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Natural Resource Assessment for Minute Man National Historical Park

Natural Resources Report NPS/NER/NRR—2009/022

ON THE COVER
Photographs by: Roland Duhaime and courtesy of Minute Man National Historical Park.

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Natural Resources Report NPS/NER/NRR—2009/022

Mary-Jane James-Pirri

Graduate School of Oceanography
University of Rhode Island
Narragansett, Rhode Island 02882

With GIS Support from
Rebecca Bannon and Roland Duhaime

Environmental Data Center
University of Rhode Island
Kingston, Rhode Island 02881

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Publisher's Note: Some or all of the work done for this project preceded the revised guidance issued for this project series in 2009/2010. See Prologue (p. x) for more information.

Executive Summary

The purpose of this document is to provide information on the current condition of natural resources at Minute Man National Historical Park (MIMA). The assessment of current condition was based upon existing data, technical reports, and the published literature; no new data were collected. Whenever possible, current condition was related to historical data or trends and was presented in a GIS framework.

The natural resources that were evaluated in this assessment were land use dynamics, vegetation communities (including information on plant diseases), wetland resources, faunal communities (including potential insect pests), water resources, and parkwide resources such as soils, air quality, soundscape, and visitor use.

Most of natural resources at MIMA appear to be in less than desirable condition based on available data. Urban lands (roads and residential housing) occupy a considerable proportion of the park and these areas may be detracting from the natural resources and cultural atmosphere of MIMA. The vegetation, forest, and wetland communities of the park are under assault from invasive plants, which have persisted and increased in abundance and distribution over the years. Even areas that are considered good examples of natural native communities, such as the kettlehole wet meadows, are threatened by invasive plants. This is the legacy of disturbed lands and the opportunistic colonization of non-native species over the past few centuries. The available data for faunal communities indicate that landbird, amphibian, and fish communities are in a less than desirable condition primarily due to a loss of specialist or sensitive species and a higher incidence of non-desirable species (e.g., non-natives/exotics, disturbance tolerant species). Threats to these communities include habitat loss/deterioration and fragmentation, competition with non-native and/or exotic species, and environmental contaminants including impaired water quality. There are potential emerging threats to the forests of MIMA from several insect pests and it would be prudent to establish early detection plans for these detrimental insects. MIMA also has had persistent degraded water quality of its streams and rivers for the past 20 years. Soil chemistry, assessed during forest monitoring, has undesirable ratios of Ca:Al and C:N that in turn may negatively impact forest vegetation. In terms of parkwide resources, air quality, and soundscape are also of concern. There may be little that MIMA can do about these resources as they are extensively influenced by factors outside of the park’s control.

Several data gaps exist especially in terms of the condition of wetland resources. Important wetland ecosystems in the park include kettlehole wet meadows, a red-maple black gum swamp, the Elm Brook wetland, and vernal pools. Threats to these include invasive plants, impacts from roads (e.g., road runoff, barriers to faunal movement), and impaired water quality. Monitoring these areas (e.g., water quality, hydroperiod, presence of rare and/or iconic flora and fauna) should be a priority for the park. Other data gaps include the uncertainty of the presence of state listed flora and fauna throughout the park, and information concerning visitor impacts on natural resources.

Acknowledgements

Many thanks are extended to Nancy Nelson, Lou Sideris, and Terrie Wallace of Minute Man National Historical Park for providing access to Natural Resource documents. Brian Mitchell, Alan Ellsworth, Brian McDonnell, Nigel Shaw, and Frank Turina of the National Park Service kindly provided information and draft data for inclusion in the assessment. Rebecca Bannon and Roland Duhaime at the Environmental Data Center of the University of Rhode Island compiled GIS data and created the GIS maps presented in this report and made the integration of these data a seamless and effortless process. Lydia Rogers from the Sudbury Valley Trustees provided information regarding ongoing studies on wildlife corridors in Concord, Massachusetts. Special thanks are extended to Sheila Colwell (National Park Service) and Chelsea Blatchley (University of Rhode Island) who assisted in gathering information. Charles Roman (National Park Service) graciously offered insight and comments on the draft document. Thanks are also extended to the reviewers who provided many helpful suggestions. This study was funded by the National Park Service and administered by the North Atlantic Coast Cooperative Ecosystem Studies Unit at the University of Rhode Island.

Prologue

Publisher's Note: This was one of several projects used to demonstrate a variety of study approaches and reporting products for a new series of natural resource condition assessments in national park units. Projects such as this one, undertaken during initial development phases for the new series, contributed to revised project standards and guidelines issued in 2009 and 2010 (applicable to projects started in 2009 or later years). Some or all of the work done for this project preceded those revisions. Consequently, aspects of this project's study approach and some report format and/or content details may not be consistent with the revised guidance, and may differ in comparison to what is found in more recently published reports from this series.

Publisher's Note: Some or all of the work done for this project preceded the revised guidance issued for this project series in 2009/2010. See Prologue (p. x) for more information.

Introduction

The National Park Service (NPS) is assessing the natural resource conditions at NPS Units as part of their Condition Assessment Program. This program is designed to assist the NPS in understanding and addressing threats and stressors to natural resources and aid in guiding management actions to prevent or reduce impairment to park resources. The scope of this document is to provide information on the current condition for some of the more prominent natural resources for Minute Man National Historical Park (MIMA). This is not meant to be an exhaustive compilation of all natural resource information for the park. The assessment of current condition was based upon existing data, technical reports, and the published literature; no new data were collected for this project. In some instances, new datasets were developed from existing ones in an effort to relate datasets to one another. In many cases, current condition was assessed by comparing historical data and/or trends with recent data to evaluate if a specific natural resource was improving or declining in condition. The results were presented in a GIS framework when appropriate.

This document is organized primarily by ecosystem resources (e.g., vegetation communities, wetland resources, water resources). To reduce redundancy faunal communities are treated separately since many species can be found across ecosystems. Additionally, parkwide resources, those that are ubiquitous throughout MIMA (e.g., soils, air quality, and soundscape) are also contained within their own section. Whenever possible, threats and stressors to natural resources are integrated into each specific ecosystem section. A list of suggested areas for further research, or inventory and monitoring needs, is provided at the end of the document.

In addition to providing an assessment of current condition, it is hoped that this document will serve as a useful reference resource for MIMA’s staff, as it contains an integrated summary of most of the natural resource research that has occurred at the park. Finally, many of the older (1990’s) reports were converted to Portable Document Format (pdf) files, delivered to Teresa Wallace (MIMA curator), and are available in electronic format from the park.

The Park

Minute Man National Historical Park was established in 1959. The park is located within a suburban setting 16 miles northwest of Boston, Massachusetts, and is spread across portions of towns of Concord, Lincoln, and Lexington in Middlesex County. The park is contained in the Sudbury/Assabet/Concord watershed (Figure 1). The park commemorates the beginning of the American Revolution at Lexington and Concord in 1775, known to history as “the shot heard round the world”. MIMA encompasses 391.5 ha (966 acres) divided into three distinct units, the North Bridge Unit (45 ha), the Wayside Unit (2.5 ha), and the Battle Road Unit (344 ha). The preservation of the park’s cultural resources and the reestablishment of the historic landscape are two primary resource management objectives for MIMA (NPS 1993).

The topography of the park is characterized by flat plains and low-rolling hills composed of unconsolidated glacial till deposits that overlie a complex geology of metamorphic and igneous bedrock (NPS 1993). Diverse habitats such as forested uplands, forested and non-forested wetlands, freshwater ponds, meadows and fields, and active agricultural land farmed under the park's agricultural leasing program make up the landscape of MIMA. The Concord River, a slow-moving river with a wide flood plain and extensive contiguous wetlands, flows through the North Bridge Unit of the park. The overall surrounding landscape of the park consists of open space and rolling hills.

The suburban and historical nature of MIMA has exerted and continues to exert a strong influence on the extent and condition of natural resources. Approximately 90% of the lands within the park's boundary had been converted to agriculture by the turn of the 18th century. When the park was established many acres of abandoned agricultural fields had reverted to forest, and old structures had been removed and were replaced by forest or meadows. The park's landscape is a product of decades of park development and historic landscape rehabilitation assembled from hundreds of privately owned parcels that include both historic features (e.g., houses, barns, stone walls) and non-historic features (e.g., modern residences, roads) (Dietrich-Smith 2005). Since the park began acquiring land in the late 1950's, over two hundred modern structures (post 1920's) were removed and many historic structures have been preserved (Dietrich-Smith 2005). The park continues to remove additional structures and restore forested, wetland, and stream ecosystems. Route 2A, a major commuter corridor to Boston, bisects the park and fragments wetlands and other open areas. L.G. Hanscom Airfield and Hanscom Air Force Base are located north of the Battle Road Unit immediately adjacent to the park boundary. The airfield has an airport runway and a mixture of open land, dense residential areas, and office buildings (NPS 1993).

Assessment of Condition

This document is organized by ecosystem resources, similar to the Northeast Temperate Network (NETN) Vital Signs approach (Mitchell et al. 2006). Each section begins with a brief description of the resource and details any historical or current inventory or monitoring efforts, and a discussion of the relationship of any threats or stressors that may impact the resource. Each section concludes with an assessment of the current condition of the resource (if known) and a table that summarizes the metrics used to assess condition, an assessment of condition ("good", "caution", or "significant concern") for each metric, as well as information about the reliability of the data used to evaluate condition.

To assist with the assessment of current condition a set of metrics for each natural resource was selected and the condition of these metrics was evaluated. Whenever possible, established metrics and thresholds were used to assist in the assessment of condition; however, in many cases, established metrics and thresholds for specific resources or the data necessary to assess condition for an established threshold were not available. Therefore, the metrics used in this document were based on those that had the best quantitative, recent, and/or reliable data for the park. Quantifying the condition of the natural resource metrics was accomplished by rating the condition as "good", "caution", or "significant concern". These three categories of condition rating are equivalent to those currently used by the NETN. Whenever possible, NETN threshold values for natural resource metrics (e.g., forest condition, landbird community) or assessments from established monitoring programs (e.g., US EPA air and water quality monitoring) were used to estimate the condition of the resource. In other cases, estimates of biotic integrity (e.g., amphibian and fish communities) from other studies were used to evaluate condition. Finally, in situations where the data were primarily qualitative in nature or no specific thresholds could be found, best professional judgment was used to assign a condition rating. When an existing assessment metric (e.g., index of biotic integrity) was available the rating ("good", "caution", or "significant concern") that most closely approximated the metric's value was assigned as the condition. To standardize estimates of condition for metrics of individual resources and among all resources the three ratings were given numerical scores. The numerical scores ranged from 0 to 1, with values near 0 indicating a less than desirable condition or a condition warranting concern, and values closer to 1 indicating a desirable and/or relatively natural condition. The numerical scale was divided into three ranges representative of "good", "caution", or "significant concern" and the midpoint of range was assigned as the numerical score (Table 1). Since there was usually more than one metric associated with each resource the numerical score assisted in the assessment of the overall condition of the resource as the scores could be averaged across all metrics. Additionally, the numerical score also assisted in standardizing ratings from other assessment methods so that this information could be incorporated into the assessment of condition. When data were available, trends in natural resource condition were also evaluated. Trends were assigned a condition of "improving condition", "stable condition" or "declining condition" after reviewing historical and recent data. Similar to the condition ratings, each trend was assigned a numerical score using the midpoint of range for each rating (Table 1).

The reliability and quality of data used to assess the condition were rated using three rating categories: "good", "satisfactory", and "limited". "Good" included extensive and/or recent quantitative data in published reports or data from state and/or government sources; "satisfactory" indicated that data were from a few studies, but they were recent and quantitative in nature; "limited" indicated data were from a few studies, were older data, were less quantitative in nature, or were found in unpublished reports. The three ratings for data reliability were also given a numerical score as the midpoint range (Table 1).

Past and Current Monitoring Programs at MIMA

As part of the Northeast Temperate Network Vital Signs Monitoring Plan several monitoring programs have been established or are planned for MIMA. Currently implemented protocols at MIMA include Breeding Landbirds, Forest Monitoring, and Water Quality (Mitchell et al. 2006). A Freshwater Wetlands monitoring protocol is currently under development. Protocols developed by others (e.g., NPS Natural Sounds Program, Commonwealth of Massachusetts) and currently implemented include soundscape, water quality, and air quality monitoring. As resources become available other protocols may be implemented. These include monitoring amphibian and reptiles, landscape dynamics, and visitor use.

There have been two major time periods of monitoring efforts for MIMA. One took place in the early 1990's, when several faunal and vegetation surveys were conducted, and more recent surveys of the NETN Inventory and Monitoring Program conducted from 2001 to present (Table 2). Previous monitoring activities usually focused on the Battle Road and North Bridge Units with little to no monitoring occurring in the Wayside Unit (Figures 2 and 3). These studies form the majority of the relevant data sources for this assessment (Table 2).

Table 1. Rating categories and numerical scores used in the assessment of condition, trend, and data reliability.

