rarely seen in the Park (K. Jones, personal communication, 26 March 2014).
[2] Trackplate markings were attributed to either this species or red squirrel (Gilbert 2008).
[3] Gilbert et al. (2008) detected woodchuck burrows and noted this species is likely to be common in Park.

Assessment points

Assessment points for mammal species (other than bat species and white-tailed deer) have not been defined. Suggested assessment points for mammal condition are shown in Table 4.22. Expected species pool includes all native mammal species on NPS certified species list for the Park (33 species) or documented in the park (an additional 7 species), in addition to beaver (*Castor canadensis*) and showshoe hare (*Lepus americanus)* for a total of 42 species.

Table 4.22. Assessment points for mammal condition in MABI.

Condition rating	Species richness
Good condition	>80 % expected species pool (>33 species)
Moderate concern	50% - 80% expected species pool (21-33 species)
Significant concern	<50 % expected species pool (<21 species)

Condition and Trend

Data are not available to determine population trend of key mammal species other than bat species and white-tailed deer, which are assessed in section 4.4.9 (Bats), and section 4.4.5 (White-tailed deer herbivory). Presence of 38 out of a potential 42 mammal species has been documented by park inventories or observations (Table 4.21), indicating good condition. For this assessment, woodchuck (*Marmota monax*) were considered present in park based on woodchuck burrows detected by Gilbert et al. (2008) and sightings by Park staff (K. Jones, personal communication, 1 July 2014). Northern flying squirrel (*Glaucomys sabrinus*) may also be present but trackplate observations were not definitive (Gilbert et al. 2008).

Data Gaps and Level of Confidence

Confidence in status assessment based on expected species pool and limited data is low. Monitoring of key mammal species, including the long-tailed weasel (*Mustela frenata*), a SGCN in Vermont, could provide useful information to park managers.

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Terrestrial Invertebrates

Description and Relevance

Invertebrates can be useful indicators of biological condition due to their diversity, abundance, and sensitivity to environmental change (Gerlach et al. 2013).

Data and Methods

No data have been collected at MABI.

Assessment Points

Assessment points have not been defined.

Condition and Trend

Condition and trend cannot be assessed at this time due to the lack of data.

Data Gaps and Level of Confidence

This data gap could be filled if funding permits. Bees can be useful indicators of environmental condition (Porrini et al. 2003, Rabea et al. 2010). Researcher Sam Droege (sdroege@usgs.gov) with the Patuxent Wildlife Research Center has collaborated with the U.S. Forest Service to develop methods for monitoring native bees. Butterflies are charismatic invertebrates which have been surveyed in locations across the state as part of the Vermont Butterfly Survey. A variety of terrestrial invertebrate taxa may serve as useful indicators of the ground layer (including ants, millipedes, snails, ground beetles, harvestmen and gnaphosid spiders), or the foliage layer (including ants, chrysomelid leaf beetles, theridiid spiders and arctiid moths) while isopods may be useful soil indicator species (Gerlach et al. 2013).

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Human Use

Visitor Usage

Description and Relevance

Visitor use has been recognized as a Vital Sign directly related to park management (Mitchell et al. 2006). Though MABI is a newly-created national park, it has served as a public recreational resource since the time of Frederick Billings (NPS 1999). Deed restrictions included by the Rockefellers prohibit the use of mountain bikes, snowmobiles or other motorized vehicles (except those needed for management), camping and camp fires, hunting, fishing and swimming in the Pogue (NPS 1999). Horseback riding and carriage riding are permitted in the park.

Until the early 2010s, the trails and carriage roads of MABI were groomed for cross-country skiing by the Woodstock Ski Touring Center, but now MABI trails and carriage roads are left in their natural state for back-country skiing and snow-shoeing. The Woodstock Resort Corporation retains an easement to operate recreational activities on existing trails and carriage roads (Public Law 102-350). Historically, local people gathered wildflowers and mushrooms from the forest (NPS 1999).

Data and Methods

Automatic counters located at the park's three primary entrances (the Prosper gate, the woodbarn, and the pony pasture) record numbers of visitors to the forest and visitors entering the Visitor Center are encouraged to sign into a log book. A survey of community residents was undertaken in 1994 to determine what uses the local population engaged in when visiting the park (NPS 1999).

Visitors traveling off established carriage roads and footpaths may trample vegetation and the forest floor. NETN forest crews have visually assessed trampling in 24 permanent forest plots during visits every four years since 2006 (Tierney et al. 2009); visible trampling may be caused by visitors, forest management, or by wildlife such as white-tailed deer.

Assessment Points

Assessment points have not been established for numbers of visitors. Trampling was rated using the following assessment points:

Good condition<1% trampled ground cover
Moderate concern 1-5% trampled ground cover
Significant concern >5% trampled ground cover

Condition and Trend

Visitation in 2012 was very similar to 5-year averages for the period 2008-2012 (averaging 19,570 visits to the forest park each year and 12,301 visits to Center; NPS 2013). Most visits to MABI occur from June to October (Table 4.23).

Table 4.23. Visitors to MABI forest park by month in 2011 and 2012 (NPS 2013).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2012	1,686	1,309	940	725	1,197	2,387	2,651	1,409	3,186	3,629	739	548	20,406
2011	1,692	1,449	967	452	1,320	1,991	1,989	1,298	2,081[1]	3,645[2]	671	694	18,249

[1] Visitation was greatly affected by Tropical Storm Irene which devastated portions of Vermont on August 28, 2011.
[2] Tropical Storm Irene was still affecting visitor numbers due to public perception that Vermont was a disaster area but school visits were dramatically up due to a new education initiative.

A survey undertaken in 1994 indicated that community resident users of MABI most often visited in the fall and summer, and primarily engaged in walking/hiking, with skiing and nature-study being secondary activities (NPS 1999).

Trampling of NETN forest plots was negligible (<1% cover) in all but 2 of the 24 plots in the current data cycle; this indicates good condition. Both plots that showed visible trampling (1-5% or 5-15% cover) in the current cycle (plots 11 and 17) are located in plantations in the western part of the park (Figure 4.29). Plot 11 lies between Prosper Road and a carriage road and this plot also showed trampling in the initial data cycle. Plot 20 showed trampling during the initial data cycle but had recovered by the current data collection. The trend in visible trampling was unchanging between the first and current data collections.

Data Gaps and Level of Confidence

Level of confidence in park visitor counts is moderate. Automatic counters may over count visitors (who may pass by counters more than once) and park log books may undercount visitors (who may fail to sign in). Activity engaged in by visitors is a data gap, which could be filled by periodic surveys of visitors. Level of confidence in trampling status assessment is moderate. Patterns of visitor trampling could be better characterized by visual assessment of selected off-trail locations adjacent to major trails and the Pogue.

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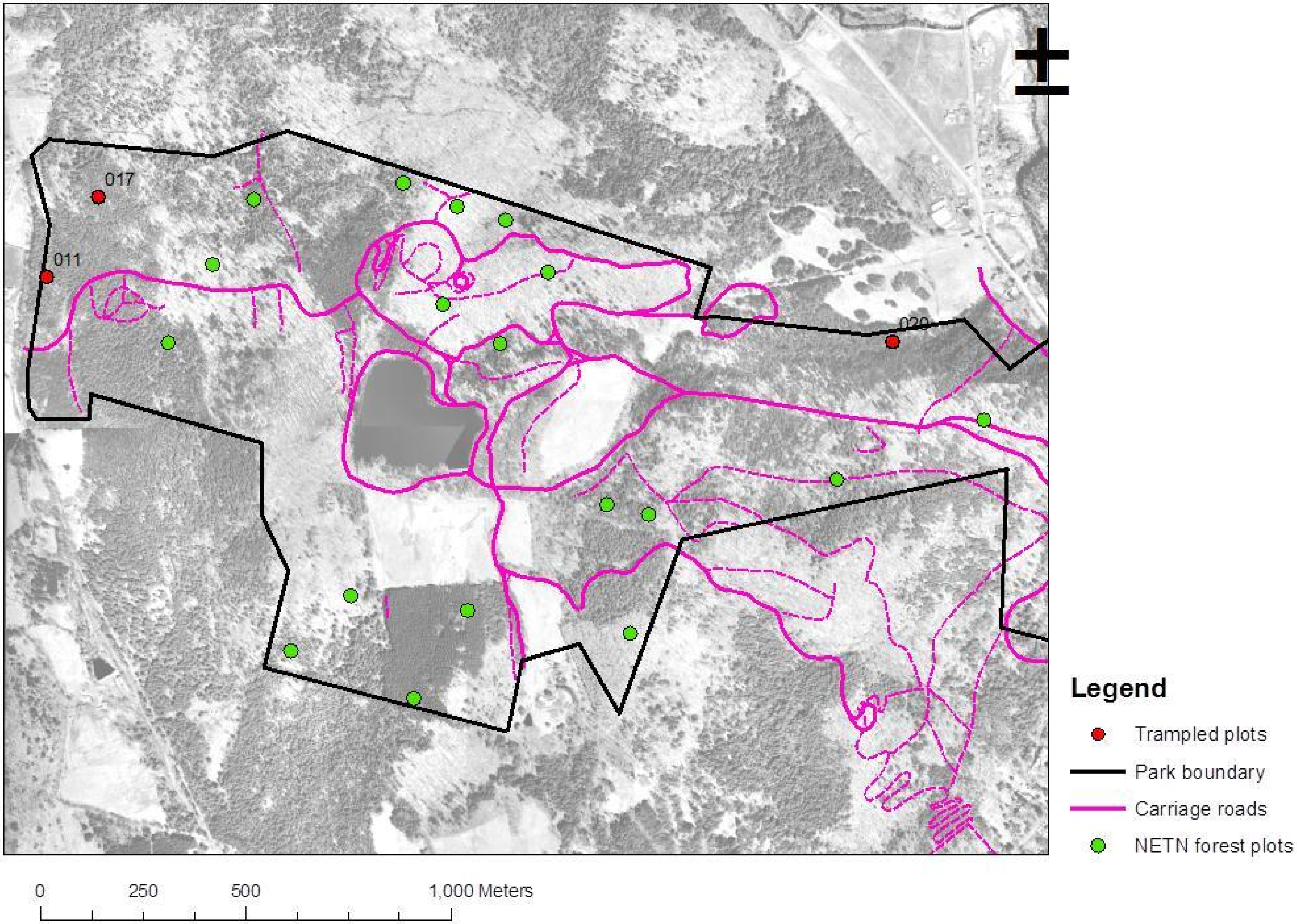

Figure 4.29. Map of trampled forest plots in Marsh-Billings-Rockefeller National Historical Park.