Condition	Icon	Numerical Score
		Condition midpoint score (range)
Good	●	0.84 (0.68 to 1.0)
Caution	●	0.50 (0.34 to 0.67)
Significant concern	●	0.16 (0 to 0.33)
Unknown condition	○	No value given
		Trend midpoint score (range)
Improving trend	↑	0.84 (0.68 to 1.0)
Stable trend	↔	0.50 (0.34 to 0.67)
Declining trend	↓	0.16 (0 to 0.33)
Unknown trend	○	No value given
		Data reliability midpoint score (range)
Good data	●	0.84 (0.68 to 1.0)
Satisfactory data	●	0.50 (0.34 to 0.67)
Limited data	●	0.16 (0 to 0.33)

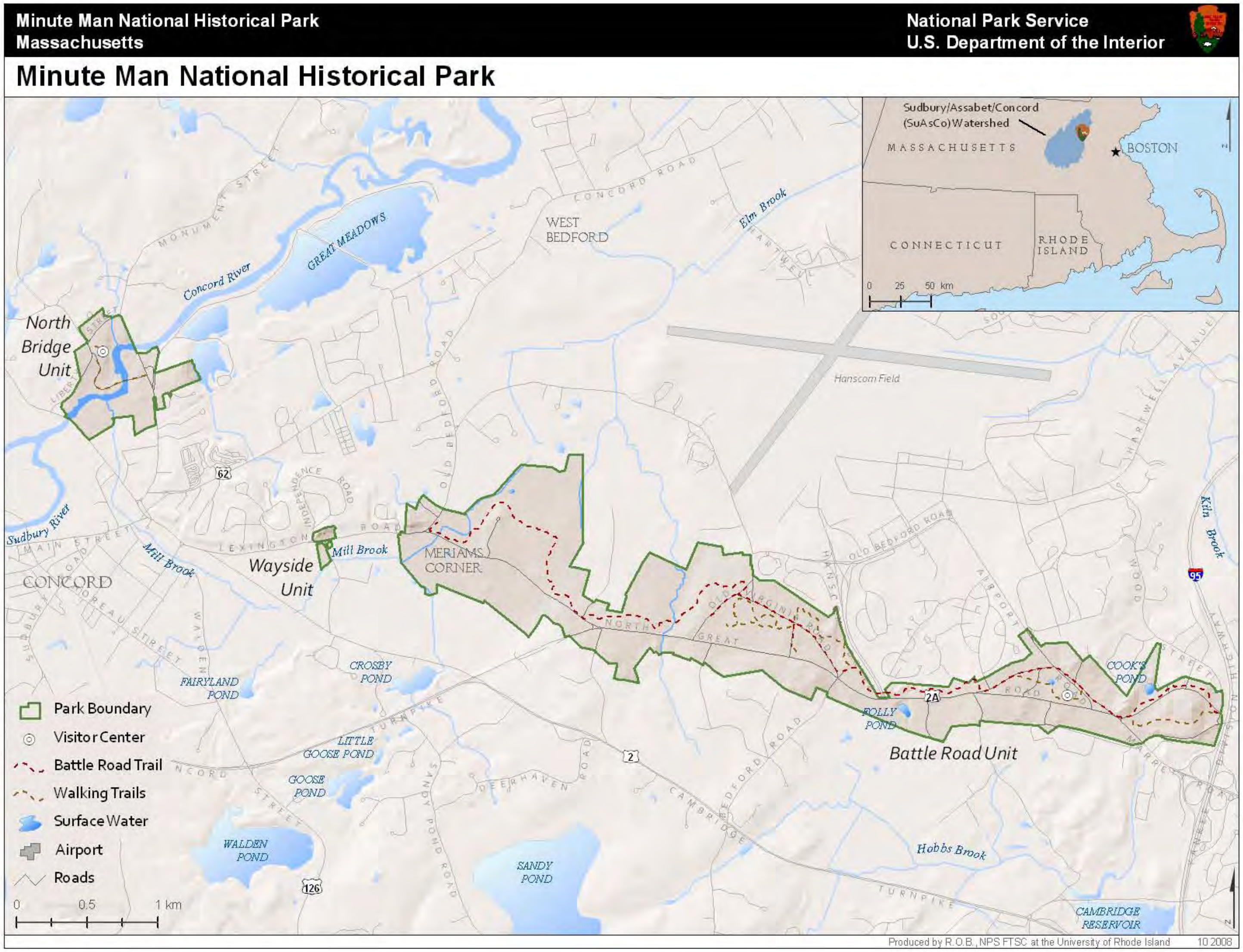

Figure 1. Map of Minute Man National Historical Park.

Table 2. Past and current inventory and monitoring programs at MIMA.

Ecosystem & Resource	Year Data were Collected	Citation or Agency Conducting Monitoring
Terrestrial		
Elm Brook wetland	1987	Rice 1987
Forest monitoring	2006 to present	NETN Inventory & Monitoring
Invasive plants	2003	Agius 2003
Landscape dynamics	1974, 1987, 2000	Wang et al. 2007
Vegetation communities	2004	Gawler et al. in review
Vegetation communities	1992	Thompson & Jenkins 1992
Vegetation communities	1986 & 1991	August et al. 1993
Faunal communities		
All animals (Biodiversity Day) [1]	1998	Alden 1998; NPSpecies data
Amphibians	1992	Martinez 1992
Amphibians	1992	Thomas 1992
Amphibians and reptiles	2001	Brotherton et al. 2005
Fish	1999-2001	Mather et al. 2003
Mammals	2004	Gilbert et al. 2008
Mammals	1992	Jones 1993
Landbirds	2002-2003	Trocki and Paton 2003
Landbirds	2006 to present	NETN Inventory & Monitoring
Selected animals	1992	Windmiller and Walton 1992
Water resources		
Water quality	1998 to present	Commonwealth of Massachusetts/ US EPA
Water quality (level I)	1999	National Park Service (Farris & Chapman not dated)
Water quality	2006 to present	NETN Inventory & Monitoring
Water quantity	1941 to present	USGS stream monitoring
Parkwide resources		
Air quality	1998 to present	Commonwealth of Massachusetts
Air quality	1998 to present	US EPA
Air quality	1992 to present	NADP/NTN monitoring
Soils	2007	NRCS Soils data
Soundscape	2007	National Park Service
Visitation	1941 to present	National Park Service

1. Biodiversity Day data were for the towns of Lincoln and Concord.

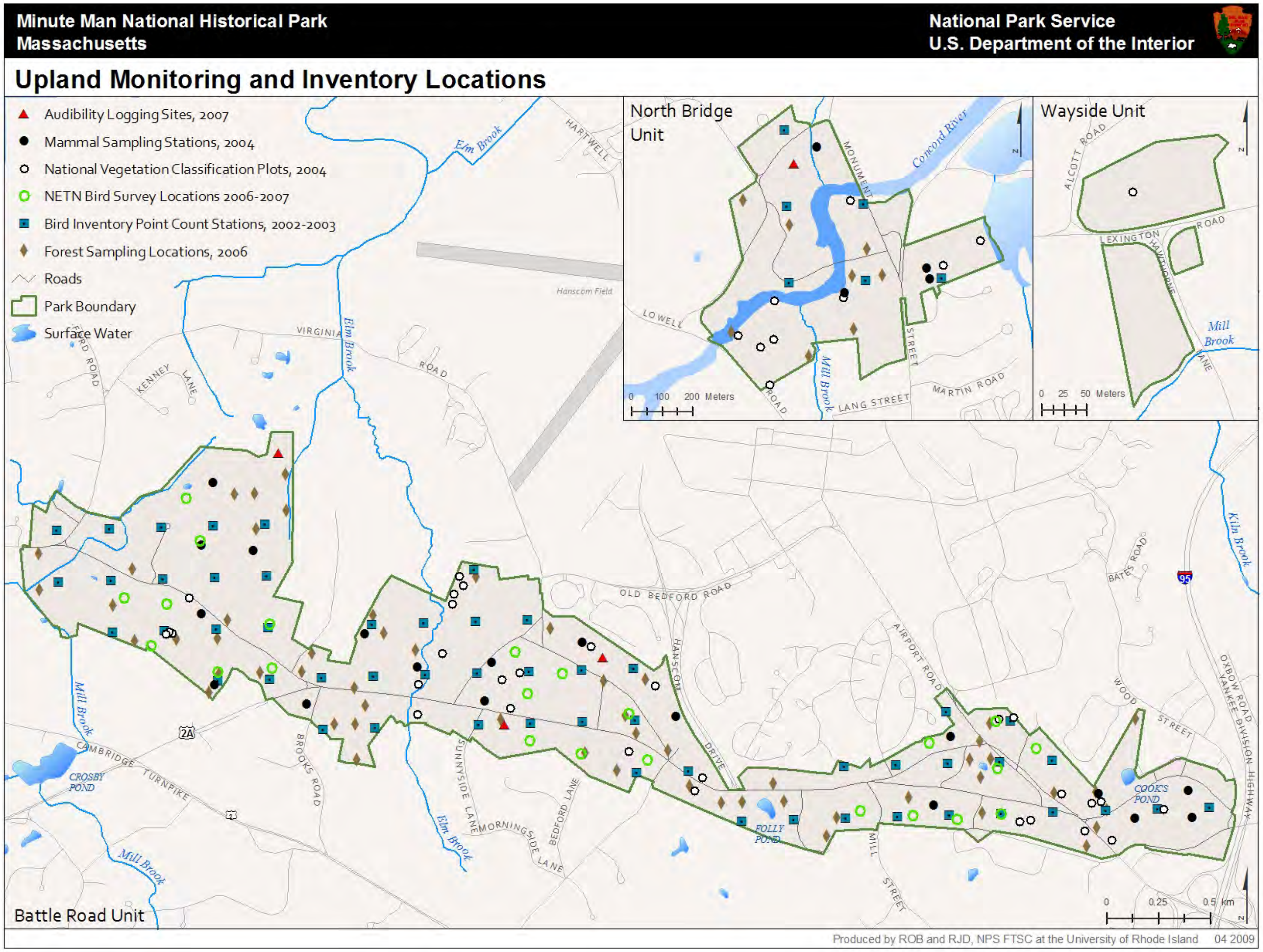

Figure 2. Past and current upland and terrestrial monitoring efforts at MIMA.

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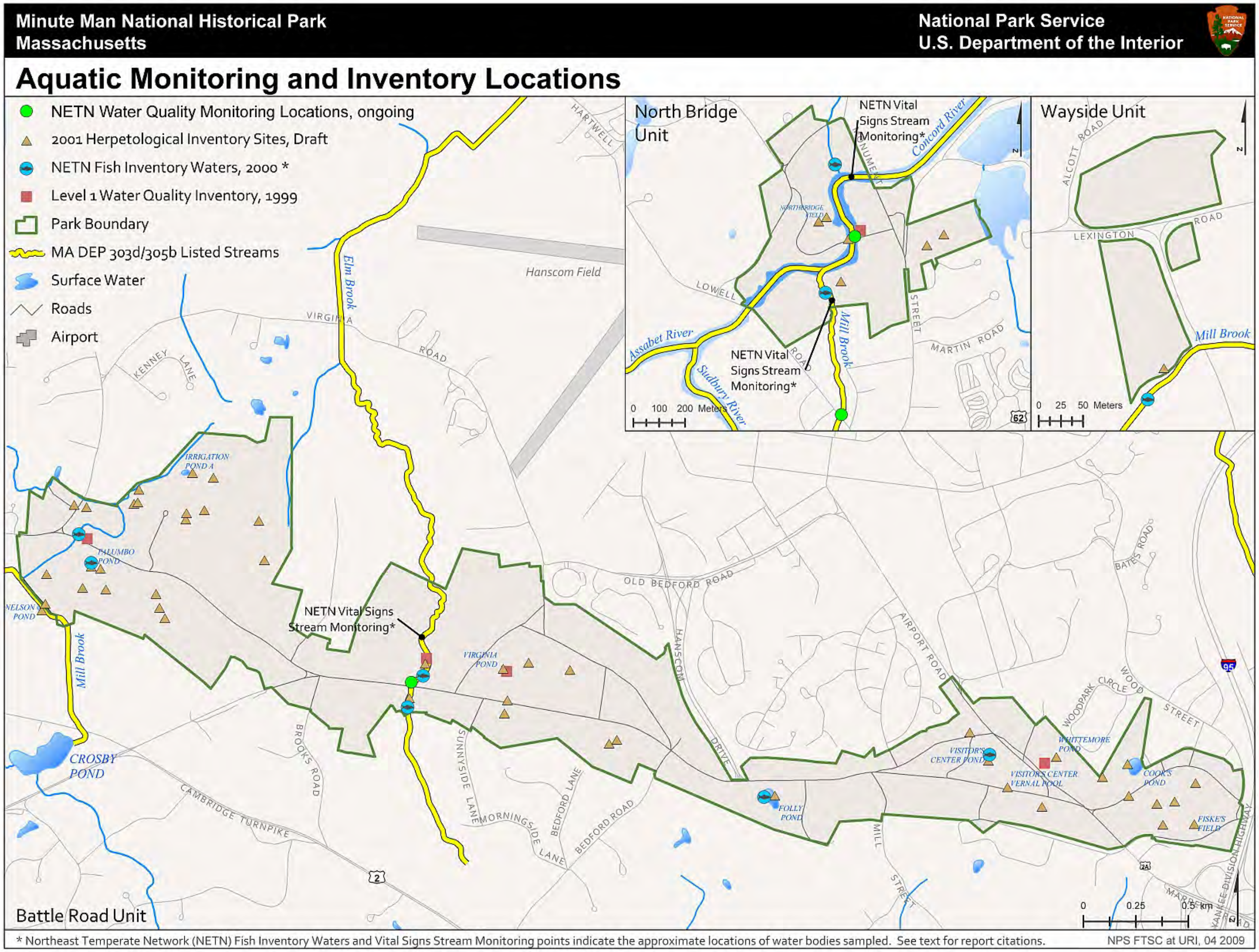

Figure 3. Past and current aquatic monitoring and inventory efforts at MIMA.

Landscape

Land Use Change

An assessment of land use change from 1600 to 1999 within MIMA was undertaken to illustrate the changes in landscape dynamics that have occurred over the past 400 years (Table 3). Land use statistics from 1600 and 1775 were from MIMA Natural Resource files and Gavrin et al. (1993). The GIS land use data from the 1600 and 1775 had little or no metadata associated with them and were therefore somewhat limited in terms of evaluating the quality and source of the data. Additionally, the boundaries of these GIS files were not consistent with the official boundary of the park and several polygons of "unknown" land use were present; however, these data were useful to illustrate a general depiction of the landscape in 1600 and 1775. Recent land use statistics were from Massachusetts Geographic Information System (MassGIS) for 1971, 1985, and 1999 and from Wang et al. (2007) for 1974, 1987, and 2000. These recent data sets had extensive metadata.

Prior to European settlement, the uplands of MIMA were primarily forested and dominated by hardwoods interspersed with patches of red maple swamp that occurred in shallow depressions with poor drainage. Native Americans probably utilized some lands using a slash and burn agricultural system in which areas were cleared using fire, planted, cultivated for several years with crops such as corn, beans, and squash, and were then allowed to revert to forest (Donahue 2004; Dietrich-Smith 2005). The first generation of English settlement occurred between 1635 and into the 1650's (Gavrin et al. 1993; Dietrich-Smith 2005). During this time there were most likely several large planting fields, probably those formerly cultivated by Native Americans, with hay mowing occurring on the meadows. Over time forests were cut and cleared, resulting in the replacement of forests with agricultural fields (Table 3, Figure 4). Flat wetland areas, such as those bordering Elm Brook, were ditched, drained and hayed, with the drier, low-lying areas tilled for farmland while grazing occurred on the hilltops and rocky areas (Gavrin et al. 1993; Gawler et al. in review). In the 1800's large tracts of fruit orchards, vegetable gardens, and dairy herds were common along the Battle road area (Dietrich-Smith 2005). After World War II the village of Concord rapidly developed. Former agricultural fields were transformed into residential lots and commercial businesses, and pastures and tilled fields reverted to woodland (Gavrin et al. 1993; Dietrich-Smith 2005; Gawler et al. in review) (Table 3, Figure 4). The landscape of the park today is the product of decades of park development and historic landscape rehabilitation. The park was assembled from hundreds of individual agricultural, residential, and commercial tracts and the landscape includes historic features, including houses, barns, stone walls, fields, and roads dating from the seventeenth century to the early twentieth century. Since the late 1950's over two hundred modern structures (post 1920's) have been removed by the park and many historic structures have been preserved in an effort to portray the cultural landscape of 1775 (Dietrich-Smith 2005). The most recent land use estimates of the park indicate that approximately 52% of the park is forested, 26% is open fields, orchards, or agriculture, 17% is residential and urban, and 5% is wetlands (Figure 4).

Table 3. Estimates of land use area (hectares) based on GIS coverages. Percent of total area for each unit is given in parentheses. Estimates of land use for 1600 and 1775 were from MIMA Natural Resource files and Gavrin et al. (1993). Recent land use data for 1971, 1985, and 1999 were from MassGIS. * These data lack sufficient GIS metadata.