Forest Management

Description and Relevance

Sustainable forest management seeks to ensure that forests are managed with regard to environmental health and social values in addition to economic vitality. Forest management certification programs provide third-party verification that management of individual forests conforms to a set of standards, such as those established by the Forest Stewardship Council (FSC) or the Sustainable Forestry Initiative (SFI).

Data and Methods

Since 2005, MABI has undergone annual audits by representatives of the Rainforest Alliance for conformance with joint forest management/chain-of-custody (FM/COC) certification under FSC standards. MABI is considered a Small and Low Intensity Managed Forest (SLIMF) site for which recertification may occur in some years with a desk audit rather than a site visit. However, site visits by auditors from the Rainforest Alliance have occurred at least every second year beginning with certification in 2005. Assessment has included evaluation of the forest management plan (NPS 2006), timber harvests, invasive species control and pesticide use, protected plant communities, protection of water quality, and plantations management, as well as outreach to stakeholders (Smartwood 2005, Rainforest Alliance Smartwood Program 2010, Rainforest Alliance 2013).

Park personnel initiated the process of forest management certification in 2000. At that time, MABI staff were beginning to develop a forest management plan, which is a key requirement of certification. Assessment toward certification resumed in 2004, after progress in drafting a forest management plan. In August 2005, MABI received conditional certification for FM/COC certification under FSC standards, with three corrective action requests (CARs). The CARs required 1) within three years, the inclusion of stand treatment schedules, growth and yield estimates, and a target allowable cut with supporting rationale in the forest management plan; 2) within one year, the development of written guidelines for minimizing spills or leaks from equipment during and following forest operations; and 3) within one year, completion of Part 4 of the Forest Management Plan “Environmental Consequences of the Proposed Alternatives.” All three CARs were corrected as required within the allotted time frame. Two additional CARs were issued during the 2006 audit requiring 1) the development of documented chain-of-custody procedures; and 2) discontinued use of pesticides considered highly hazardous by FSC. The former was corrected as required by the time of the 2007 audit, and the latter requirement was met by excluding three ha (eight acres) surrounding the mansion from FSC-certified land due to ongoing treatment of ornamental trees and landscaping with pesticides considered highly hazardous by FSC. No new CARs have been issued since 2006. MABI was reassessed by Rainforest Alliance auditors in 2010, and recertified for five years (April 2011 to April 2016) with ongoing annual conformance audits (Smartwood 2005, Rainforest Alliance Smartwood Program 2010, Rainforest Alliance 2013).

Assessment Points

FSC uses ten principles to assess forest practices. Each principle is defined by one or more criteria, and national or regional indicators specify the requirements needed to fulfill each criteria. The current U.S. standard (FSC-US 2010) defines the ten principles to be:

Principle 1: Forest management shall respect all applicable laws of the country in which they occur, and international treaties and agreements to which the country is a signatory, and comply with all FSC Principles and Criteria.

Principle 2: Long-term tenure and use rights to the land and forest resources shall be clearly defined, documented and legally established.

Principle 3: The legal and customary rights of indigenous peoples to own, use and manage their lands, territories, and resources shall be recognized and respected.

Principle 4: Forest management operations shall maintain or enhance the long-term social and economic well-being of forest workers and local communities.

Principle 5: Forest management operations shall encourage the efficient use of the forest's multiple products and services to ensure economic viability and a wide range of environmental and social benefits.

Principle 6: Forest management shall conserve biological diversity and its associated values, water resources, soils, and unique and fragile ecosystems and landscapes, and, by so doing, maintain the ecological functions and the integrity of the forest.

Principle 7: A management plan -- appropriate to the scale and intensity of the operations -- shall be written, implemented, and kept up to date. The long term objectives of management, and the means of achieving them, shall be clearly stated.

Principle 8: Monitoring shall be conducted -- appropriate to the scale and intensity of forest management -- to assess the condition of the forest, yields of forest products, chain of custody, management activities and their social and environmental impacts.

Principle 9: Management activities in high conservation value forests shall maintain or enhance the attributes which define such forests. Decisions regarding high conservation value forests shall always be considered in the context of a precautionary approach.

Principle 10: Plantations shall be planned and managed in accordance with Principles and Criteria 1-9, and Principle 10 and its Criteria. While plantations can provide an array of social and economic benefits, and can contribute to satisfying the world's needs for forest products, they should complement the management of, reduce pressures on, and promote the restoration and conservation of natural forests.

For the purposes of this NRCA, certification under FSC or similar standards with no open non-conformity reports (NCRs) or corrective action requests (CARs) is considered Good condition; conditional certification subject to one or more NCRs or CARs is considered Moderate concern; and loss or lack of certification corresponds to Significant concern.

Condition and Trend

The forest at MABI has been continuously FSC certified since 2005. CARs identified during assessment in 2005 and 2006 were corrected by the 2008 audit, and no new CARs or NCRs have been reported from 2008 to 2013. This indicates good condition with improving trend over the period 2005 - 2013.

Data Gaps and Level of Confidence

Level of confidence in status assessment is medium.

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Landscapes

Landcover / Ecosystem Cover / Connectivity

Description and Relevance

Habitat fragmentation is a key threat to biodiversity. In general, large forest patches tend to support larger populations of fauna and more native, specialist, and forest interior species (Harris 1984, Forman 1995). The impacts of fragmentation have been especially well documented upon avian communities, and population declines of a variety of forest interior avian species are linked to habitat fragmentation (Austen et al. 2001, Boulinier et al. 2001).

National historic parks and sites such as MABI are particularly vulnerable to impacts from fragmentation due to their relatively small size and layout, typically determined by the location of historical features; both of these factors can increase vulnerability to fragmentation beyond park borders. These parks may also be more vulnerable to fragmentation due to their mandate to preserve and interpret historical features, which may include fragmented landscapes. MABI's primary purpose is for "preservation, education and interpretation" of the nationally significant cultural landscape, which reflects a history of land cover conversion and agricultural and forestry management. Determination of Landcover condition at MABI must consider both ecological integrity and preservation of the historical landscape, as laid out in the Park GMP (NPS 1999) and FMP (NPS 2006).

Data and Methods

Data to interpret the condition of landcover at MABI came from several sources. Wang and Nugranad-Marzilli (2009) used Landsat remote sensing data with ground-truthing to assess landcover change within a 5-km (3.1-mile) buffer surrounding MABI during three time periods: the late 1970s, the late-1980s, and 2002. Over the 24-year time period studied, they found an increase in deciduous forest and a decrease in mixed forest both within the park and within the 5-km buffer, while amounts of coniferous forest were roughly equivalent between the 1978 and 2002 assessments.

Miller et al. (2011) assessed forest patch size at MABI in 2010 using recent, leaf-on 1:6,000 scale orthophotography (Figure 4.30; Miller et al. 2011). This analysis will be repeated periodically to update status and determine trend.

The NPScape program provides several sources of data for assessing status and trend in landscape dynamics within national parks. Using the 2006 National Land Cover Database (NLCD), NPScape provided national coverage of Anderson level 2 landcover categories (Figure 4.31), as well as forest density within 66-ha (162-acre) pixels (Figure 4.32; NPS 2014). Forest density (p) was interpreted within seven categories: intact ($p = 1.0$), interior ($0.9 \leq p < 1.0$), dominant ($0.6 \leq p < 0.9$), transitional ($0.4 \leq p < 0.6$), patchy ($0.1 \leq p < 0.4$), rare ($0.0 \leq p < 0.1$) and none ($p = 0.0$; Ritters 2011). We considered landcover within a 5-km buffer surrounding MABI, corresponding to the window assessed by Wang and Nugranad-Marzilli (2009), and also roughly corresponding to the largest neighborhood size assessed by the Heinz Center (2002).

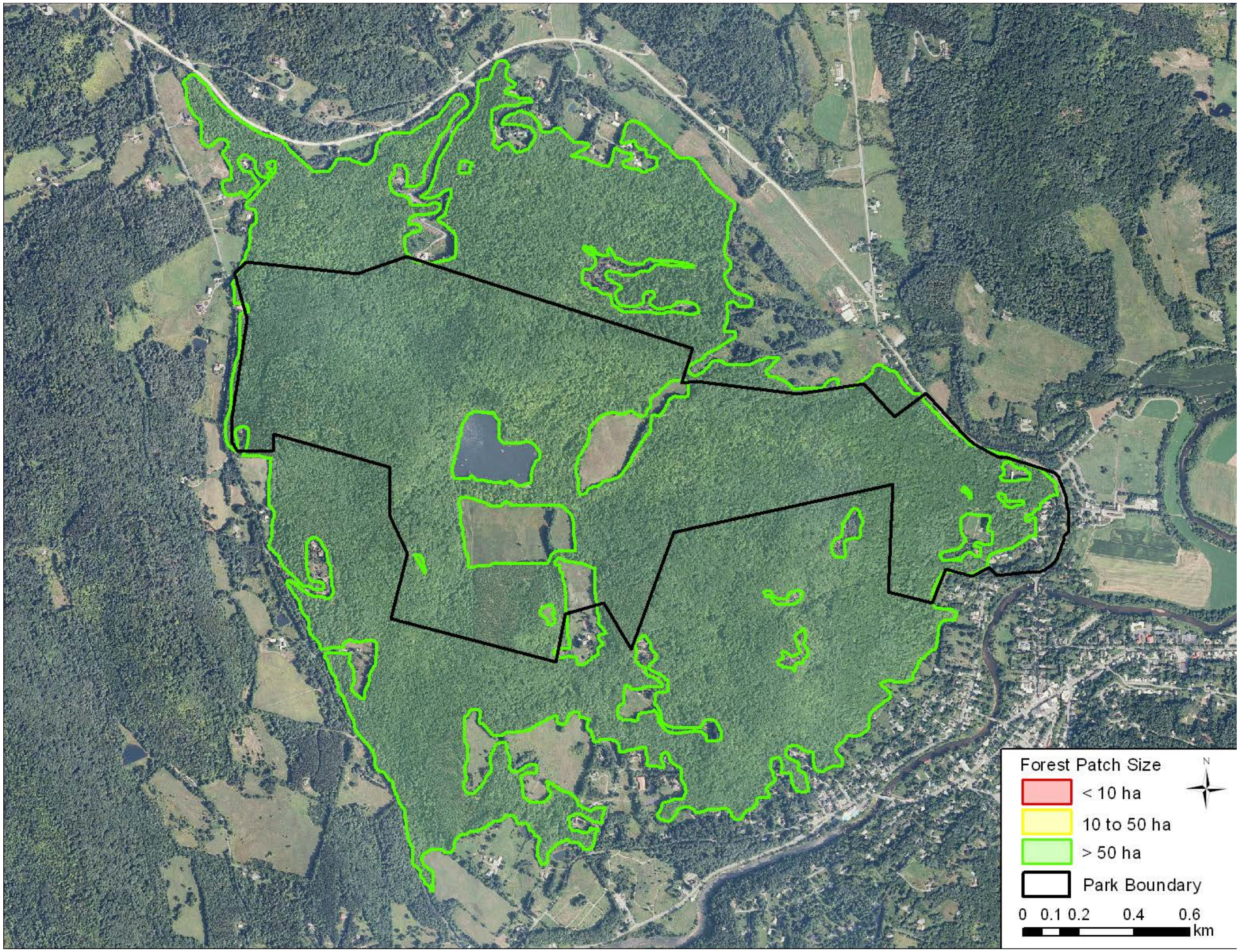

Figure 4.30. Forest patch size delineated at Marsh-Billings-Rockefeller National Historical Park (excerpted from Miller et al. 2011).

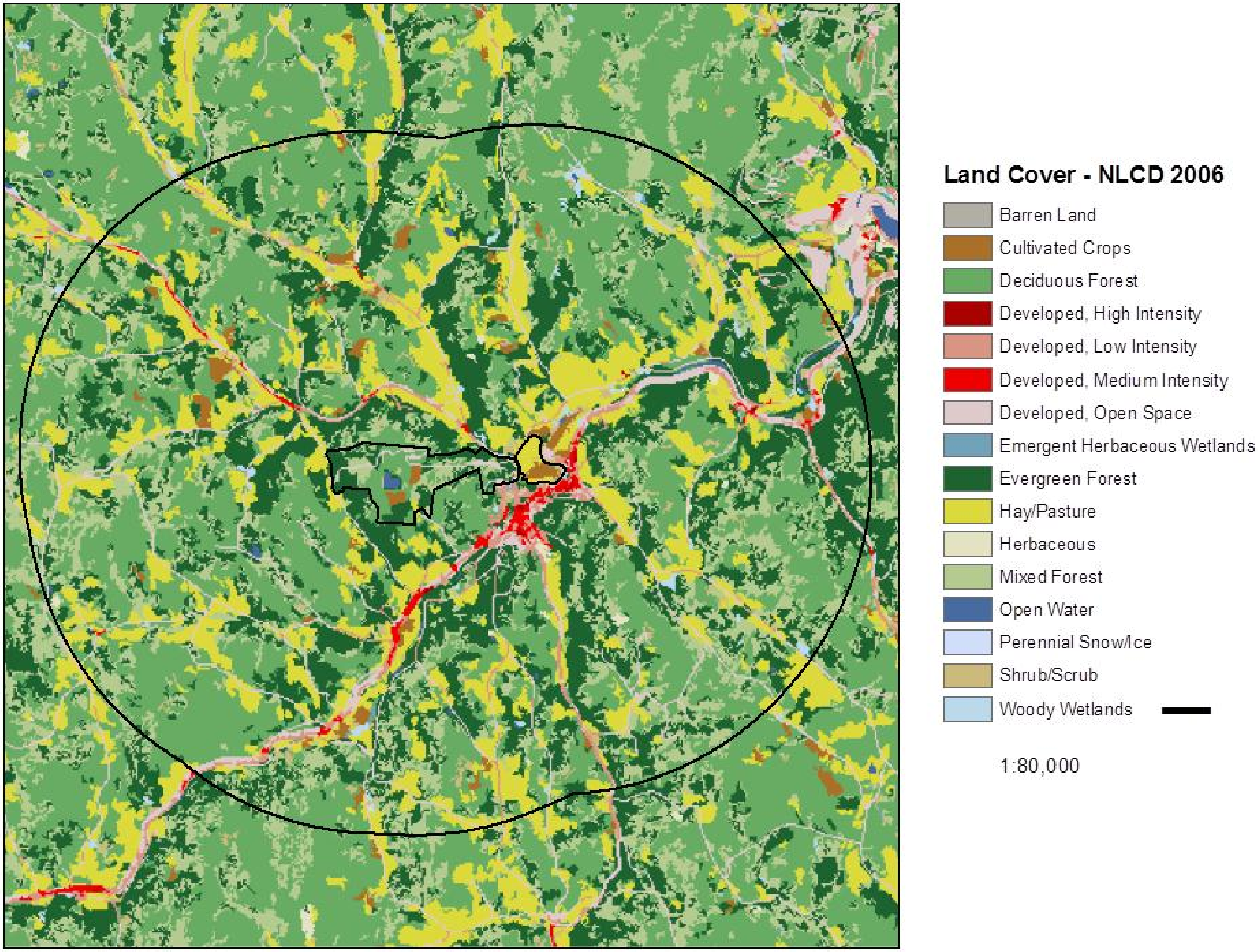

Figure 4.31. Andersen level 2 land cover categories surrounding Marsh-Billings-Rockefeller NHP (NPS 2014).

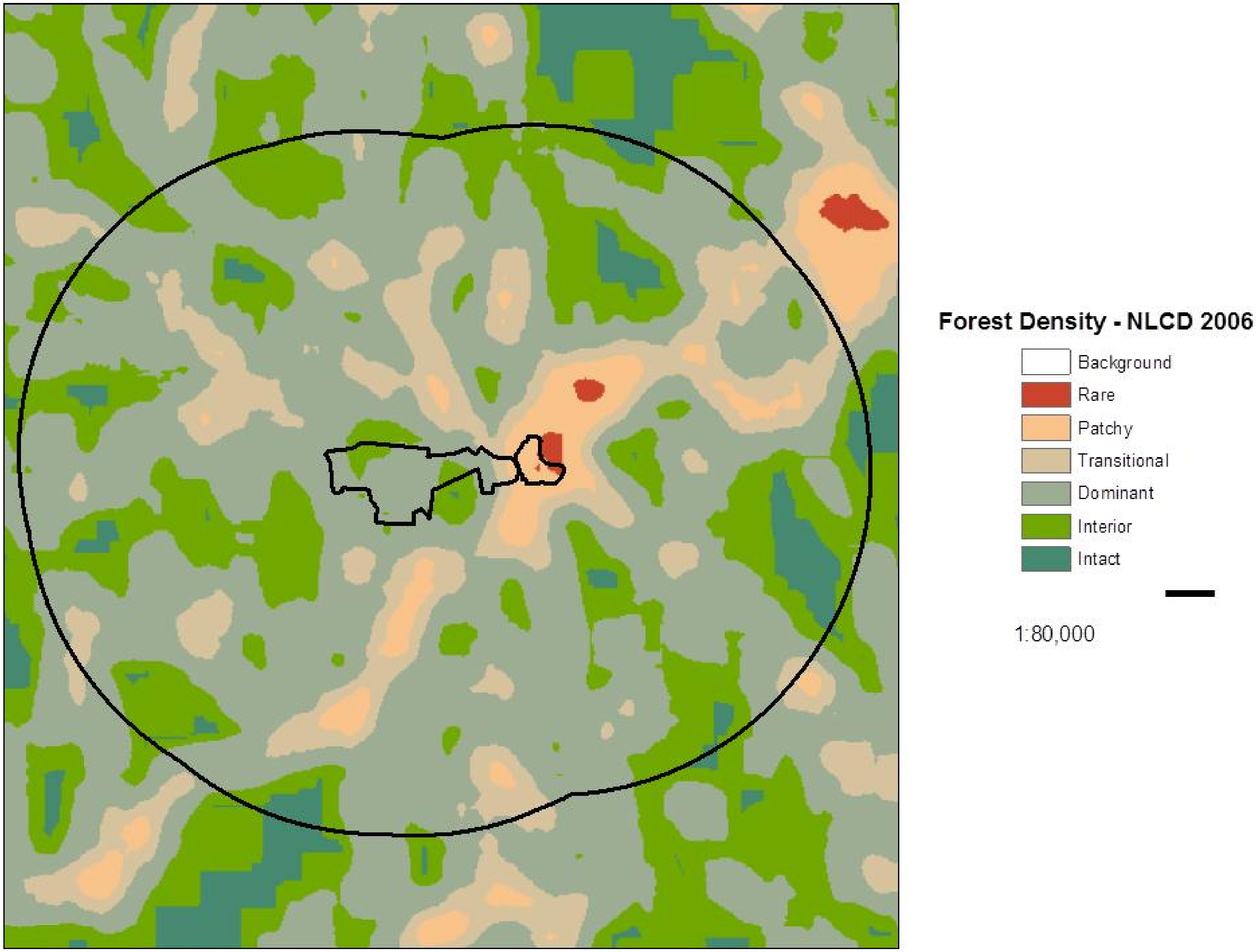

Figure 4.32. Forest density surrounding Marsh-Billings-Rockefeller National Historical Park (NPS 2014).