	Area in hectares and percent (in parentheses)				
Description	1600	1775*	1971	1985	1999
North Bridge & Wayside Units					
Agriculture and crop land (tilled land)	-	10.2 (21%)	6.8 (14%)	6.8 (14%)	6.8 (14%)
Forest	20.1 (42%)	-	15.3 (32%)	15.3 (32%)	15.3 (32%)
Native American agriculture	2.6 (5%)	-	-	-	-
Open field, pasture or meadow [a]	25.3 (53%)	18.6 (39%)	3.8 (8%)	2.8 (6%)	2.8 (6%)
Orchard	-	0.2 (<1%)	-	-	-
Residential/Road/Urban [b]	-	2.1 (5%)	13.4 (28%)	14.5 (30%)	14.5 (30%)
River and wetlands [c]	-	-	8.7(18%)	8.7 (18%)	8.7 (18%)
Unknown	-	11.0 (23%)	-	-	-
Battle Road Unit					
Agriculture (tilled land)	-	40.4 (12%)	62.6 (18%)	62.6 (18%)	62.0 (18%)
Forest	228.6 (66%)*	20.2 (6%)	178.9 (52%)	178.2 (52%)	187.3 (55%)
Native American agriculture	12.5 (4%)*	-	-	-	-
Open field, pasture or meadow [a]	102.4 (30%)*	169.0 (49%)	17.8 (5%)	15.4 (4%)	15.8 (5%)
Orchard	-	5.2 (2%)	21.4 (6%)	21.3 (6%)	13.1 (4%)
Residential/Road/Urban [b]	-	18.4 (5%)	50.2 (14%)	53.3 (16%)	52.6 (15%)
River and wetlands [c]	-	-	12.6 (4%)	12.6 (4%)	12.6 (4%)
Unknown	-	92.8 (27%)	-	-	-

[a] Includes MassGIS LU_21 categories open land, urban open, and pasture.
[b] Includes MassGIS LU_21 categories low density residential, medium density residential, and multi-family residential, participation recreation, mining, and transportation.
[c] Includes MassGIS LU_21 categories non-forested freshwater wetland and water.

MIMA has experienced urban expansion over the past 30 years (Wang et al. 2007). To illustrate this change, the percent difference in land use was calculated over this time both within MIMA and within a 1 km buffer adjacent to MIMA using the analyses of Wang et al. (2007) and from MassGIS land use data (Figure 5a and 5b). Wang et al. (2007) estimated land use for the years 1974, 1987, and 2000 using LandSat remote sensing data. Different types of LandSat image data were available for the three years that were analyzed. Data from the earliest LandSat image data set (1974) were from a Multispectral Scanner (MSS) consisting of four spectral bands with a spatial resolution of approximately 80 meters. LandSat image data from 1985 were derived from a Thematic Mapper (TM) consisting of seven spectral bands with a resolution of 30 meters for most bands. Image data from 2000 were derived from an Enhanced Thematic Mapper Plus (EMT+) consisting of eight spectral bands with a resolution of approximately 30 meters. These data are presented with the caveat that difference in spatial resolution exist among the LandSat data. Data from MassGIS for this same general period (1971, 1985, and 1999) were based on photo interpretation of 1:25,000 scale aerial photography (MassGIS 2008). The data from both sources are presented as an illustration of the percent change in land use that has occurred over the past 30 years both inside and outside the park (Figure 5a and 5b).

In general, the data from MassGIS showed a less dramatic change, compared to Wang et al. (2007) (Figure 5a and 5b), in the percent change of land use from the 1970's to late 1990's. There was a more dramatic increase in the percent of urban and residential areas in the 1 km area surrounding MIMA than within MIMA (Figure 5a and 5b). From the early 1970's to late 1990's there was an increase of urban area within MIMA of 14% and 1% (data from Wang et. al 2007 and MassGIS, respectively) whereas in a 1 km area surrounding MIMA there was an increase of 27% and 6% (data from Wang et al. 2007 and MassGIS, respectively). This coincides with a lower rate of loss for forested and agricultural lands inside the park than outside the park. This indicates that the rate of urbanization was lower in the park, as expected, than outside the park and that the conversion of forested and agricultural lands to urban land in the park has been relatively low over the past 30 years (Figure 5a and 5b). The discrepancies in the analyses from Wang et al. (2007) and MassGIS are most likely due to the resolution and interpretation of the imagery from the different datasets; however, the relative patterns in percent change of the amount of urban and residential areas are similar.

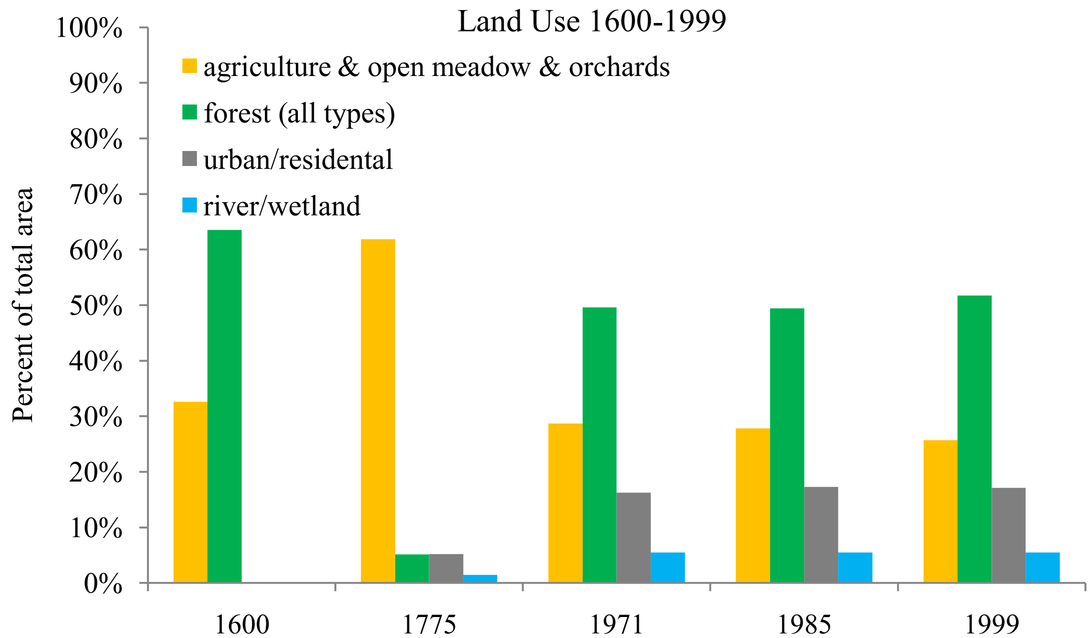

Figure 4. Land use (percent of area, all MIMA units combined) for MIMA from 1600-1999, data were from MIMA Natural Resource files, Gavrin et al. (1993), and MassGIS.

Figure 5a.

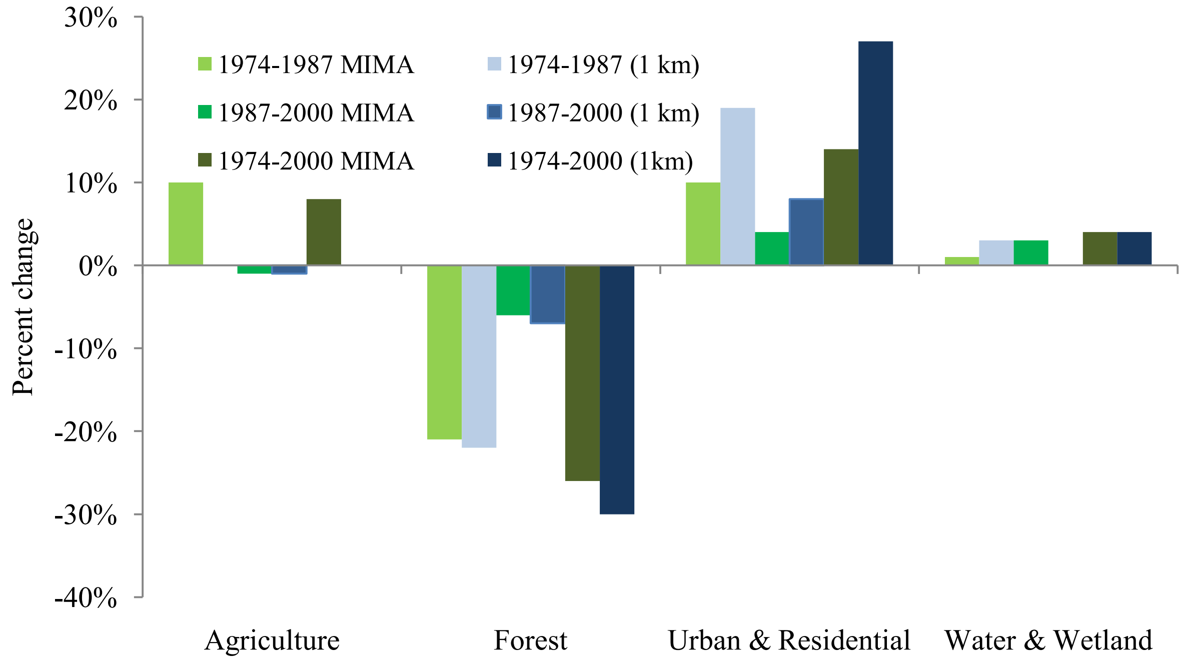

Figure 5b.

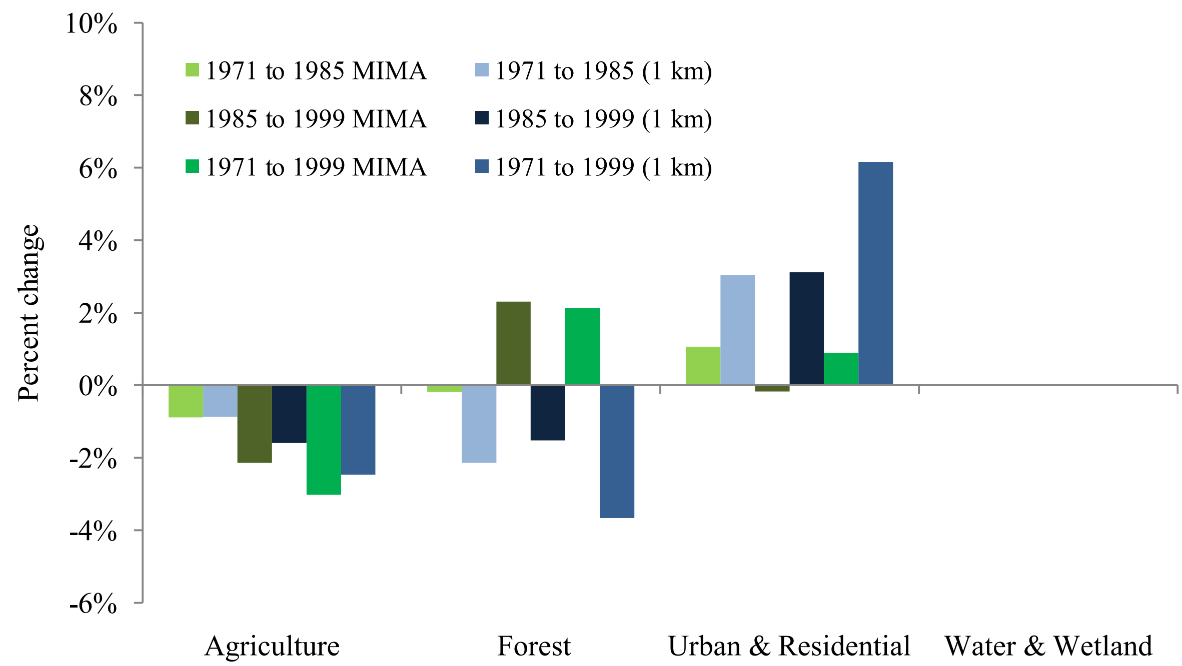

Figure 5. Percent change in land use from 1970's to late 1990's both in MIMA and in a 1 km buffer area surrounding MIMA. Analyses based on LandSat image analyses of Wang et al. (2007) (top, Figure 5a) and Mass GIS data (bottom, Figure 5b).

Condition Assessment of Land Use Change

The current condition of land use for MIMA was based upon the percent urban area of the park (e.g., residential housing and roads) from the most recent land use data (1999 for MassGIS and 2000 LandSat data). Both datasets indicated that urban lands occupy approximately 17% of the park (Table 3). One of the park's main management objectives is to portray the landscape as it existed in 1775 and this amount of modern urbanization may detract from the historic and cultural atmosphere the park is trying to portray. Therefore, based on best professional judgment, the current condition of land use was rated "caution" since there was a considerable proportion of land that is urbanized in the park (Table 4).

The trend in land use was estimated from the direction of the percent change in urban land over the past 30 years in the park (early 1970's to late 1990's). Data from both Wang et al. (2007) and MassGIS data indicated that the percent increase in urban land was lower in MIMA than in a 1 km buffer surrounding the park (Figure 5). Even though the rate of increase in urban lands was less in the park than outside the park, there were still areas that were converted to urban land within MIMA over the past 30 years. If the mission of the park is to portray the area as it existed in 1775, than any conversion to urban land could be viewed as a negative trend. Therefore, based on best professional judgment, the trend in land use change was assessed as a "declining trend" condition due to the increase in urbanization, albeit small (1% to 14%), within the park's boundary.

The average data reliability score was "satisfactory" (0.61 falling in the range of 0.34 to 0.67) primarily due to the lack of metadata regarding the historical (1600 and 1775) GIS land use files (Table 4). These older data were not used in the assessment of condition and were only used for historical information. If they are omitted from the average, the data reliability score would be 0.84, or "good".

Table 4. Condition assessment ratings for land use change at MIMA. Average scores are given when more than one metric was assigned a condition rating.

Metric	Condition	Numerical Score	Comments
Current Condition of Land Use			
Percent of urbanized land within MIMA	Caution	0.50	17% of land in the park is urbanized (Table 3).
Trend Data for Land Use Change			
Proportion of non-urban land loss over the past 30 years in and adjacent to MIMA	Declining trend	0.16	Increase in urbanization, albeit small (1% to 14%), within the park's boundary (Figure 5).
Data reliability for Land Use			
MIMA Natural Resource files, historic land use (1600 and 1775)	Limited	0.16	Metadata data were lacking for 1775 GIS files.
MassGIS land use data	Good	0.84	
Wang et al. (2007)	Good	0.84	
Average data reliability score	Satisfactory (0.34-0.67)	0.61	

Vegetation Communities

The vegetation communities of MIMA have been highly influenced by historical land use including human habitation, dissected land ownership, agriculture, and various practices such as forestry, grazing, and mowing of hay fields. Prior to the park's establishment, the area was suburban with commercial development (e.g., motels, restaurants, gas stations, and car dealerships). After the formation of the park in 1959, the landscape began to transition from suburban development to a more natural vegetated state, and the NPS continues to restore portions of the park to reflect the colonial period of 1776 (Gawler et al. in review).

Plant Community

There have been two plant community studies and two vegetation mapping efforts at MIMA (Table 2). Thompson and Jenkins (1992) and Agius (2003) completed plant community studies, with Agius (2003) focusing on invasive species in the park. Vegetation communities were mapped in the 1990's (using aerial photography from 1986 and field sampling in 1991) by the Environmental Data Center at the University of Rhode Island (August et al. 1993) in association with the Thompson and Jenkins (1992) study (Figure 6). The most recent vegetation mapping effort was conducted in 2003 (from photo-interpretation of leaf-off color infrared 2003 aerial photography) as part of the USGS-NPS Vegetation Mapping Program using the vegetation classification system of NatureServe's National Vegetation Classification (NVC) (Gawler et al. in review) (Figure 7).