Assessment Points

Miller et al. (2011) assessed ecological integrity of forest patch size based on the needs of invertebrates, small mammals and many bird species dependent upon intact forest habitat (Kennedy et al. 2003). MABI is too small to support large mammal populations, so the needs of large mammals were not factored into the assessment points for this metric. Assessment points based on forest density classes are suggested as shown in Table 4.24.

Table 4.24. Assessment points for forest patch size and forest density.

Metric	Good condition	Moderate concern	Significant concern
Forest patch size	> 50 ha	10-50 ha	0.5 to < 10 ha
Forest density	Forested area is predominantly interior or intact class	Forested area is predominantly dominant class	Forested area is predominantly transitional or less dense class

It is important to also consider park management goals and desired future condition. MABI's primary purpose is preservation, education and interpretation of the historical landscape (16 U.S.C. § 410vv), and accordingly the selected forest management plan seeks to "recognize and work with ecological change in preserving the historic character of the forest." The selected forest management plan alternative directs park managers to:

- Maintain the overall mix of plantations, hardwood and mixed forest stands, and fields on the landscape;
- Retain at least portions of key plantations in visible locations but allow plantations in other areas to succeed to native species;
- Maintain existing vistas, though locations may change if needed to achieve other management objectives, and consider reestablishment of historic vistas" (NPS 2006).

Assessment points based on park management goals have not been determined, but would need to include assessment of change in overall patch configuration, assessment of individual plantation stands, and assessment of key vistas.

Condition and Trend

NETN analysis of forest patch size delineated MABI as a single, large (455 ha) forest patch, which extended beyond the boundaries of the Park into Billings Park, portions of King Farm, and privately-owned land north of MABI (Figure 4.30; Miller et al. 2011). Figure 4.32 shows that MABI is primarily comprised of dominant forest, with patches of interior and transitional forest. While patch size indicated good condition for having sufficient size to support invertebrates, small mammals and many bird species dependent upon forest habitat, the configuration of patches reduces the amount of interior and intact forest available for species that require that high-quality habitat, warranting moderate concern. Trend was not assessed.

Data Gaps and Level of Confidence

Assessment of condition from forest patch delineation and forest density based on ecological integrity is medium; trend in condition was not assessed. Assessment of landcover using assessment points based on park management goals would be informative. Condition of key vistas with historical or cultural significance is a data gap.

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Land Use

Description and Relevance

Land conversion to anthropogenic uses eliminates and fragments wildlife habitat, reduces watershed buffering, and increases sources of local pollution and pathways for invasive exotic species.

Data and Methods

Data to assess land use within and surrounding MABI comes from the same sources considered above for Landcover. Wang and Nugranad-Marzilli (2009) assessed landcover change within a 5-km buffer surrounding MABI during three time periods. Within the 5-km MABI buffer, this study found a moderate increase (64%) in urban land from 1978 to 1989, and a larger increase (444%) in urban land from 1989-2002. This increase was due in part to urban development near Woodstock and along Route 12 and Route 4, but may also in part be an artifact created by the increase in resolution and spectral bands of later Landsat sensors.

Miller et al. (2011) assessed the percentage of anthropogenic versus natural landuse within a 200-m radius circle surrounding each forest plot (Figure 4.33). NPScape provided past (1970), current (2010), and projected future (2100) housing density in the 5-km park neighborhood (Figure 4.34; NPS 2014). Housing density in the park neighborhood increased in several areas from 1970 to 2010, but shows little projected future change from 2010 to 2100 (Figure 4.34).

Assessment Points

Miller et al. (2011) assessed anthropogenic landuse (ALU) using the assessment points shown below, based on theoretical models that examined the combined impacts of habitat loss and fragmentation (McIntyre and Hobbs 1999, O'Neill et al. 1997).

Good conditionALU < 10%
Moderate concern ALU 10 – 40%
Significant concern ALU > 40%

Assessment points for housing density in the park neighborhood have not been established.

Condition and Trend

Anthropogenic landuse (ALU) in the local neighborhood (200 m radius) surrounding NETN forest plots at MABI averaged 11%, just over the 10% assessment point and warranging moderate concern. Most plots at MABI had no ALU in the assessed radius, and the most common ALUs were plantations of exotic tree species and open fields (Miller et al. 2011). Both housing density and urban land area surrounding the park showed increasing trends over the periods assessed.

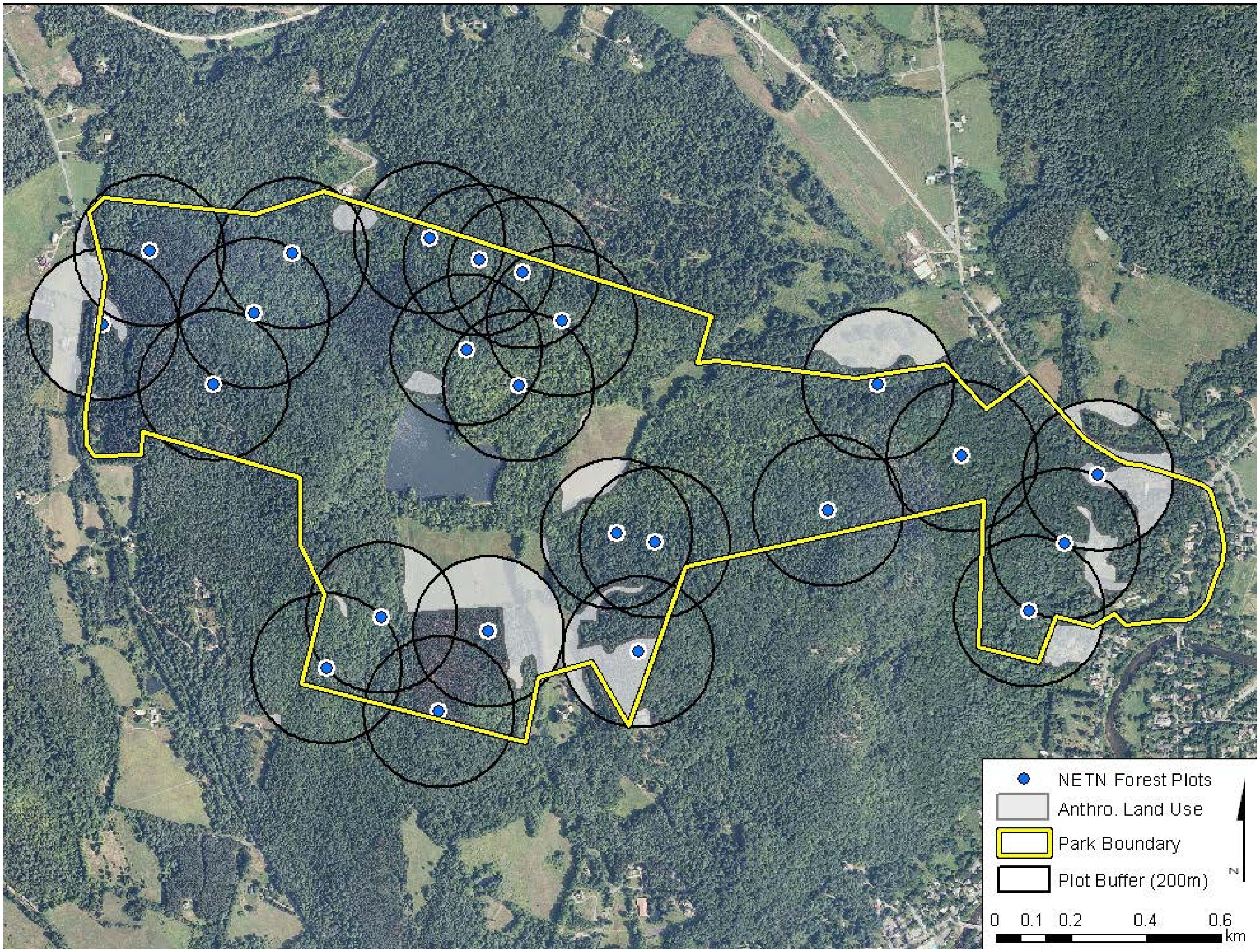

Figure 4.33. Anthropogenic land use surrounding forest plots at Marsh-Billings-Rockefeller NHP (excerpted from Miller et al. 2011).

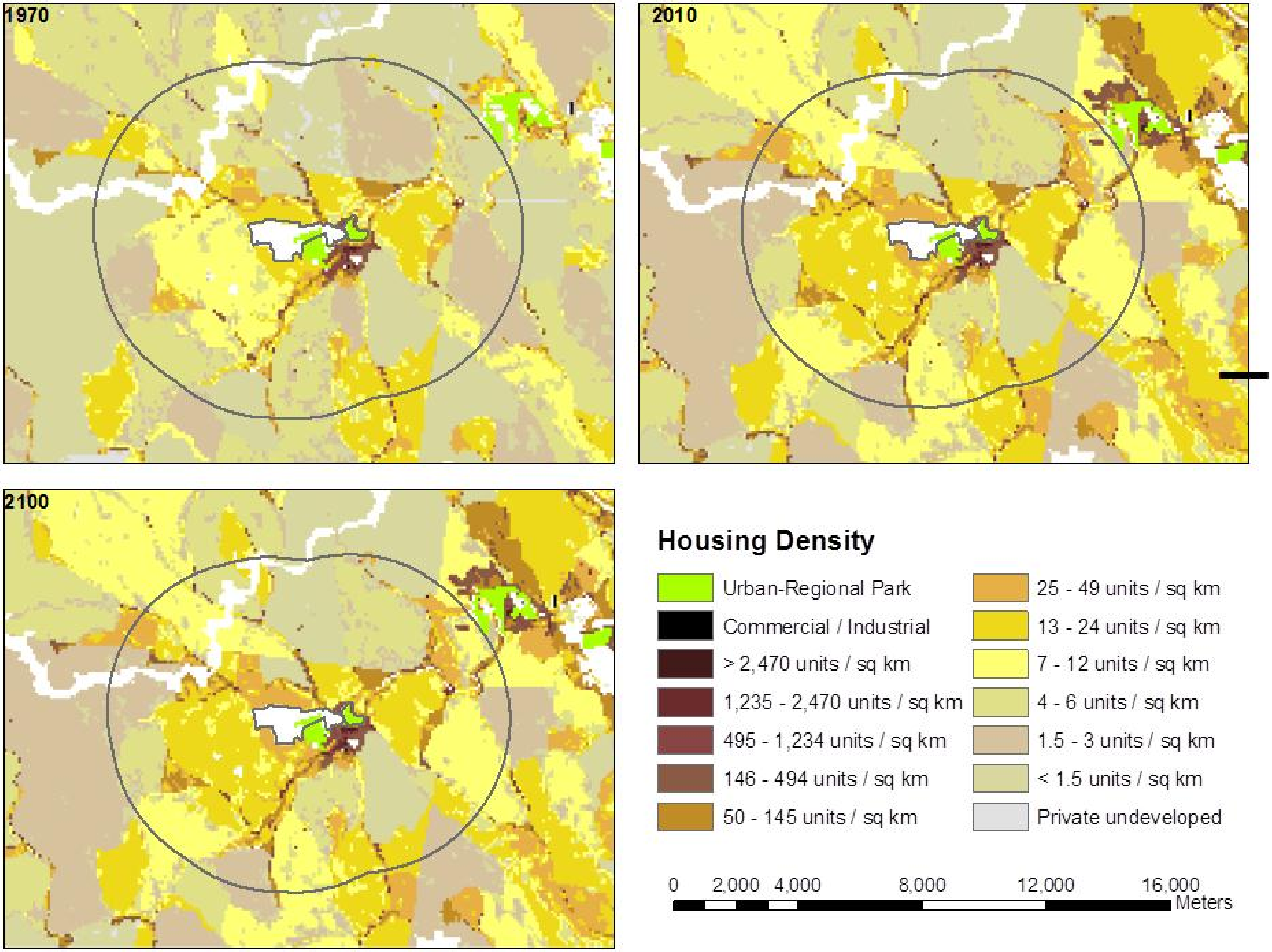

Figure 4.34. Past, current and projected future housing density surrounding Marsh-Billings-Rockefeller National Historical Park (NPS 2014).

Data Gaps and Level of Confidence

Assessment of park landuse condition was based on a single metric ALU surrounding forest plots and fell close to the assessment point. Confidence in status assessment is low, and confidence in trend is medium.

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Soundscape

Description and Relevance

The natural soundscape is an inherent component of "the scenery and the natural and historic objects and the wildlife" protected by the NPS Organic Act of 1916 (16 USC 1). NPS Management Policies require the NPS to "restore to the natural condition wherever possible those park soundscapes that have become degraded by unnatural sounds (noise)," "protect natural soundscapes from unacceptable impacts," and preserve the cultural soundscape "for appropriate transmission of cultural and historic sounds that are fundamental components of the purposes and values for which the parks were established" (§ 4.9 and 5.3.1.7 in NPS 2006). NPS Director's Order 47 (2000) directs park managers to monitor the park soundscape and manage noise. Parks may be affected by noise sources originating both within the park (due to park equipment and management) as well as outside the park (such as airplane and automobile traffic, and nearby land uses and development).

To understand soundscape condition, it is useful to distinguish between acoustic resources (physical sound sources such as wildlife, waterfalls, wind, rain, and cultural or historical sounds), the soundscape (the human perception of physical sound sources), and the acoustic environment (all acoustic resources, including anthropogenic noise). Clarifying this distinction allows managers to create objectives for safeguarding both the acoustic environment and the visitor experience (NPS NSNSD 2014).

Data and Methods

Soundscape data have not been collected at MABI. However, using acoustic data collected at 244 sites, the NPS Natural Sounds & Night Skies Division (NSNSD) has developed a geospatial model which predicts both natural and existing ambient sound levels with 270 meter resolution using 109 spatial explanatory layers (such as location, landcover, hydrology, wind speed, and proximity to noise sources; Mennitt et al. 2013). Natural ambient sound level refers to the acoustical conditions that exist in the absence of human-caused noise and represents the level from which the NPS measures impacts to the acoustic environment (Figure 4.35). Existing ambient sound level refers to the current sound level in an area, including both natural and human-caused sounds (Figure 4.36). In addition, the model calculates the difference between these two metrics, providing a measure of impact to the natural acoustic environment from anthropogenic sources. The resulting impact metric indicates how much anthropogenic noise has raised the existing sound pressure levels in a given location (Figure 4.37). Sound pressure levels are shown as L_{50} dBA, where L_{50} represents the level that is exceeded 50 percent of the time during a summer day, and dBA is the sound pressure level (amplitude) in decibels (dB) adjusted (weighted) to reflect human hearing sensitivity to frequencies from 1,000 to 6,000 Hz (Turina et al. 2013). As would be expected, existing and anthropogenic sound levels near MABI appear to be highest in the Village of Woodstock and along the Route 4 and Route 12 corridors (Figures 4.36 and 4.37).

Assessment Points

Soundscape assessment points should address the effects of noise on human health and physiology, wildlife, the quality of the visitor experience, and finally, the inherent value of the acoustic environment (NPS NSNSD 2014). Various characteristics of sound can contribute to how noise affects the acoustic environment. These characteristics include rate of occurrence, duration, amplitude (loudness), pitch, and whether the sound occurs consistently or sporadically. In order to capture these aspects, the quality of the acoustic environment should be assessed using a number of different metrics including existing ambient sound level (measured in decibels), percent time human-caused noise is audible, and noise free interval. Functional effects produced by increases in sound level should also be considered. For example, the listening area (the area in which a sound can be perceived by an organism) is reduced when background sound levels increase due to sound masking (Barber et al. 2010).

NPS NSNSD has developed interim guidance to assist Park units in assessing soundscape condition (Turina et al. 2013). The suggested assessment points for non-urban parks (Table 4.25) are applicable to MABI, but may be adjusted to accommodate management objectives and functional effects specific to MABI. Since each 3 dB increase in background sound level will reduce a given listening area by half, the assessment point between moderate and significant concern corresponds to a 50% reduction in listening area (Turina et al. 2013).

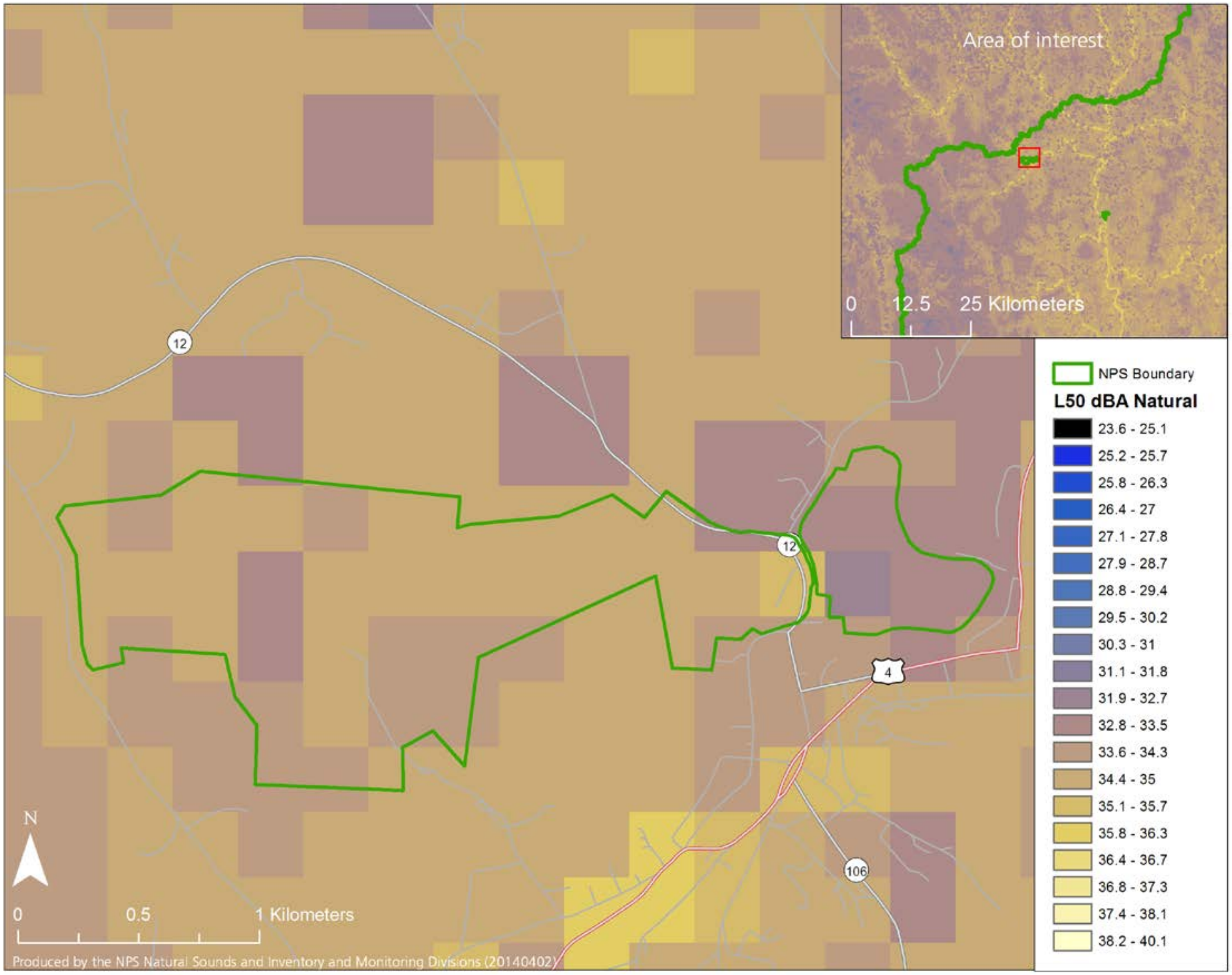

Figure 4.35. Modeled natural ambient sound levels (L50 dBA) at Marsh-Billings-Rockefeller NHP and the Billings Farm & Museum (unpublished data provided by NPS NSNSD).