Thompson and Jenkins (1992) conducted their study under a contract with the Massachusetts Natural Heritage and Endangered Species Program to document and evaluate the plant communities, locate exemplary communities, and record rare species. Their primary focus was limited to natural communities and they did not examine developed, agricultural, or recent post-agricultural lands. They ranked the plant communities as A, B, C, or D, with "A" assigned to communities with the best examples of natural communities (i.e., those with little physical disturbance, a relatively natural nutrient budget and hydrology [for wetlands], few or no non-native species, and a full suite of native species representing good example of the native community throughout eastern Massachusetts). A rank of "B" was given to communities that, although they had more disturbance and non-native species, were still biologically representative of the community type, were above average, and merited protection within the park. Ranks of "C" and "D" were indicative of both an increasing level of disturbance and percentage of non-native species (more than 25% and 50% of the community, respectively) (Thompson and Jenkins 1992). Most communities failed to meet the criteria for natural nutrient budget and hydrology and non-native species and as such, many communities in the park received ranks of "C". Thompson and Jenkins (1992) classified 32% of the mapped area (as depicted by August et al. 1993), composed of 19 ha in the North Bridge Unit and 137 ha in the Battle Road Unit; no communities were classified within the Wayside Unit. To evaluate the percent of area occupied by each of the ranks, the information for 153 specific polygons as noted in the maps of Thompson and Jenkins (1992) were added to the August et al. (1993) GIS coverage layer (Figure 8), and the total area of each rank was calculated. Although Thompson and Jenkins (1992) describe their criteria for the rank of "D", the specific community descriptions and maps in their report do not identify these communities. Since the maps only represent 32% of the park area, it cannot be assumed that the unlabeled areas are those ranked as “D”.

Thompson and Jenkins (1992) assessed 156 ha of vegetation communities in park. Only three communities received a rank of “A”, representing 5% of the assessed area. Twenty-two sites received ranks of “B+” or “B”, representing 22% of the assessed area. The remaining 73% of the assessed area was ranked as “B-” or “C” (Figure 9). Thompson and Jenkins (1992) concluded that due to the fragmentation and small patch size of most communities, the establishment of native species was improbable and the communities were unlikely to resist invasion by non-native species.

Gawler et al. (in review) conducted field surveys of vegetation communities by sampling 39 vegetation plots, stratified across known vegetation communities, in the summer of 2004 (Figure 2). Vegetation plots were specifically located in areas that were not dominated by invasive species, with the caveat that these plots were intended to reflect past and remnant communities in order to document the range of vegetation variability and to provide possible restoration models (Gawler et al. in review). Twenty-seven vegetation communities were identified, including 11 forest types, one woodland, four shrublands, and 11 herbaceous communities; of these, 17 were wetlands and 10 were uplands (Figure 8). Only three community types (red oak-red maple successional forest, oak-hickory forest, and successional old field) were widely distributed within the park, with the remaining 24 associations found in limited parts of the park (Gawler et al. in review).

Comparing the August et al. (1993) with the Gawler et al. (in review) GIS data was difficult due to the difference in the complexity of the vegetation community categories; however, by introducing a very simple community classification system (Table 5) these two datasets could be compared in an effort to detect changes in vegetation communities in the recent past (Figure 10). From 1992 to 2003 there was an increase in the amount of agriculture in both the Battle Road and North Bridge Units and an increase in forested areas in all units, while a decrease in old fields and swamp/wetland areas occurred in all three units (Figure 10). These data sets were difficult to compare to the Wang et al. (2007) and MassGIS land use datasets due to the time periods that each dataset covered and the criteria used to classify vegetation categories. The increase in agriculture lands corresponds to the changes Wang et al. (2007) observed between 1987 and 2000, whereas the increase in forested area corresponds to MassGIS changes over the period from 1971 to 1999.

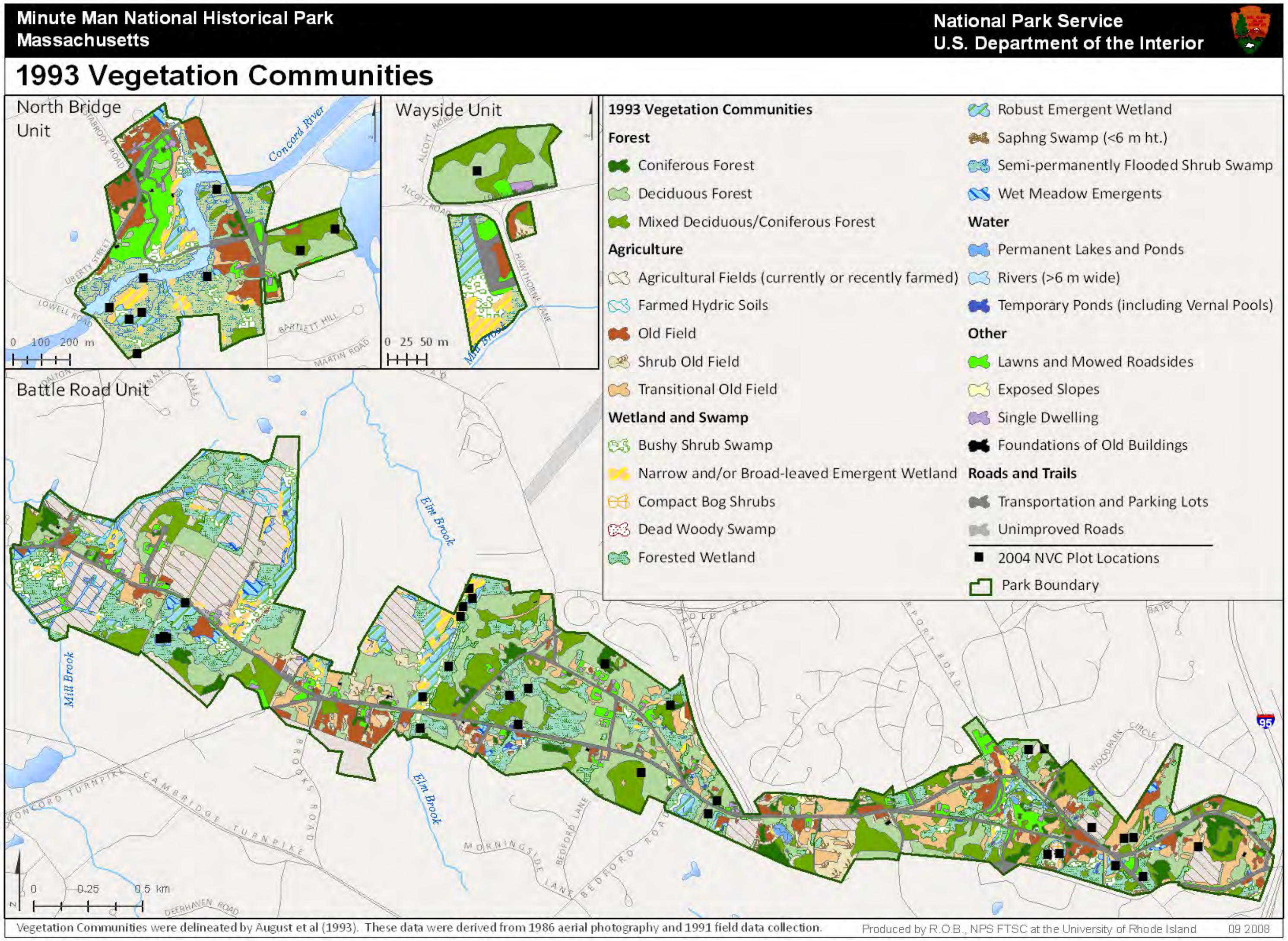

Figure 6. Vegetation communities of MIMA mapped in 1990’s (August et al. 1993).

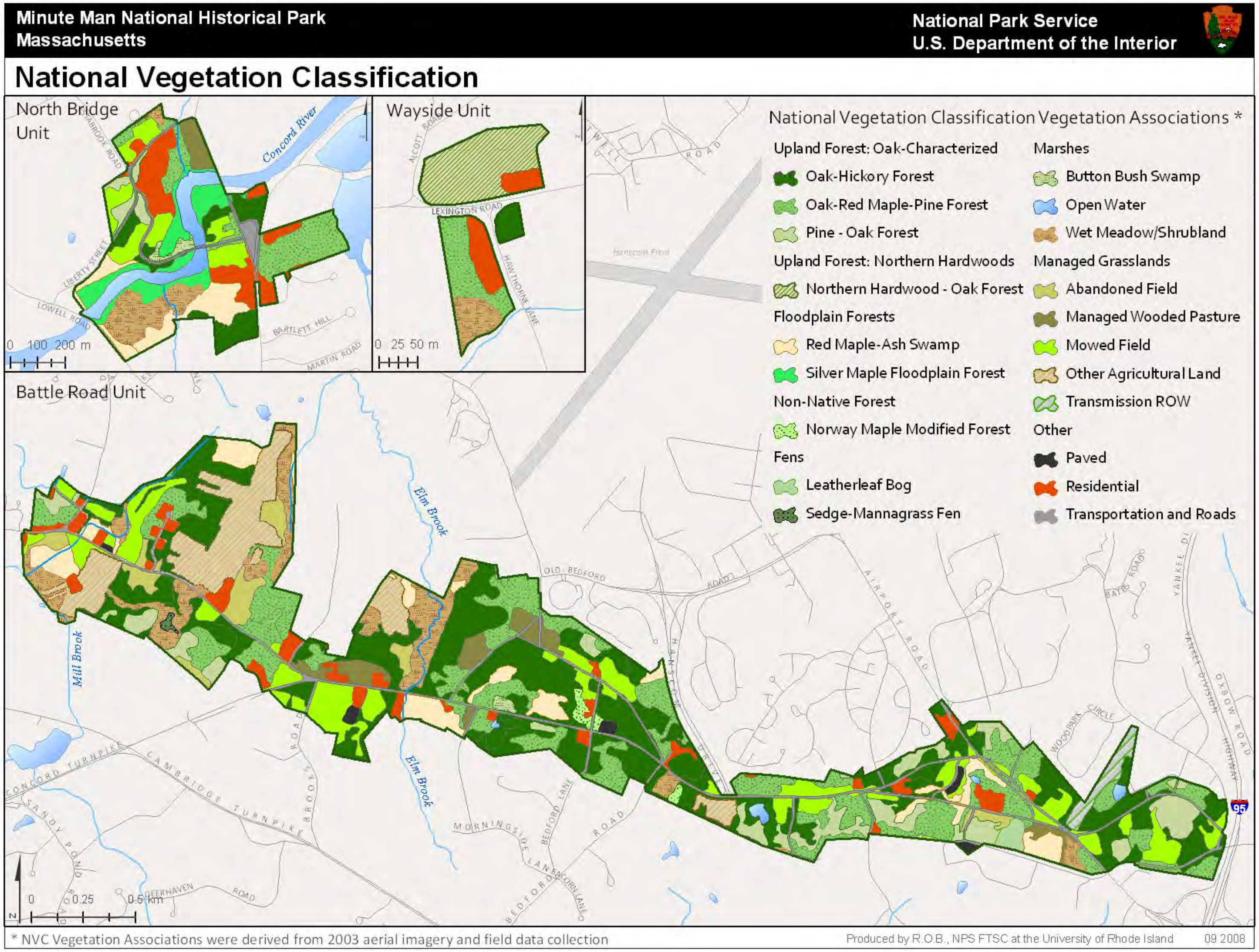

Figure 7. Vegetation communities of MIMA mapped in 2003 (Gawler et al. in review).

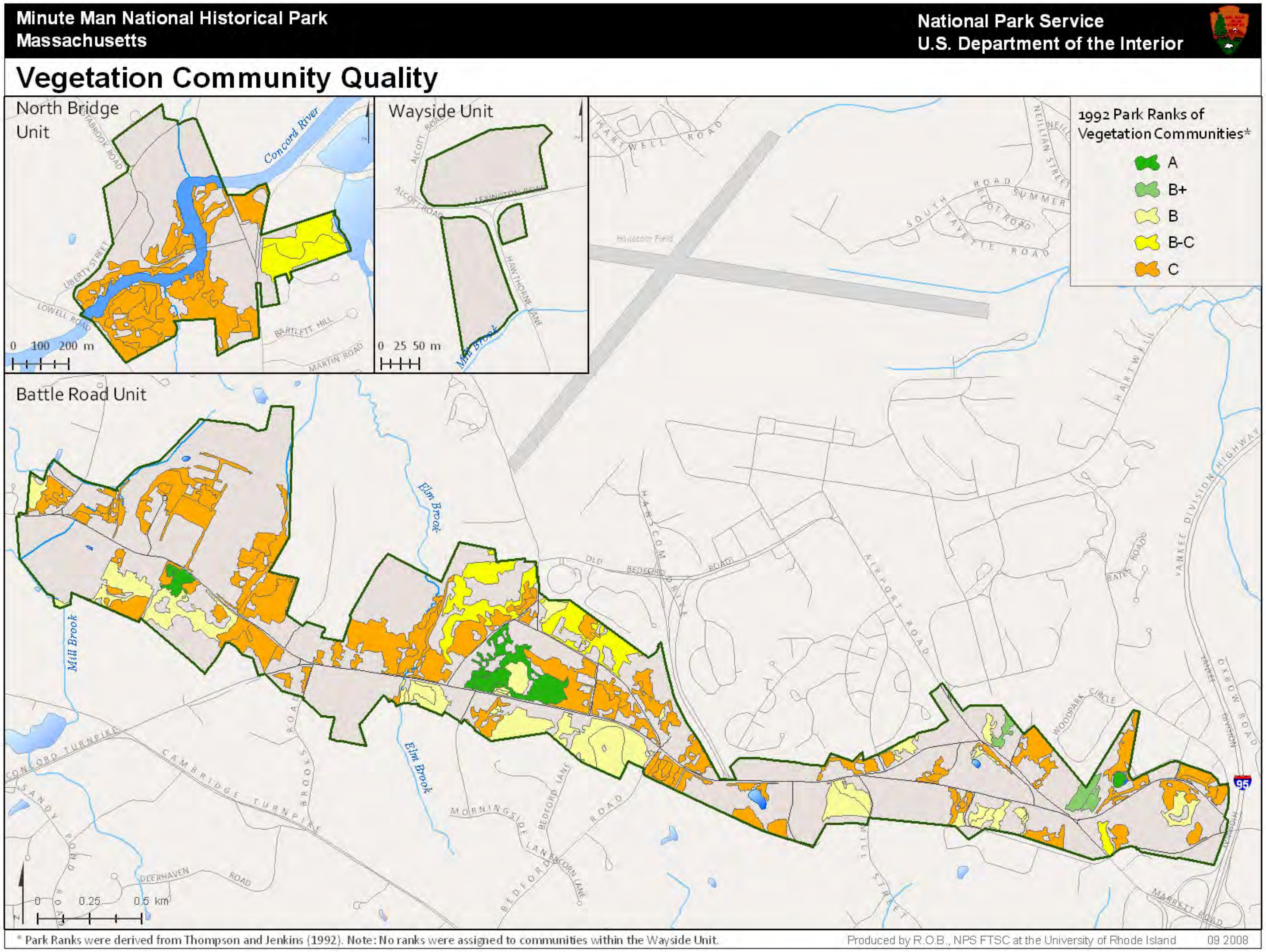

Figure 8. Classification of vegetation communities as ranked by Thompson and Jenkins (1992) based on GIS maps produced by August et al. (1993). Individual communities with a rank of “D” were not identified in the Thompson and Jenkins (1992) report.