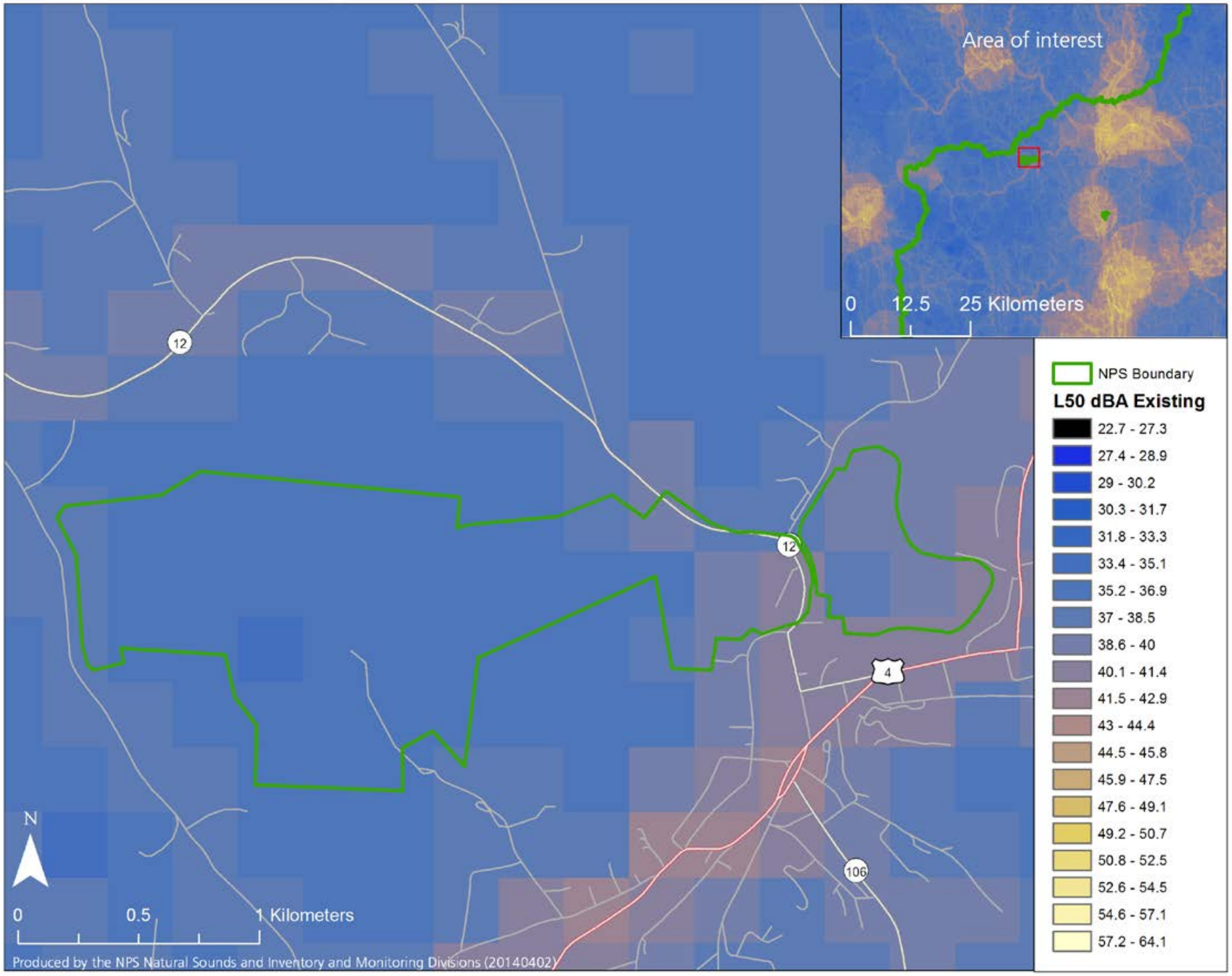

Figure 4.36. Modeled existing ambient sound levels (L_{50} dBA) at Marsh-Billings-Rockefeller NHP and the Billings Farm & Museum (unpublished data provided by NPS NSNSD).

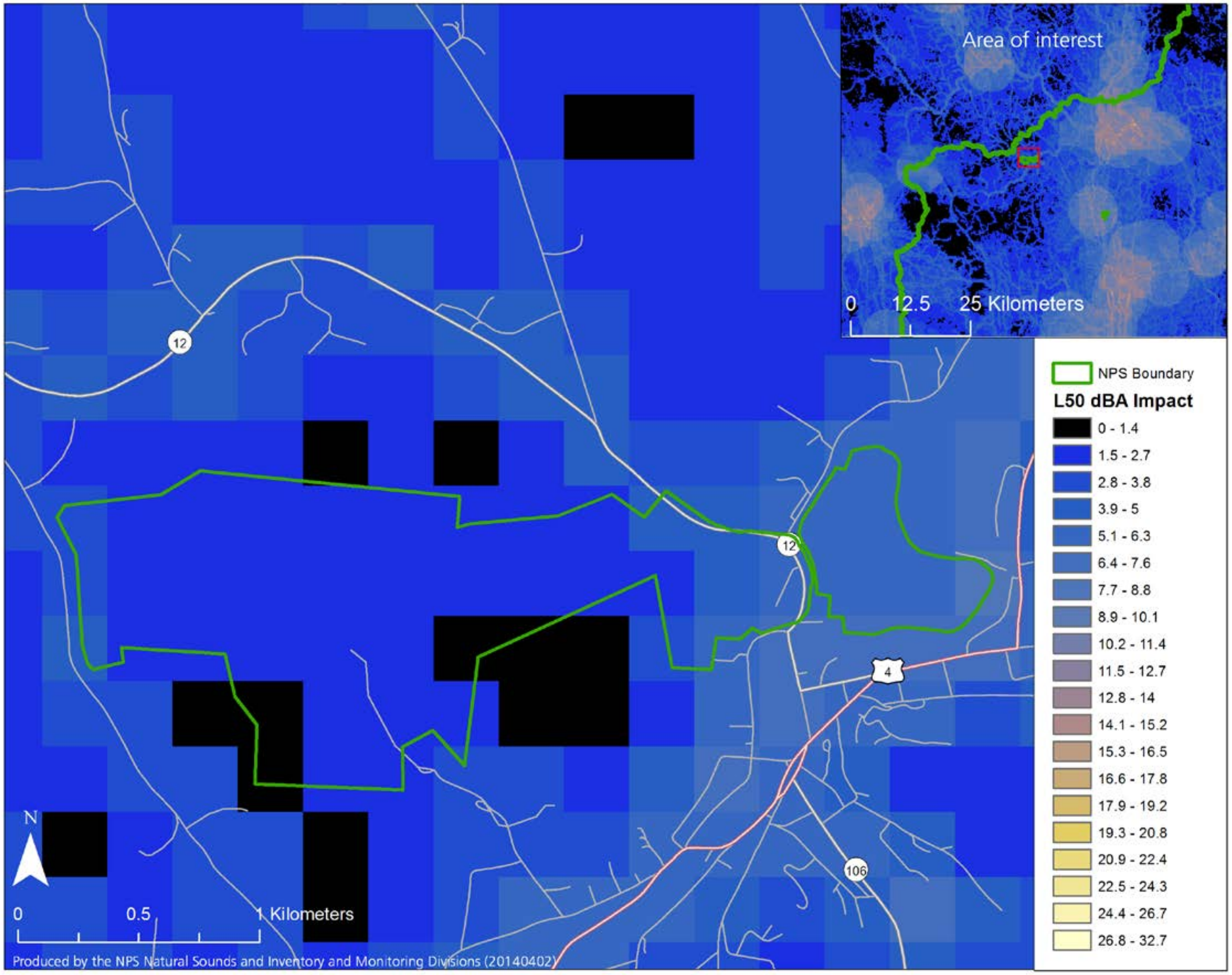

Figure 4.37. Modeled impact sound levels (L50 dBA) at Marsh-Billings-Rockefeller NHP and the Billings Farm & Museum (unpublished data provided by NPS NSNSD). Impact sound levels represent alteration to the natural acoustic environment from anthropogenic sources (i.e., noise).

Table 4.25. Suggested assessment points for Soundscape condition in non-urban parks (Turina et al. 2013).

Condition rating	Mean Impact Sound Pressure Level (L_{50} dBA)	Corresponding Reduction in Listening Area
Good condition	≤ 1.5	≤ 30%
Moderate concern	1.5 -3.0	30 – 50 %
Significant concern	≥ 3.0	≥ 50%

Condition and Trend

Soundscape condition was assessed for MABI and the adjacent Billings Farm & Museum by NPS NSNSD using a modeled dataset (Mennitt et al. 2013). Impact SPL across most of MABI fell within the range 1.5-2.7 L_{50} dBA (Figure 4.37), corresponding to a reduction in listening area of 30 – 50 % and warranting moderate concern. Trend in soundscape condition at MABI was not assessed. Nationwide trends indicate that prominent sources of noise in parks (namely vehicular traffic and aircraft) are increasing (FHWA 2013, FAA 2010). However, conditions in specific parks may differ from national trends.

Data Gaps and Level of Confidence

Confidence in status assessment is low, because this assessment did not incorporate onsite monitoring. Trend was not assessed.

Confidence in soundscape assessment could be increased by onsite monitoring. NPS has developed an Acoustical Monitoring Training Manual (NPS NSNSD 2013) which provides guidance to park managers seeking to define park acoustical zones, select sounds and sites of interest for monitoring, deploy and maintain automated recorders and meteorological instruments, collect data, conduct on-site listening sessions, and analyze acoustical data. A useful first step is to develop an inventory of audible sounds to better understand what sounds presently contribute to the acoustic environment, which are the most common, and which could possibly threaten the quality of the acoustic environment. Inventory data can be collected simply by a single, focused listener in calm weather conditions during a series of listening sessions in several different locations and across different times of day to capture spatial and temporal variation in acoustic conditions (Lynch et al. 2011).

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Lightscape

Description and Relevance

Visitors to the national parks may enjoy the star-gazing and natural darkness protected within National Park Units. In addition to having substantial impact on the quality of the visitor experience, natural darkness has ecological value to many species, including species which use darkness to evade predators or which navigate using patterns of light and dark. NPS uses the term "natural lightscape" to describe resources and values that exist in the absence of anthropogenic light at night. The natural lightscape can be compromised by light pollution from sources both within and outside the national parks. NPS management policies require the NPS to "preserve, to the greatest extent possible, the natural lightscapes of parks, which are natural resources and values that exist in the absence of human-caused light" (§ 4.10 in NPS 2006).

Data and Methods

Lightscape data has not been collected at MABI. However, modeled data were provided by the NPS Natural Sounds & Night Skies Division (NSNSD; Figure 4.38). Using data from the 2001 World Atlas of Night Sky Brightness (Cinzano et al. 2001), NSNSD scientists have modeled a measure of anthropogenic light pollution across the contiguous U.S. This measure, called the anthropogenic light ratio (ALR), is a measure of how much total nighttime sky brightness is elevated over natural nighttime light levels across the entire sky. ALR is calibrated such that a ratio of 0.0 indicates pristine conditions of natural light, while a ratio of 1.0 indicates a sky 100% brighter than a natural sky. Average natural sky luminance is 78 nL (nanolamberts; Moore et al. 2013).

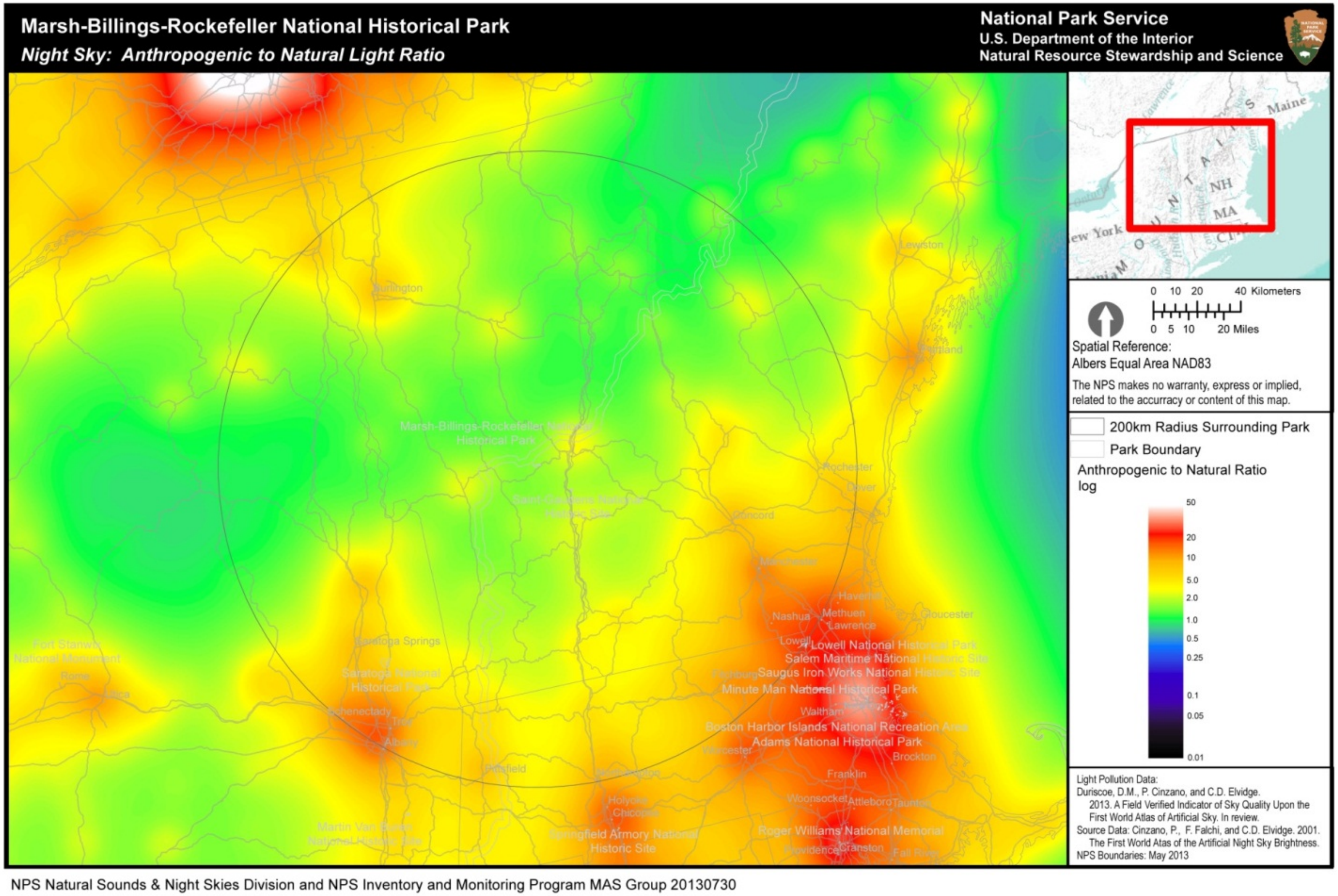

Figure 4.38. Modeled anthropogenic light ratio (ALR) in a 200 km (124 mile) radius surrounding Marsh-Billings-Rockefeller NHP (unpublished data provided by NPS NSNSD).

Assessment Points

Lightscape assessment points should consider park management objectives and wilderness status and the impact of light pollution on sensitive species or species of concern. Ideally, condition would be assessed from several lightscape metrics such as maximum vertical illuminance, horizontal illuminance, spectral characteristics, and impacts to wildlife species of concern (Moore et al. 2013).

NPS NSNSD has developed interim guidance to assist Park units in assessing lightscape condition using a single metric (ALR). The suggested assessment points for non-urban parks are applicable to MABI (Table 4.26). The assessment point between good condition and moderate concern represents a 33% increase in luminance over a natural sky, and corresponds to a threshold at which the human eye is unable to fully adapt to the dark and some visual sensitivity is lost. The assessment point between moderate and significant concern represents a 200% increase in luminance over a natural sky, and corresponds to a level at which the Milky Way is not fully visible, and full adaptation to darkness is no longer possible by the human eye (Moore et al. 2013).

Table 4.26. Suggested assessment points for Lightscape condition in non-urban parks (Moore et al. 2013).

Condition rating	Median Anthropogenic Light Ratio (ALR)
Good condition	≤ 0.33
Moderate concern	0.33 - 2.0
Significant concern	≥ 2.0

Condition and Trend

NPS NSNSD has modeled median ALR value for MABI to be 1.89, indicating the night sky is 189% brighter than a natural night sky (NPS NSNSD unpublished data). This warrants moderate concern. At this level of light pollution, the Milky Way is visible but lacks fine detail and dim celestial objects may not be visible.

Data Gaps and Level of Confidence

Confidence in lightscape condition at MABI is low, because assessment was made from modeled data and did not incorporate onsite monitoring. Trend was not assessed.

Confidence could be increased by onsite monitoring of lightscape parameters, including maximum vertical illuminance, horizontal illuminance, spectral characteristics, impacts to wildlife species of concern, measures in certain quadrants of the sky, and qualitative indices (Moore et al. 2013). NPS has developed a protocol for monitoring park lightscape using automated digital photography (Duriscoe et al. 2007). Alternatively, citizen scientist monitors may be engaged to monitor lightscape using simple star counts, such as in the Globe at Night Program (www.globeatnight.org).

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Chapter 5. Discussion

Overall, assessment of natural resource condition at MABI reflects condition supportive of a wide variety of native flora and fauna, as well as a satisfying visitor experience. Within the water category, trends are unchanging, with water chemistry indicating good condition in Pogue Stream, and possible moderate concern for mild nutrient enrichment in The Pogue. Refinement of assessment criteria may enhance the water quality assessment; and establishment of water quantity assessment points will allow determination of water quantity condition in future assessments.

A wide variety of Vital Signs were considered within the category of biotic integrity. Of the five faunal groups considered, three (Breeding birds, Amphibians and reptiles, and Mammals) appeared to be in good condition; while a fourth (Bats) reflects a significant concern largely outside of the control of park managers, and the last (Terrestrial invertebrates) is a data gap. The regional white-tailed deer population size appears to be within desired state and regional management goals. Preliminary assessment of deer-browse indicator species in forest plots did not detect over-browsing but warranted continued assessment. MABI remains relatively uninvaded by exotic plants, but the approach of key invasive exotic forest pests, such as the hemlock wooly adelgid, pose a significant concern to the park. Legacy trees are not explicitly monitored, but large trees appear to be increasing in number in the park.

Assessed for ecological integrity, forest vegetation at MABI warranted moderate concern overall, with lower than desired levels of snags, CWD and tree regeneration, and notable problems with beech bark disease. Assessment of forest condition may be improved in future assessments by incorporation of park management goals and desired future condition of forest stands. Wetland vegetation is a data gap that could be filled using rapid assessment methods noted below.