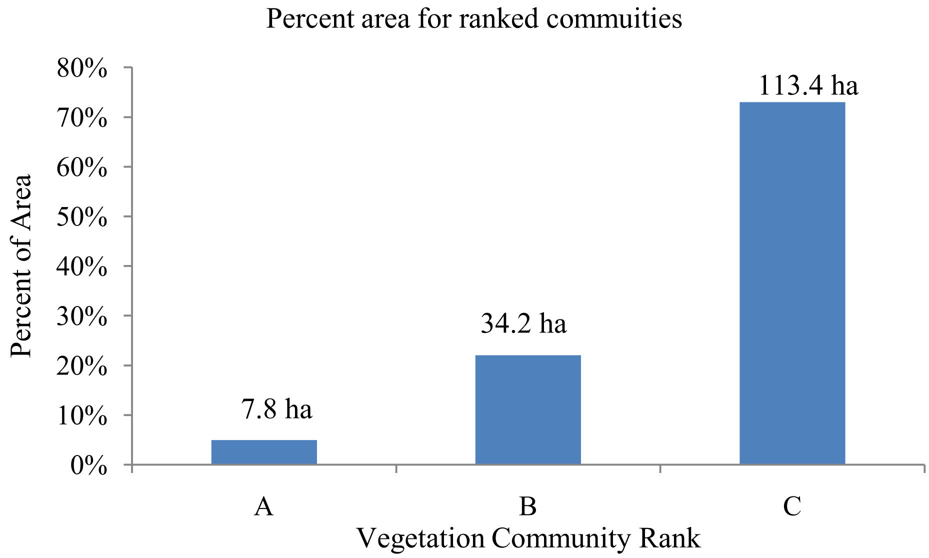

Figure 9. Percent area occupied by vegetation communities ranked by Thompson and Jenkins (1992). Percent of the total area assessed for each rank was calculated from GIS files produced by August et al. (1993). The total area (ha) for each rank is indicated above each bar. Individual communities with a rank of "D" were not identified in the Thompson and Jenkins (1992) report.

Table 5. Combined land use categories (underlined) used to compare August et al. (1993) and Gawler et al. (in review) GIS datasets. [1] Category from August et al. (1993); [2] Category from Gawler et al. (in review).

New Community Category	New Community Category
Agriculture	Open water
Agricultural fields[1]	Open water[2]
Farmed hydric soils[1]	Permanent lakes and ponds[1]
Managed wooded pasture[2]	Rivers[1]
Mowed field[2]	Paved
Other agricultural land[2]	Paved[2]
Bog	Transportation and parking lot[1]
Compact bog shrubs[1]	Transportation and roads[2]
Leatherleaf bog[2]	Unimproved roads[1]
Sphagnum swamp[1]	Residential
Exposed	Foundations of old buildings[1]
Exposed slopes [1]	Lawns and mowed roadsides[1]
Forest	Residential[2]
Coniferous forest[1]	Single dwelling[1]
Deciduous forest[1]	Transmission ROW[2]
Mixed deciduous/coniferous forest[1]	Wetland
Northern hardwood - oak forest[2]	Bushy shrub swamp[1]
Norway maple modified forest[2]	Button bush swamp[2]
Oak-hickory forest[2]	Dead woody swamp[1]
Oak-red maple-pine forest[2]	Forested wetland[1]
Pine - oak forest[2]	Narrow and/or broad-leaved emergent[1]
Silver maple floodplain forest[2]	Red maple-ash swamp[2]
Old Field	Robust emergent wetland[1]
Abandoned field[2]	Sedge-mannagrass fen[2]
Old field[1]	Semi-permanently flooded shrub swamp[1]
Shrub old field[1]	Temporary ponds[1]
Transitional old field[1]	Wet meadow emergents[1]
	Wet meadow/shrubland[2]
	Unknown[1]

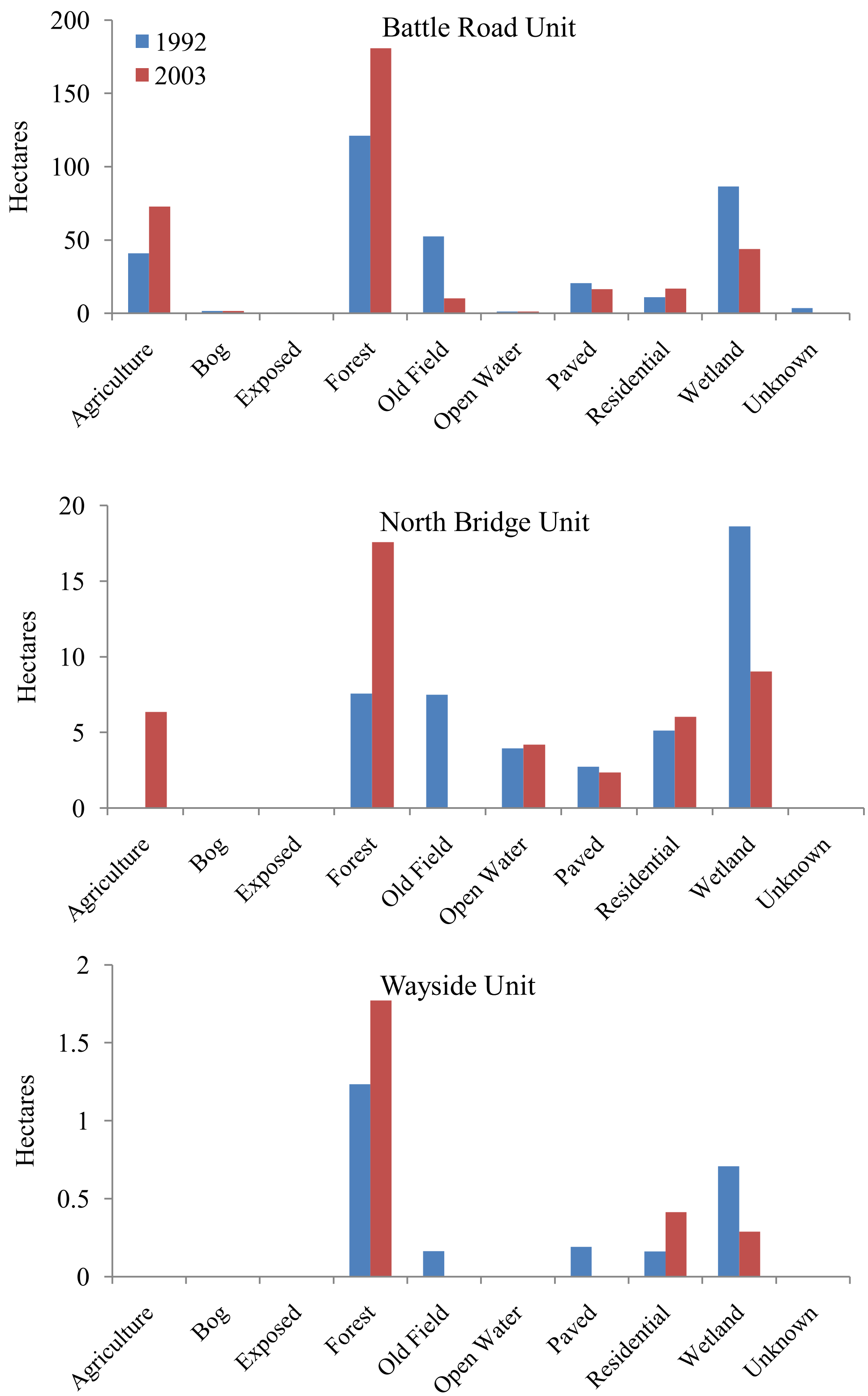

Figure 10. Comparison of the total area (ha) of vegetation communities from mapping efforts conducted in 1992 (August et al. 1993) and in 2003 (Gawler et al. in review).

Forest Condition

In 2006, the NETN Forest Monitoring Protocol was implemented throughout the Network including at MIMA. The vital signs associated with this protocol are forest vegetation, forest soil condition, invasive/exotic plants, invasive/exotic animals, land and ecosystem cover, white-tailed deer herbivory, and atmospheric deposition and stress (Tierney et al. 2009; Tierney and Faber-Langendoen in review). This protocol addresses multiple vital signs at co-located permanent plots (10 plots sampled in 2006 and another 10 sampled in 2008) within MIMA.

Forest condition from the NETN protocol was measured using several metrics such as the amount of fallen coarse woody debris, snags, presence of invasive species, stand structure, overall tree condition, tree regeneration and soil chemistry (soil chemistry is discussed in the *Parkwide Resources* section). The NETN protocol assigns forest condition scores for each of these parameters as “good”, “caution”, or “significant concern”. Ratings for four of the metrics (coarse woody debris, stand structure, tree condition, and tree regeneration) were estimated by averaging the scores (using the midpoint of rating range, refer to Table 1) across all plots to attain an average score for that metric. Summary park ratings were available for two of the six metrics (Table 6).

Three of the six forest structure parameters classified as “significant concern” and the remaining three were classified as “caution” based on recent NETN monitoring (B. Mitchell, personal communication) (Table 6). Overall, the numerical scoring of the forest condition at MIMA was rated “caution” (the value of 0.34 falling within the range of 0.34-0.67) indicating that MIMA’s forests exhibited signs of stress (Table 6). Forest structure parameters that were rated “significant concern” were the amount of fallen coarse woody debris, invasive species, and tree regeneration. Snags and coarse woody debris provide important habitat for arthropods, amphibians, reptiles, small mammals, birds, and fungi (NETN 2007b).

Six of the 10 forest monitoring plots sampled in 2006 were within communities that were ranked by Thompson and Jenkins (1992). Forest monitoring plots 1, 8, 9, and 10 fall within communities that were ranked as “B” (site J35, site J38, site 20, and site J38, respectively), and plots 3 and 6 are located within communities that were ranked as “C” (there were no specific site names linked to these areas in Thompson and Jenkins 1992). To briefly re-iterate, Thompson and Jenkins (1992) gave ranks of “B” to communities that were above average, although were still somewhat disturbed and contained non-native species. Ranks of “C” were given to communities that had more than 25% non-native species and were more disturbed. Overall, the forest monitoring plots at MIMA were classified as “significant concern” by the NETN for invasive species (the NETN’s uses the number of key invasive species present as a metric) while Thompson and Jenkins (1992) ranked four of forest monitoring plot areas as “B” (above average communities). The data used to characterize these two ranking methods were far from equivalent, but it is interesting to note the large discrepancy between the rating of “B” given in 1992 and rating of “significant concern” given in 2006 for these areas.

Table 6. Results from recent NETN forest condition monitoring, NETN ratings, and estimation of scores used to evaluate condition in this report (B. Mitchell, personal communication). * Only NETN park summary ratings were available for these metrics and the midpoint of the rating range was used to estimate a numerical score (refer to Table 1).

Forest Condition Metric	Forest Score	Numerical equivalent score
Coarse woody debris	Significant concern	0.20
Invasive species	Significant concern*	0.16
Snags	Caution*	0.50
Stand structure	Caution	0.46
Tree condition	Caution	0.46
Tree regeneration	Significant concern	0.28
Overall average score	Caution	0.34

Core Habitats and Natural Communities

Massachusetts Natural Heritage and Endangered Species Program (MA-NHESP) has delineated Priority Habitats based on the known geographic extent for all state listed species (plants and animals) and is codified under the Massachusetts Endangered Species Act (MESA). Any activity that results in habitat alteration within these Priority Habitats that may result in the unintended harm to state listed species is subject to regulatory review by the MA-NHESP (MA-NHESP 2008a). The North Bridge Unit of the park lies within the MA-NHESP Estimated Habitats for Rare Wildlife delineation area EH44 (Figure 11), a subset of the Priority Habitat designation that is based upon the geographical extent of habitat for state listed rare wetlands wildlife. State listed wetland wildlife species are protected under MESA as well as the Wetlands Protection Act. The areas encompassed by the Estimated Habitats for Rare Species are based on the occurrences of rare wetland wildlife observed over the last 25 years and documented in the MA-NHESP database and are for use with the Wetlands Protection Act. The Estimated Habitats for Rare Species are published in 12th Edition of the Massachusetts Heritage Atlas and are effective as of October 1, 2006. Projects that fall within areas designated as Estimated Habitats for Rare Wildlife require a Notice of Intent (NOI) to be filed under the Wetlands Protection Act, with a copy of the NOI sent to the MA-NHESP (MA-NHESP 2008a). While federal lands are exempt from state law, compliance with the Wetlands Protection Act is encouraged by the National Park Service.

Portions of MIMA also fall within MA-NHESP delineated BioMap Core Habitats (Core Habitat IDs C637, C604, C672, and C673) (MA-NHESP 2004a, 2004b, 2008a) (Figure 11). Core Habitats are areas that are critical to the long-term viability of terrestrial, wetland, and estuarine elements of biodiversity in Massachusetts (MA-NHESP 2004a, 2004b). Detailed information concerning these Core Habitats is also presented in the *Wetlands* section of this document. Approximately 70% of the North Bridge Unit falls within the BioMap Core Habitat identified as C604, a small-river flood plain forest that is an imperiled habitat in the state. This habitat is located along portions of the Concord and Assabet Rivers and includes two of the eight remaining small-river flood plain forests. Small-river flood plain forests are silver maple-green ash forests that occur on alluvial soils of small rivers and streams (MA-NHESP 2004a). This community type is highly threatened by the encroachment of invasive exotic plant species. Rare species that occur within the Core Habitat include four plant and seven animal species, although only one, Blanding's turtle (*Emydoidea blandingii*), has been documented at MIMA (Table 7) (MA-NHESP 2004a). The MA-NHESP promotes riparian buffers that extend up to 100 m from the water's edge to help maintain cooler water temperatures and to maintain nutrients, energy, and the natural flow of water needed by freshwater species (MA-NHESP 2004a). There was no information available on the width of riparian buffers for the streams and rivers at MIMA, and gathering this information could be a management priority.