Within the human use category, forest plots show little sign of trampling. Likewise, forest management conforms to FSC standards.

Within the landscape category, landcover warranted moderate concern for low levels of interior or intact forest habitat, while landuse rated similarly for slightly elevated levels of anthropogenic land use in the local neighborhood surrounding forest plots. These assessments were based largely on ecological integrity. Future assessments could be refined by further considering park management goals and desired future conditions. Soundscape and lightscape were both assessed using modeled data, and warranted moderate concern.

Some notable problem areas reflect regional trends outside of the control of park managers. Within the air quality category, three Vital Signs (Acidic deposition & stress, Contaminants, Climate & phenology) warranted significant concern, while the last (Ozone) rated moderate concern. Park managers can continue to monitor impacts and work collaboratively with federal, state and local partners to reduce regional air pollution. Likewise, the approach of invasive exotic forest pests is largely beyond the control of park managers, but managers can continue to focus on early detection and eradication within the park. WNS is regional wildlife health crisis that is outside the control of park staff; however, establishing an annual bat monitoring program at MABI as outlined below may provide useful data on populations of several SGCN species.

Status and trend in park natural resource condition at MABI are summarized in report card format in Appendix A.

Data gaps

NPS staff and collaborators have collected a wealth of data which provide a detailed picture of natural resource condition for most of the 25 Vital Signs considered here. However, this assessment revealed several data gaps which could be filled by additional park monitoring if funding permits. These gaps and potential new monitoring activities are summarized in Table 5.1.

Table 5.1. Data gaps and potential monitoring activities at Marsh-Billings-Rockefeller NHP.

Data gap	Potential monitoring activities
Climate change	Expand efforts to identify and monitor status and trend of key indicators of climate change, and to identify and monitor valued park resources at high risk to climate change impacts.
Stream macroinvertebrates	Monitor using available protocols, perhaps with citizen scientists.
Wetland vegetation	Monitor key sites using USA-RAM methods (US EPA 2011).
Amphibians and reptiles	Implement monitoring recommendations for annual acoustic surveys, vernal pool egg mass counts, and coverboard transects (Faccio 2001) and monitoring of stream salamanders (S. Faccio, personal communication, 23 June 2014).
Legacy trees	Inventory legacy trees. Monitor key sites using repeat photography.
Bats	Monitor community with annual, automated acoustic monitoring. Follow up with mist-netting at key sites to confirm status of SGCN species.
Mammals	Monitor using game camera networks for medium or larger mammals, and live-trapping grids for small mammals including SGCN species.
Terrestrial invertebrates	Consider monitoring pollinators, butterflies and moths, isopods, ants, chrysomelid leaf beetles or theridiid spiders (Gerlach et al. 2013).
Trampling at key locations	Monitor key locations using visual assessment.
Key vistas	Monitoring key sites using repeat photography.
Lightscape	Monitor with automated photography using NPS methods (Duriscoe et al. 2007) or with simple star counts using citizen scientists.
Soundscape	Monitor with automated recorders using NPS methods (NPS NSNSD 2013).

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Appendix A: Vital Sign Report Card for Marsh-Billings-Rockefeller NHP

Table A-1. Key to NPS symbology for reporting resource condition, trend and confidence in assessment

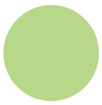
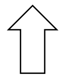
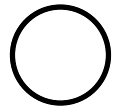
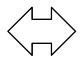
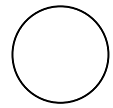
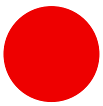
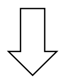
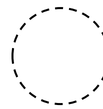
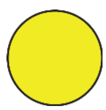
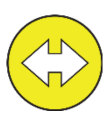
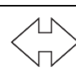
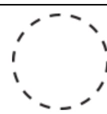
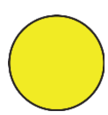
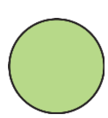
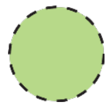
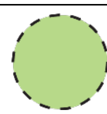
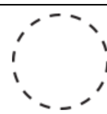
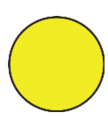
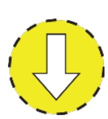
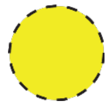
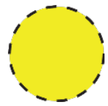
Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in Good Condition		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Warrants Significant Concern		Condition is Deteriorating		Low

Table A-2. Vital sign report card for Marsh-Billings-Rockefeller National Historical Park.

Category	Vital Sign	Condition & Trend	Findings
Air and Climate	Ozone		Ozone pollution may be affecting sensitive vegetation in some years.Trend was not assessed. Ozone pollution reflects regional trends resulting from activities occurring outside NPS boundaries.
	Acidic deposition & stress		Acidic deposition rates for both N and P have declined, but remain at levels which may cause harm to park ecosystems. Acidic deposition reflects regional trends resulting from activities occurring outside NPS boundaries.
	Contaminants		Mercury deposition exceeds levels which may cause harm to park ecosystems. Nine-year trend is unchanging. Mercury deposition reflects regional trends resulting from activities occurring outside NPS boundaries.
	Climate & Phenology		Temperature and precipitation show increasing trends over the historical record. Climate change reflects global and regional trends resulting from activities occurring outside NPS boundaries.
Geology and soils	Forest soil condition		Forest soils are well buffered and fertile, but may be deficient in potassium, sensitive to nitrogen saturation and affected by aluminum toxicity. Four-year trend is unchanging. Forest soil condition is affected by activities occurring both within and outside NPS boundaries.
Water	Water quantity		Assessment points for water quantity are not defined. Seven-year trend is unchanging.
	Water chemistry (Pond)		Water quality in the Pogue may warrant moderate concern for mild nutrient enrichment. Seven-year trend is unchanging. Water chemistry is affected by activities occurring both within and outside NPS

Category	Vital Sign	Condition & Trend	Findings
			boundaries.
	Water chemistry (Pogue Stream)		Water quality in the Pogue stream showed good condition. Seven-year trend is unchanging. Water chemistry is affected by activities occurring both within and outside NPS boundaries.
	Streams-macroinvertebrates		Stream macroinvertebrates are not monitored.
Biological integrity	Invasive exotic plants		Pond and natural forest habitats remain relatively uninvaded by exotic plants. Forest plantations were mildly invaded by exotic plants. Four-year trend is unchanging. The spread of invasive exotic plants is affected by activities occurring both within and outside NPS boundaries.
	Invasive exotic animals		The advance of hemlock woolly adelgid in southern Vermont is a significant concern, and the spread of emerald ash borer and Asian longhorned beetle pose enormous threats to forest resources. The spread of invasive exotic animals reflects regional trends resulting from activities occurring outside NPS boundaries.
	Wetland vegetation		Wetland vegetation was not monitored.
	Forest vegetation		Forest vegetation has been assessed for ecological integrity. Most forest stands displayed mature or late-successional stand structure, and the proportion of large trees in forest stands has increased over four years. Snag and CWD levels were lower than desired in both naturally regenerating forests and plantations. Plantations were particularly lacking medium to large-sized snags. Low levels of tree regeneration warrant moderate concern. Beech bark disease (BBD) has impacted tree condition. Tree growth rates in the park may be lower than regional means. Tree mortality rates were high for American beech, which is suffering from beech bark disease, and for several pine species. Four-year trend varied by metric. Future assessments should incorporate park management goals and desired future condition for a more refined assessment of forest condition.
	White-tailed deer herbivory		Deer density within the Eastern Foothills region of VT appeared to be within desired levels to minimize negative impacts on vegetation. Preliminary assessment of deer-browse indicator species in forest plots indicated continued monitoring is warranted. Trend was not assessed. White-tailed deer herbivory reflects regional trends resulting from activities occurring both within and

Category	Vital Sign	Condition & Trend	Findings
			outside NPS boundaries.
	Breeding birds		Assessment of bird guilds showed good representation of specialist compared to generalist species overall. Trend in condition was not assessed. Relative abundance and species richness of birds declined in 2012. Breeding birds condition reflects regional trends resulting from activities occurring both within and outside NPS boundaries.
	Amphibians and reptiles		Sensitive species, pond-breeding salamanders and vernal pool-breeding amphibians were well represented in the amphibian community.
	Legacy trees		Legacy trees were not explicitly monitored, but the numbers of large trees in forest plots has increased over four years.
	Bats		Populations of some bat species are in dramatic decline in the park and across the region over the last 10 years. Bats condition reflects regional trends resulting from activities occurring outside NPS boundaries.
	Mammals		Mammal species richness is > 80% of expected levels. Population trend of key mammal species is a data gap.
	Terrestrial invertebrates		Invertebrates were not monitored.
Human Use	Visitor usage		Forest plots showed little sign of trampling. Four-year trend is unchanging.
	Forest management		Forest management conformed to standards for sustainability established by the Forest Stewardship Council (FSC). Eight year trend was improving.
Landscapes	Landcover / ecosystem cover / connectivity		Landcover was assessed for ecological integrity. Forest patch size is sufficient to support invertebrates, small mammals and many bird species dependent upon forest habitat, but patch configuration reduced the amount of interior or intact forest habitat. Landcover condition is affected by activities occurring both within and outside NPS boundaries. Future assessments should incorporate park management goals and desired future condition for a more refined assessment of landcover condition.
	Land use		Levels of anthropogenic landuse in the local neighborhood surrounding forest plots may be a moderate concern. Housing density and urban land area surrounding the park have increased since the 1970s. Land use condition is affected by activities occurring both within and outside NPS

Category	Vital Sign	Condition & Trend	Findings
			boundaries.
	Soundscape		Modeled data indicate anthropogenic noise may warrant moderate concern. Soundscape condition is affected by activities occurring both within and outside NPS boundaries.
	Lightscape		Modeled data indicate anthropogenic light pollution may warrant moderate concern. Lightscape condition is affected by activities occurring both within and outside NPS boundaries.

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