Portions of the Wayside Unit and Battle Road Unit fall within BioMap Core Habitat C637. This Core Habitat encompasses the grasslands of L. G. Hanscom Field/Hanscom Air Force Base as well as the "Bedford Levels", an area of wetlands and meadow habitats, including black gum swamp and kettlehole wet meadow habitat (MA-NHESP 2004a) (although refer to information in the *Wetlands* section of this document regarding the re-classification of the black gum community within this BioMap Core Habitat). The black gum swamp is an imperiled community while the kettlehole wet meadow is a vulnerable community (MA-NHESP 2004a, 2004b). The state listed grasshopper sparrow (*Ammodramus savannarum*) and the upland sandpiper (*Bartramia longicauda*) are known to utilize these habitats statewide (Table 7) (MA-NHESP 2004a). Portions of the Battle Road Unit also fall within the BioMap Core Habitats C672 and C673, a mix of wetland and meadow habitats (refer to *Wetlands* section for more detail) (MA-NHESP 2004b). One state threatened plant and two state listed dragonfly species are known to utilize these habitats although neither has been recorded at MIMA (Table 7).

Table 7. State listed plant and animals that are known to occur within BioMap Core Habitats (indicated by "X"). Portions of MIMA fall within these BioMap Core Habitats (refer to Figure 11). BioMap Core Habitats: C604: small-river floodplain forest; C637: black gum swamp and kettlehole wet meadow; C672: wetlands and meadows. State status: SC= special concern, T=threatened, E=endangered. * Indicates species that have been observed at MIMA (refer to Tables 8 and 27 for a complete list of MIMA rare plant and animal species, respectively).

			BioMap Core Habitat		
Common Name	Scientific Name	State Status	C604	C637	C672
Plants					
Britton's violet	*Viola brittoniana*	T	X		
Cornel-leaved aster	*Doellingeria infirma*	E			X
Engelmann's umbrella-sedge	*Cyperus engelmannii*	T	X		
River bulrush	*Bolboschoenus fluviatilis*	SC	X		
Violet wood-sorrel	*Oxalis violacea*	E	X		
Animals					
American bittern	*Botaurus lentiginosus*	E	X		
Blanding's turtle*	*Emydoidea blandingii*	T	X		
Blue-spotted salamander	*Ambystoma laterale*	SC	X		
Common moorhen	*Gallinula chloropus*	SC	X		
Grasshopper sparrow	*Ammodramus savannarum*	T		X	
King rail	*Rallus elegans*	T	X		
Least bittern	*Ixobrychus exilis*	E	X		
Mocha emerald	*Somatochlora linearis*	SC			X
Umber shadowdragon	*Neurocordulia obsoleta*	SC			X
Upland sandpiper	*Bartramia longicauda*	E		X	
Wood turtle	*Glyptemys insculpta*	SC	X		

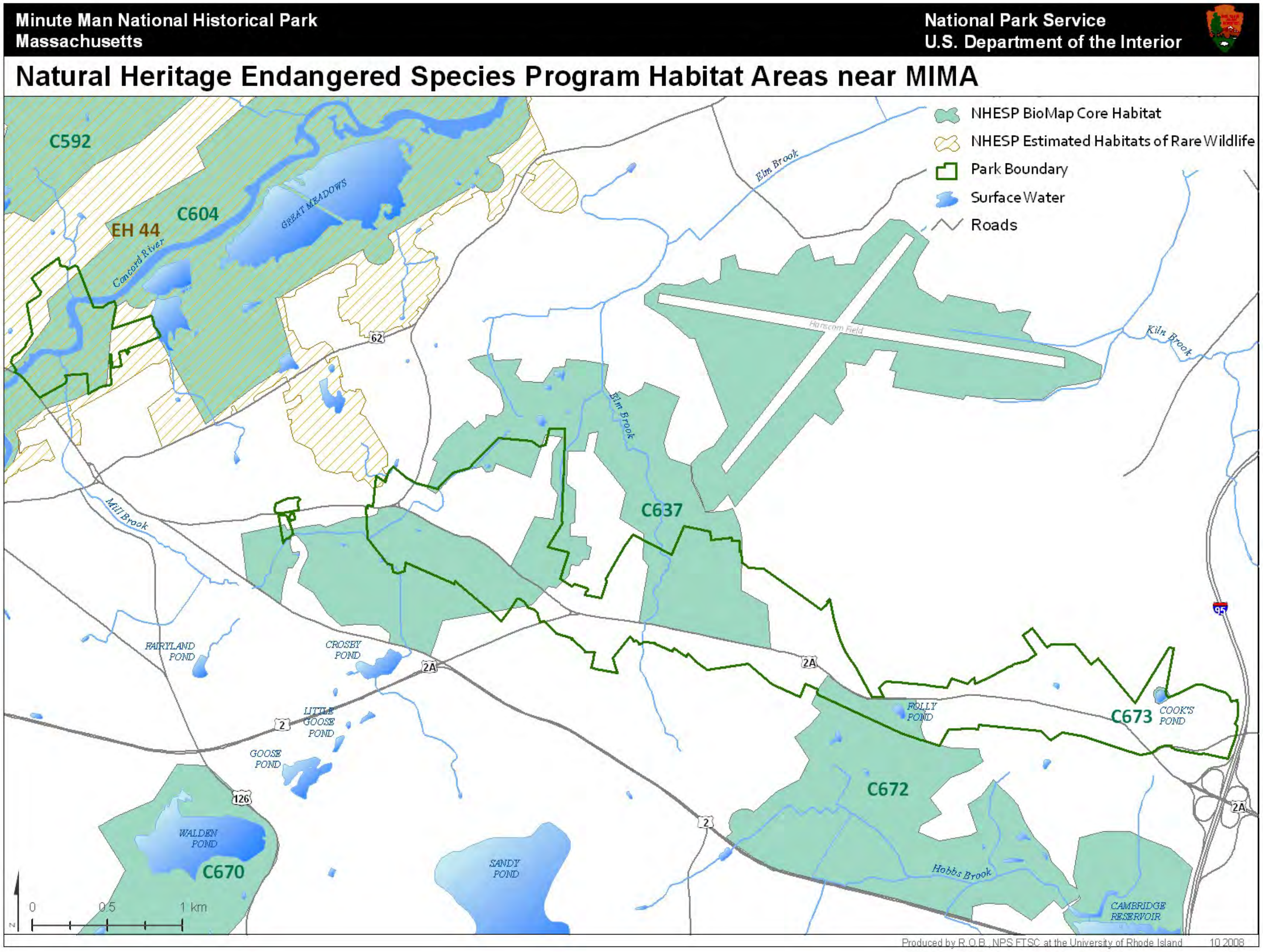

Figure 11. Massachusetts priority habitats near MIMA (MA-NHESP 2004a, 2004b). Codes refer to MA-NHESP BioMap Core Habitat identifiers (refer to Table 7).

State Listed Plant Species

Although previous vegetation surveys have stated that no state listed plant species were found at MIMA (e.g., Thompson and Jenkins 1992; Gawler et al. in review), there have actually been records, from these and other surveys (e.g., NETN Forest Plots, B. Mitchell personal communication), that combined have recorded five state listed plant species, all of which are threatened, in the park (Table 8). A survey in the vicinity of MIMA, a Biodiversity Day event held on July 4, 1998 (Alden 1998; NPS 2008d), recorded species in the towns of Lincoln and Concord. While portions of MIMA are located within these towns the exact locations of the Biodiversity Day observations were not known. To be conservative this report assumes that these observations were not recorded within the park's boundary; however, the Biodiversity Day data were useful as they give an indication of the rare species that could potentially be present in the park, and these data are presented with this caveat. Twelve state listed plant species were observed in the towns of Lincoln and Concord during the Biodiversity survey (Alden 1998; NPS 2008d) (Table 8). The MA-NHESP (2008a) lists 38 state listed vascular plants that are found in the towns of Concord, Lincoln, and Lexington. Only two, Britton's Violet (*Viola brittoniana*) and Andrew's bottle gentian (*Gentiana andrewsii*), of the 17 species recorded either in MIMA or in the area surrounding MIMA (Table 8) are listed for these towns. This indicates that the remaining 15 species would be new records for this area of Massachusetts (for one species, Andrew's bottle gentian, the most recent observation was from 1896), for a net total of 53 possible state listed plant species in the area of the park.

Although Gawler et al. (in review) remarked that they did not encounter any state listed or federally listed rare plant species during their surveys, their plant list (Appendix E: Vascular Plant Species) showed three plants that are Massachusetts state listed threatened species: Gray's sedge (*Carex grayi*), hairy-fruited sedge (*Carex trichocarpa*), and intermediate spike-sedge or matted spike-rush (*Eleocharis intermedia*) (MA-NHESP 2008a). Gawler et al. (in review) observed Gray's sedge in the swamp white oak floodplain forest and it was mentioned in the vegetation description as "other common species". It is not known where specimens of hairy-fruited sedge or intermediate spike-sedge were observed by Gawler et al. (in review) in MIMA since they were only mentioned in Appendix E.

Data collected, in 2006 and 2008, as part of the NETN Forest Monitoring Protocol (B. Mitchell, personal communication) indicate that three listed species: fen cuckoo flower, *Cardamine pratensis* L. *v. pratensis* (synonym: *Cardamine pratensis* L. var. *palustris*, [ITIS 2008; USDA NRCS 2008c]), Gray's sedge, and woolly rosette grass or rough panic-grass (*Dichanthelium scabriusculum*), all state listed threatened species, were observed in forest monitoring plots.

Thompson and Jenkins (1992) similarly stated that they observed no rare or listed plant species but in their plant list they list two species, fen cuckoo flower and intermediate spike-sedge, both of which are currently threatened species in Massachusetts (Thompson and Jenkins 1992; MA-NHESP 2008a). Thompson and Jenkins (1992) observed fen cuckoo flower at Sites 61 and 62 along the shores of the Concord River in the North Bridge Unit. The exact site where intermediate spike-sedge was observed by Thompson and Jenkins (1992) is unknown as it was not listed under the descriptions of the individual sites that were assessed.

Table 8. Massachusetts state listed plant species have been observed in MIMA or in the area surrounding MIMA (SC= special concern, T=threatened, E=endangered). [1] Indicates species observed by Thompson and Jenkins (1992) in MIMA, [2] Indicates species observed by Gawler et al. (in review) in MIMA, [3] Indicates species observed by NETN forest plot monitoring in MIMA (2006 and 2008 data). Species documented in the towns of Lincoln and Concord, but may not be necessarily present in MIMA, were observed during the July 4, 1998 Biodiversity Day (Alden 1998; NPS 2008d). Synonyms for species are indicated in parentheses.

Common Name	Scientific Name	State status
Documented in MIMA		
Fen cuckoo flower	*Cardamine pratensis* L. *v. pratensis* [1, 3] (*Cardamine pratensis* L. var. *palustris*)	T
Gray's sedge	*Carex grayi* [2, 3]	T
Hairy-fruited sedge	*Carex trichocarpa* [2]	T
Intermediate spike-sedge/Matted spike-rush	*Eleocharis intermedia* [1, 2]	T
Woolly rosette grass/Rough panic-grass	*Dichanthelium scabriusculum* [3]	T
Documented in the towns of Lincoln and Concord		
American waterwort	*Elatine americana*	E
Andrew's bottle gentian	*Gentiana andrewsii*	E
Black maple	*Acer nigrum*	SC
Britton's violet	*Viola brittoniana*	T
Bur oak	*Quercus macrocarpa*	SC
Culver's root	*Veronicastrum virginicum*	T
Downy arrowwood	*Viburnum rafinesquianum*	E
Great laurel	*Rhododendron maximum*	T
Northern bedstraw	*Galium boreale*	E
Ovate spikerush	*Eleocharis ovate*	E
Red mulberry	*Morus rubra*	E
White cedar	*Thuja occidentalis*	E

Data from Biodiversity Day, conducted in the towns of Lincoln and Concord in 1998, indicate 12 additional Massachusetts listed plant species were identified in the vicinity of MIMA (Alden 1998; NPS 2008d). Those species were American waterwort (*Elatine americana*), Andrew's bottle gentian, black maple (*Acer nigrum*), Britton's Violet, bur oak (*Quercus macrocarpa*), Culver's root (*Veronicastrum virginicum*), downy arrowwood (*Viburnum rafinesquianum*), great laurel (*Rhododendron maximum*), northern bedstraw (*Galium boreale*), ovate spikerush (*Eleocharis ovate*), red mulberry (*Mores rubra*), and white cedar (*Thuja occidentalis*) (Alden 1998; NPS 2008d) (Table 8). It is not known where these species were observed in Lincoln and Concord as there was no information on location of plants associated with the Biodiversity Day data.

There is evidence that at least five rare plant species occur in MIMA and another 12 occur in the vicinity of MIMA (Table 8). Combined with the state listed species already known to occur in the towns of Concord, Lincoln, and Lexington (38 species) there would be an estimated net total of 53 state listed plant species in this area. Only five species (9%) were recorded in MIMA and 12 species (23%) were recorded in the vicinity of MIMA.

Non-native and Invasive Plant Species

An invasive plant species inventory was conducted at MIMA during the summer of 2003 (Agius 2003). The park was surveyed systematically using grids uploaded into a GPS unit (100 m x 100 m grids for the Battle Road and North Bridge Unit and 50 m x 50 m grids for the Wayside Unit). All invasive species were quantified and mapped by bushwhacking the grid perimeter and then making numerous transverse passes through the grid. In the field the areal extent of 14 primary invasive species within each grid were sketched as polygons and the percent cover (cover scale <1%, 1-5%, 6-25%, 26-50%, 51-75%, or 76-100%) for each species was recorded for each polygon. Percent cover of secondary invasive species, if present, was also recorded for each grid. All data were converted into GIS coverages using "head-up" digitizing, resulting in individual GIS coverages for the 14 primary invasive species (Agius 2003). Sketches also denoted vertical stratification and overlapping of invasive species within each grid. Agius (2003) then calculated the coverage of each invasive species through spatial analyses.

In addition to mapping the areal extent of the 14 primary invasive species, Agius (2003) identified another 55 exotic species (secondary species) in MIMA. Aquatic plants (e.g., water chestnut, *Trapa natans*), were not surveyed by Agius but it is likely they were present (Agius 2003). Twenty-five of species identified by Agius (2003) are considered invasive or potentially invasive by the Massachusetts Invasive Plants Advisory Group (MIPAG) (2005) (Table 9). Invasive plant species were extensively dispersed throughout MIMA, with approximately 64% of the park covered by the 14 primary invasive species based on Agius' (2003) GIS mapping (this estimate also included managed areas and agriculture lease areas). When the managed and agriculture areas (and open water) were excluded from the calculation approximately 84% of the available natural habitat was occupied by the 14 primary invasive species. Additionally, there were areas of the park where there was vertical stratification of invasive species in which six or more primary invasive plant species occupied a single 1 m^2 vertical column (e.g., invasive species occupied the ground cover, shrubs, lower trees, and the canopy layers), indicating that invasive species were invading in a three dimensional fashion (Agius 2003). The full extent of exotic plant species was probably underestimated as plants growing in newly mowed fields and manicured lawns were difficult to identify. These areas likely supported non-native grasses and exotic small flowering plants (e.g., sand spurrey [*Spergularia rubra*], silvery cinquefoil [*Potentilla argentea*], common chickweed [*Stellaria media*]) (Agius 2003). The most problematic invasive species was the glossy buckthorn (*Frangula alnus*), which dominated 50% (144.7 ha) of the undeveloped habitat in MIMA. The second most problematic species was purple loosestrife (*Lythrum salicaria*) (Agius 2003). The combined acreage of glossy buckthorn and purple loosestrife (192.5 ha) totals more than the other 12 primary invasive species. Similarly, Gawler et al. (in review) reported notable occurrences of invasive species in their vegetation plots, even though the plots were specifically located within sites not dominated by invasive species, indicating the extent of the invasive plant expansion in the park.

Gawler et al. (in review) noted that some invasive species (e.g., Norway maple [*Acer platanoides*], black locust [*Robinia pseudoacacia*], purple loosestrife, and common reed [*Phragmites australis*]) were so prevalent that they defined the community type as the dominant species in six of the 27 vegetation associations. Other invasive species, glossy buckthorn, garlic mustard (*Allaria petiolata*), Japanese barberry (*Berberis thunbergii*), winged euonymus (*Euonymus alatus*), and multiflora rose (*Rosa multiflora*) were locally dominant, but did not define the community type (Gawler et al. in review).

Forest monitoring data collected as part of the NETN Forest Monitoring Protocol recorded 15 invasive species in forest plots during the 2006 and 2008 sampling seasons (Table 9). Invasive species were present in all of the plots. The recent NETN Forest Monitoring observed fewer invasive species than Agius (2003) observed. This most likely does not reflect a decline in invasive species since Agius (2003) searched for invasive species throughout the entire park, while the 20 forest plots were randomly located and sample a smaller area than that surveyed by Agius (2003).

Biodiversity Day held in the towns of Lincoln and Concord recorded 25 potentially invasive plant species in 1998. Thompson and Jenkins (1992) observed 14 invasive species in 1992 (Table 9). These authors remarked that alien species were most prevalent in the wet and mesic woods and were less prominent in the dry woods. Four species (purple loosestrife, reed canary grass [*Phalaris arundinacea*], common buckthorn [*Rhamnus cathartica*], and glossy buckthorn) were extremely common in wetland areas (Thompson and Jenkins 1992).

USDA approved the *Galerucella* beetle for use as a biocontrol agent for purple loosestrife in 1992. Since then the beetles have been released in Great Meadows National Wildlife Refuge and more recently in several areas around the state (Suedmeyer 2007). The state biocontrol coordinator surveyed areas of purple loosestrife at MIMA in 2008 and it was observed that all of these areas were infested with *Galerucella* beetles (S. Colwell, personal communication).

A total of 85 plants have been evaluated by MIPAG and they have determined that 66 species are either invasive or likely invasive (more information is required on the remaining 19 species before they can be classified as invasive) (MIPAG 2005). In total there have been 34 potentially invasive species recorded in MIMA since 1992 (Table 9). Of these 23 are known invasive species, six are likely to be invasive, with the invasive status of the remaining five unknown. An additional 13 potentially invasive species have been identified in the towns of Lincoln and Concord (Alden 1998; NPS 2008d) (Table 9).

MIMA was one of nine parks in the Northeast visited by the NPS Exotic Plant Management Team (EPMT) (NPS 2004). The EPMT assists parks with the identification and control of invasive exotic plant infestations that threaten the park's natural resources. The EPMT visited MIMA in 2004 and more recently in 2008. In 2008, the team treated a total of 1.57 ha in the park, 1.55 ha in the Battle Road Unit (Sunnyside Road area and Miriam's Corner) and 0.02 ha in the North Bridge Unit, either by manual removal or with herbicides. Invasive plants that were treated were Amur maple (*Acer ginnala*), Asian bittersweet (*Celastrus orbiculatus*), buckthorn species (*Frangula* species), exotic honeysuckle (*Lonicera* species), Louis' swallow-wort (*Cynanchum louiseae*), Japanese barberry, and multiflora rose (B. McDonnell personal communication).

Invasive plant species occupy a considerable amount of habitat at MIMA. The natural native vegetation communities are under assault from a variety of invasive and exotic species, which if they are not controlled or eradicated, could spread to those few areas in the park that are devoid of invasive plant species.

Table 9. Invasive plant species known to occur in and in the vicinity of MIMA. Status of invasiveness from MIPAG (2005): I: invasive; L: likely invasive; U: unknown and indicates species was evaluated for invasiveness and it was determined that further information was required (MIPAG 2005). 1992: data from Thompson and Jenkins 1992; 2003: data from Agius (2003); 2006 & 2008: NETN forest plot monitoring data; 1998: data from Biodiversity Day for the towns of Lincoln and Concord (Alden 1998; NPS 2008d). Synonyms for species are indicated in parentheses. Note: [a] Agius (2003) and NETN data only identified honeysuckle as *Lonicera* species or as *Lonicera*-exotic.

			Surveys in MIMA			Survey in Vicinity of MIMA
Common Name	Scientific Name	Status	1992	2003	2006 & 2008	1998
Amur cork-tree	*Phellodendron amurense*	L				X
Amur peppervine	*Ampelopsis brevipedunculata*	L				X
Asian bittersweet	*Celastrus orbiculatus (Celastrus orbiculata)*	I		X	X	
Autumn olive	*Elaeagnus umbellata*	I		X		X
Bishop's goutweed	*Aegopodium podagraria*	I		X	X	
Black locust	*Robinia pseudoacacia*	I		X	X	X
Carolina fanwort	*Cabomba caroliniana*	I				X
Chocolate vine	*Akebia quinata*	U				X
Coltsfoot	*Tussilago farfara*	L				X
Common barberry	*Berberis vulgaris*	L		X		X
Common buckthorn	*Rhamnus cathartica*	I	X	X	X	
Common mullein	*Verbascum thapsus*	U		X		X
Common reed	*Phragmites australis*	I		X		
Creeping buttercup	*Ranunculus repens*	L	X			X
Creeping jenny	*Lysimachia nummularia*	I	X	X	X	X
Curly pondweed	*Potamogeton crispus*	I	X			
Cypress spurge	*Euphorbia cyparissias*	L				X
Dame's rocket	*Hesperis matronalis*	I		X		
European privet	*Ligustrum vulgare L.*	U	X			
Forget-me-not	*Myosotis scorpioides*	L	X			X
Garlic mustard	*Allaria petiolata*	I		X	X	X
Glossy buckthorn	*Frangula alnus (Rhamnus frangula)*	I	X	X	X	X
Japanese barberry	*Berberis thunbergii*	I	X	X	X	X
Japanese honeysuckle	*Lonicera japonica*	I		X [a]	X [a]	X
Japanese knotweed	*Polygonum cuspidatum*	I		X	X	X
Leafy spurge	*Euphorbia esula*	I		X		
Louis' swallow-wort	*Cynanchum louiseae (Vincetoxicum nigrum)*	L		X		
Morrow's honeysuckle	*Lonicera morrowii*	I	X	X [a]	X [a]	X
Multiflora rose	*Rosa multiflora*	I	X	X	X	X
Northern catalpa	*Catalpa speciosa*	U			X	X
Norway maple	*Acer platanoides*	I		X	X	X

Table 9. Invasive plant species known to occur in and in the vicinity of MIMA (continued).

Common Name	Scientific Name	Status	Surveys in MIMA 1992	Surveys in MIMA 2003	Surveys in MIMA 2006 & 2008	Survey in Vicinity of MIMA 1998
Purple loosestrife	*Lythrum salicaria*	I	X	X		X
Reed canary-grass	*Phalaris arundinacea*	I	X	X	X	X
Rugosa rose	*Rosa rugosa*	U				X
Russian olive	*Elaeagnus angustifolia*	U				X
Sheep fescue	*Festuca ovina*	U				X
Spotted knapweed	*Centaurea biebersteinii (Centaurea maculosa)*	L		X		X
Sycamore maple	*Acer pseudoplatanus*	I				X
Tatarian honeysuckle	*Lonicera tatarica*	L		X [a]	X [a]	X
Tree of heaven	*Ailanthus altissima*	I		X		X
Two-leaf water-milfoil	*Myriophyllum heterophyllum*	I				X
Water-chestnut	*Trapa natans*	I				X
Watercress	*Rorippa nasturtium-aquaticum*	U				X
White poplar	*Populus alba*	U		X		
Winged euonymus	*Euonymus alatus* (*Euonymus alata)*	I		X	X	X
Witch's moneybags	*Sedum telephium ssp. telephium*	U	X			
Yellow iris	*Iris pseudacorus*	I	X	X		X
Total potentially invasive species observed			14	26 [a]	15 [a]	36

Diseases

Beech Bark disease is a disease of the American beech (*Fagus grandifolia*) that causes significant mortality in affected trees. Beech bark disease results when tree bark that has been attacked and altered by the beech scale insect (*Cryptococcus fagisuga*) is invaded and killed by fungi (primarily *Nectria coccinea* var. *faginata*, but sometimes *N. galligena*) (Houston and O'Brien 1998). Large trees, those over eight inches in diameter, are more susceptible than smaller ones. The pattern of insect spread and subsequent occurrence of nectria infection and death has been classified into three general categories. The "advancing fronts" are areas recently invaded by beech scale that are characterized by forests with many large, old trees supporting scattered, sparse, populations of the insect. The "killing fronts" are areas that are characterized by high populations of beech scale, severe nectria infestation, and heavy tree mortality. The "aftermath zones" are areas where heavy tree mortality occurred at sometime in the past and that now contain some residual large trees and many stands of small trees. The beech scale was accidently brought to Nova Scotia around 1890. By 1932, the scale and associated fungus were killing trees in the Maritime Provinces, localized areas of Maine, and isolated areas of eastern Massachusetts. The scale insect has continued to spread northward into Quebec and to the west and south throughout New England, New York, New Jersey, and portions of Pennsylvania (Houston and O'Brien 1998). The American beech is present in MIMA (NPS 2008d; Gawler et al. in review). The beech scale insect, *Cryptococcus fagisuga*, is present in Middlesex County but the forest susceptibility for the county was rated as low for this pest (refer to *Faunal Communities* section, Table 28, for more detail).

Chestnut blight is a disease of American chestnut trees (*Castanea dentata*) caused by a fungus (*Cryphonectria parasitica*). The parasitic fungus enters through the cracks and wounds in the tree's bark causing dead areas called cankers. Once introduced, the fungus grows quickly, destroys the vascular system of the tree, and causes the leaves to die (USDA Forest Service 2008c). The fungus was most likely introduced from nursery stock in the late 1800's and was first noticed when American chestnut trees in the Bronx Zoological Park started dying. While a weak parasite in its native China, the fungus spread quickly in America, killing an estimated four billion trees in a half a century (Kubisiak 2008). American chestnut trees are found in MIMA (NPS 2008a; Gawler et al. in review). The fungus, *Cryphonectria parasitica*, is present in Middlesex County and the forest susceptibility for the county was rated as extreme for this pest (refer to *Faunal Communities* section, Table 28, for more detail).

Ash yellow is a disease of ash trees (*Fraxinus* species). At least a dozen ash species are susceptible to this disease with white ash (*Fraxinus americana*) and green ash (*Fraxinus pennsylvanica*) the most commonly affected trees. Ash yellow is caused by a phytoplasma (a type of bacteria parasite) which causes branch dieback in the crown of the tree eventually causing death within one to three years in highly susceptible trees. The exact nature of the transmission of the phytoplasma is unclear but it may be vectored by insects. Currently, there is no way to prevent or cure ash yellow (Gillman 2005). Both white and green ash trees are present in MIMA (Gawler et al. in review). Many ash trees, particularly white ash in the vicinity of the park, have been infected by ash yellow (NPS 2008a) (refer to *Faunal Communities* section, Table 28, for more detail).

Condition Assessment for Vegetation Communities

The current condition of vegetation communities in MIMA was based on the quality of vegetation communities, quality of forest condition, the extent of invasive plant species, and the percent state listed plant species found in MIMA.

Thompson and Jenkins (1992) categorized vegetation communities in 1992, and while these were somewhat older data, they provided an estimate of historical condition for several sites within MIMA. Only 27% of the communities assessed by Thompson and Jenkins (1992) were given ranks of “A” or “B”, indicating that they were biologically representative of the community and were above average examples of the community throughout eastern Massachusetts. Based on best professional judgment, the condition of the vegetation communities as assessed by Thompson and Jenkins (1992) was rated as “significant concern” as it would seem a healthy vegetation community would have more than 27% of community ranked as good.

The NETN has recently implemented the Forest Monitoring Protocol (Tierney and Faber-Langendoen in review). These data indicated that the overall condition of the forest structure at MIMA rated as “caution” based on the score card of the NETN Forest Monitoring (B. Mitchell personal communication) (Tables 6 and 10).

Invasive plant species occupy a large percent of the park. Agius (2003) estimated that 84% of MIMA’s natural area was occupied by 14 primary invasive species and that another 55 secondary invasive species were present in the park. Invasive species are a threat to a variety of natural resources and invasive plants are extensive in MIMA. Therefore, based on best professional judgment this metric was rated as “significant concern” (Table 10).

A total of five state listed plant species have been recorded in MIMA since 1992. The towns of Concord, Lincoln, and Lexington identify 38 state listed species. Fifteen of the species either observed in MIMA or in the vicinity of MIMA (in the towns of Lincoln and Concord) would be new records, for a net total of 53 listed species for these towns. Therefore, only 9% (five species) of the state listed plant species for this area have been observed in MIMA, and 23% (12 species) have been observed in the vicinity of the park. It is not known what would be the appropriate number of rare plant species to be found at MIMA, but there are fewer state listed plants recorded in the park than in the surrounding area. There have not been specific surveys to search for rare plants at MIMA, and it is difficult to determine whether the apparent lack of rare species is truly reflective of a paucity of rare species or a lack of effort to verify the existence of these species within the park. Therefore, the condition for this metric was assessed as “unknown” (Table 10).

Although there was a notable discrepancy between the community ratings for six of the 10 NETN forest monitoring plots that were located in communities ranked by Thompson and Jenkins (1992), these data were not directly comparable and trends in forest condition could not be evaluated. The NETN Forest Monitoring will be able to detect trends in forest condition in the future, but since monitoring was only initiated in 2006 there were not enough data to evaluate trends in forest condition. Therefore, the trend in forest condition was rated as “unknown”.

Information on trends for vegetation communities was harder to evaluate principally due to the difficulty in making direct comparisons among the vegetation surveys that have been conducted over the years; however, there was general evidence that the number of invasive plant species has increased over the years or in the very least that invasive species have not declined. Therefore, based on best professional judgment a condition of “declining trend” was given for vegetation communities primarily due to the consistent and continued extent of invasive species in MIMA.

The data reliability for vegetation communities was “good”, with an overall average rating of 0.74 (Table 10).

Table 10. Conditional assessment ratings for vegetation communities at MIMA. Average scores are given when more than one metric was assigned a condition rating.

Metric	Condition	Numerical Score	Comments
Current Condition of Vegetation Communities			
Condition of vegetation communities	Significant concern	0.16	Only 27% of communities ranked "A" or "B" (above average) (Figure 9).
Forest condition	Caution	0.34	Average scores from NETN 2006 forest monitoring (Table 6).
Extent of invasive plants in MIMA	Significant concern	0.16	Invasive species occupy 84% of MIMA (Agius 2003).
Number of state listed plants in MIMA.	Unknown	-	Need more data to evaluate existence of rare plants in MIMA (Table 8).
Average condition score	Caution (0.34 to 0.67)	0.61	
Trend Data for Vegetation Communities			
Forest condition	Unknown	-	Forest Condition monitoring was initiated in 2006 and there were not enough data available to evaluate trends.
Vegetation communities	Declining trend	0.16	All vegetation surveys have noted a persistent presence of invasive species (Table 9).
Data reliability for Vegetation Communities			
Agius (2003)	Good	0.84	
August et al. (1993)	Good	0.84	
Biodiversity Day data for towns of Lincoln and Concord (Alden 1998; NPS 2008d)	Satisfactory	0.50	No documentation of specific species location.
Massachusetts Natural Heritage & Endangered Species Program	Good	0.84	

Table 10. Conditional assessment ratings for vegetation communities at MIMA (continued).

Metric	Condition	Numerical Score	Comments
NETN forest monitoring data	● Good	0.84	Data collection just recently initiated, no long-term data available, but expected to be of "good" quality.
Thompson & Jenkins (1992)	● Satisfactory	0.50	The locations of all ranked communities were not explicitly identified.
Average data reliability score	● Good (0.68 to 1.0)	0.74	

Wetland Resources

Wetlands

The wetlands within MIMA are palustrine wetlands. Palustrine wetlands are inland freshwater (<0.5 ppt salinity) non-tidal wetlands that are characterized by trees, shrubs, and emergent vegetation (Cowardin et al. 1979). These areas can include small, shallow bodies of open water and range from seasonally flooded vernal pools and riverine wetlands to permanently flooded lands such as lake shores, bogs, swamps, or fens. There are approximately 78 ha of wetlands dispersed among the three park units with the majority (64 ha or 81%) located within the Battle Road Unit. The North Bridge Unit contains 14 ha (18%) and the Wayside Unit contains 0.3 ha (0.4%) of wetlands. Currently, wetland resources are not monitored. It is anticipated that in the future the NETN will begin monitoring wetland resources at MIMA (Mitchell et al. 2006). MassGIS has estimated the change in the areal extent of wetlands for the state from 1991 to 2005, and there was no change in the extent of wetlands within the boundaries of MIMA over this time period.

One of the most extensive wetland systems in MIMA is the Elm Brook wetland located within the Battle Road Unit. This is an area of emergent wetland vegetation bordered by shrub-scrub wetland (Rice 1987). The wetland is bisected by Route 2A, with the majority of the wetland located on the north side of the road (Figure 12). Elm Brook itself is a narrow stream that flows northward from the south side of Route 2A, passes through a culvert under the road, and emerges into the wetland. The Elm Brook wetland has been historically ditched and is fed by an extensive network of ditches (Rice 1987). Two culverts constrict the outflow of Elm Brook (Rice 1987). A portion of Elm Brook to the west of Sunnyside Lane and to the south of Route 2A (Sunnyside Stream) was restored in 2003 (Figure 12). This project restored natural hydrologic functions to Elm Brook and its associated wetlands. The surface flow of the stream had been historically re-directed into buried culverts affecting both the surface and sub-surface hydrology, diminishing both the riparian and wetland environments of the area. Upstream of Sunnyside Lane pipes were opened and a culvert was installed under the road to improve hydrology. The project "daylighted" or exposed and restored a 91 m section of the stream that had been previously contained within underground culverts and restored a portion of diverted surface flow to the adjacent Elm Brook wetland area. This restoration will improve habitat quality for herpetofauna, fish migration, and potentially provide breeding habitat for brook trout (NPS 2003; A. Ellsworth personal communication).

There have been few studies focused primarily on wetland ecosystems (aside from surveys of amphibians) at MIMA. One study that specifically addressed wetlands was Rice (1987). Rice (1987) focused on the strengths and weaknesses of two wetland assessment methodologies, the Connecticut Department of Environmental Protection method (CTDEP method) and the Federal Highway Administration method (Adamus method), using Elm Brook as a study area. The historic condition of the Elm Brook wetland based on Rice's (1987) evaluation using the CTDEP and the Adamus methods can be generally estimated. The CTDEP method is an evaluation system that assigns functional wetland value scores from 0 (low functional value) to 1.0 (high functional value), for 13 wetland functions to estimate the quality of a wetland in terms of wetland value units that incorporate the acreage for each wetland function (Table 11). Based on Rice's (1987) evaluation of wetland value units the weighted (by functional area) average for Elm Brook was 0.64, a score towards the middle (moderate wetland function) of the functional wetland values and equivalent to a rating of "caution" in this report based upon best professional judgment (Table 11). The Adamus method evaluates 20 wetland functions as low, moderate, or high. The end product of the evaluation is a "functional significance" rating for each wetland function from four perspectives: the opportunity the wetland has to perform that function ("opportunity"); its ability to perform the function ("effectiveness"); the local significance attributed to the function ("significance"); and the integration of these three to yield a "functional rating" (Table 12). By converting the Adamus categories ("low", "moderate", and "high") to the three categories used in this report ("good", "caution", and "significant concern", respectively) and assigning the midpoint score (refer to Table 1) to each function (the rating of "very low" was given a score of 0), an overall average of value 0.45 was estimated (equivalent to a condition rating of "caution" in this report) for the "functional significance" of this wetland (this score does not include "recreation" functions of swimming and boating) (Table 12). Both the CTDEP and Adamus methods rated the Elm Brook wetland functions of shoreline anchoring, wildlife habitat, and nutrient retention as high to moderate; while functions such as fish habitat were rated low by both methods (Rice 1987) (Tables 11 and 12). Rice (1987) did note the dominance of purple loosestrife in the Elm Brook wetland, but classified this as moderate to high in value due to its aesthetic appeal. As previously noted, invasive species are generally considered a problem, not an asset.

Thompson and Jenkins (1992) described the Elm Brook wetland (Site 68 in their report) as a post agricultural wetland that was dominated by purple loosestrife and a few other common wetland species. They gave this wetland a park rank of "C" (increasing level of disturbance with more than 25% invasive species present) (Thompson and Jenkins 1992). Other invasive species that were present in the wetland included common buckthorn, common reed, creeping buttercup (*Ranunculus repens)*, glossy buckthorn, multiflora rose, reed canary grass, and yellow iris (*Iris pseudacorus*) (Rice 1987; Thompson and Jenkins 1992). Although invasive species were present, this wetland has extensive edge habitat and open water, and as such is valuable wildlife habitat for the park (Rice 1987). Brook trout are present in Elm Brook (Mather et al. 2003) and it is possible this is a native population. In the very least it is a self-reproducing population of brook trout (refer to *Faunal Communities* section for more detail). Elm Brook may also be the only breeding location in MIMA for the two-lined salamander (Windmiller and Walton 1992). This was the only location in the park where this species was found in the most recent amphibian survey (Brotherton et al. 2005).

Elm Brook is impacted by habitat fragmentation by Route 2A which alters hydrologic flow and poses a barrier to the movement of animals utilizing the wetland (e.g., amphibians, fish). Adjacent land use practices such as road runoff (e.g., excess road salts, heavy metals, and oil), pollution and nutrients from adjacent agriculture, residential, and industrial areas also impact the wetland (Rice 1987). Since Elm Brook and its associated wetland are within 200 m of Route 2A road salts may alter the salinity of the wetland (Forman and Deblinger 2000). Even though the park is within a "low salt use" area, excessive road salt and contaminated road runoff are potential threats to the quality of the wetlands bordering Route 2A (NPS 1993).

Table 11. Assessment of Elm Brook wetland based on Connecticut DEP method (after Rice 1987). Scores for Functional Value Index (FVI) of wetland functions are after Rice (1987). FVI ranges from 0 (lowest functional value) to 1.0 (highest functional value).

Wetland Function	FVI
Flood control	0.70
Ecological integrity	0.75
Wildlife habitat	0.79
Finfish habitat rivers & streams	0.51
Finfish habitat lakes & ponds	0.18
Visual/aesthetic quality	0.79
Agricultural potential	0.78
Nutrient retention	0.81
Education potential	0.67
Forestry potential	0.78
Water based recreation	0.29
Groundwater use potential	0.53
Shoreline anchoring & dissipation of erosive forces	1.00
Noteworthiness	0.00
Average functional value index (not including water based recreation)	0.64

Table 12. Assessment of Elm Brook wetland based on Adamus method for Wetland Functions (low, moderate, high) after Rice (1987). "-" indicates the wetland function was not assigned a rating for this parameter. Condition scores using the midpoint of the range ("good", "caution", and "significant concern", respectively, for the Adamus categories) are indicated in parentheses after the final Functional Significance rating. Functional Rating of "very low" was given a score of "0".

Wetland Function	Opportunity	Effectiveness	Significance	Functional Rating	Function Significance
Ground water recharge	moderate	low	moderate	low	low (0.16)
Ground water discharge	-	low	moderate	low	low (0.16)
Flood storage & desynchronization of erosive forces	high	high	moderate	high	high (0.84)
Shoreline anchoring & dissipation of erosive forces	moderate	high	low	high	moderate (0.50)
Sediment trapping	low	moderate	moderate	moderate	moderate (0.50)
Nutrient retention & removal long-term	high	moderate	moderate	high	high (0.84)
Nutrient retention & removal short-term	high	moderate	moderate	high	high (0.84)
Food chain support- downstream	-	high	moderate	high	high (0.84)
Food chain support- in basin	-	moderate	moderate	moderate	moderate (0.50)
Habitat for fishes warmwater	-	low	low	low	very low (0)
Habitat for fishes- coldwater	-	low	low	low	very low (0)
Habitat for fishes-coldwater riverine	-	low	low	low	very low (0)
Habitat for wildlife - general diversity	-	moderate	moderate	moderate	moderate (0.50)
Habitat for wildlife - waterfowl 1	-	low	moderate	low	low (0.16)
Habitat for wildlife- waterfowl 2	-	high	moderate	high	high (0.84)
Active recreation- swimming	-	low	low	low	very low (0)
Active recreation-boat launch	-	low	low	low	very low (0)
Active recreation-power boat	-	low	low	low	very low (0)
Active recreation-canoeing	-	low	low	low	very low (0)
Passive recreation & heritage value	-	-	moderate	-	moderate (0.50)
Average Functional Significance score (not including water based recreation)					caution (0.45)

MA-NHESP Natural Communities

The MA-NHESP has identified three wetland communities in MIMA as communities of uncommon and/or of exemplary status that are important for biodiversity conservation on a statewide basis (MA-NHESP 2008a). These areas are included in a GIS database available from the MassGIS entitled “NHESP Natural Communities” (MassGIS 2008). To identify potential threats from invasive plants to these natural communities, the GIS maps of the 14 primary invasive species mapped by Agius (2003) were superimposed over these areas and the invasive plants within a 100 ft buffer were identified (Figures 13, 14, and 15). A 100 ft buffer was chosen as this is the area of protection offered under state regulations (Massachusetts Wetlands Protection Act) for certified vernal pools (MA-NHESP 2008a; MA-NHESP 2009).

The Battle Road Unit of MIMA has two wetland communities that are listed as exemplary natural communities by the MA-NHESP, a black gum swamp and kettlehole wet meadow (Figure 12) (MassGIS 2008). Recent information (P. Swain personal communication, S. Gawler personal communication) has indicated that the categorization of the black gum swamp community by the MA-NHESP in the GIS data layer “NHESP Natural Communities” is most likely incorrect and that this community is in fact a red maple swamp community that contains black gum. This classification is consistent with the assessment by Gawler et al. (in review) who identified this area as a red maple swamp-black gum swamp based on two study plots (plot numbers: MIMA 7 and MIMA 30) and categorized it as NVC association, *Acer rubrum / Rhododendron viscosum – Clethra alnifolia* Forest (NVC code: CEGL006156). Although this wetland is not a black gum swamp as defined by MA-NHESP it still is a valuable wetland resource for the park. The MA-NHESP noted that although this swamp is on protected land it includes invasive species.

Thompson and Jenkins (1992) also assessed the red maple-black gum swamp (Site 67 in their report) and gave it a park rank of “A”. They described this area as “the best example of a wooded wetland in the park”, observing that the wetland trees were red maple and black gum with occasional white pine and yellow birch, with some invasive species (honeysuckle, glossy buckthorn) present but in lower abundance than in the surrounding woods (Thompson and Jenkins 1992). Superimposing the invasive plant species GIS layers of Agius (2003) with the MA-NHESP data layer indicated that there were nine invasive species present within the 100 ft buffer around this wetland. Invasive species occupied 43% of the 100 ft buffer area, with the dominant species being glossy buckthorn (Figure 13, Table 13). Thompson and Jenkins (1992) only listed four invasive plant species in this area (Table 13), possibly indicating that the five additional species observed by Agius (2003) may be recent invaders to this important wetland area.

The other MA-NHESP designated natural community that occurs in MIMA is the kettlehole wet meadow which is listed as vulnerable habitat (Core Habitat C637 and C673) by MA-NHESP (2004a, 2004b) (Figure 2). Two of the five statewide kettlehole wet meadow communities are located in the Battle Road Unit, one is located near Fiske Hill and the other is located in the western section of the unit (Figure 12). Kettlehole wet meadow communities are graminoid/emergent herbaceous or mixed shrub/herbaceous communities that are small (usually <2 ha), seasonally inundated kettle depressions in sandy glacial outwash, usually with no inlet or outlet. During the summer months they look like shallow ponds, but become covered with emergent vegetation by late summer (Swain and Kearsley 2001). The kettlehole wet meadow near Fiske Hill is small in size, with good species diversity, and a minimum of exotic invasive species (MassGIS 2008). There were several (eight) invasive species in the 100 ft buffer around this community, dominated by glossy buckthorn and to a lesser degree, Asian bittersweet and common buckthorn (Figure 14). Invasive plants occupied 69% of the 100 ft buffer area around this kettlehole wet meadow (Table 13). Thompson and Jenkins (1992) described this area (Site 4) as a small but pretty kettlehole pond with a ring of shrubs. They noted a modest diversity of native shoreline herbs and very few alien species in the immediate vicinity of the pond and shoreline area. None of the invasive species observed in the 100 ft buffer around this area were listed by Thompson and Jenkins (1992). Five of the nine species (common buckthorn, Asian bittersweet, honeysuckle, glossy buckthorn, and Japanese knotweed) intersected with the area of the kettlehole wet meadow as delineated by MassGIS (2008) indicating that these are possibly new invasions since 1992.

The second kettlehole wet meadow is located on the southern side of Route 2A in the area of the Olive Stowe House (Figure 12). It is an example of a large kettlehole wet meadow and is relatively well buffered by surrounding forest despite occurring within a developed landscape (MassGIS 2008). Even though only two invasive species (glossy buckthorn and purple loosestrife) were present in the 100 ft buffer around this community, they occupied an extensive percentage (95%) of the buffer (Figure 15, Table 13). Thompson and Jenkins (1992) gave this site a park rank of "A" (Site J41). They described the wet tussock sedge meadow in this area as dominated by native species and having a higher diversity of native bryophytes and native herbs than in any other open wetland and containing more sedges than anywhere else in the park (Thompson and Jenkins 1992). Thompson and Jenkins (1992) also listed purple loosestrife as one of the species in the meadow. Based on the GIS maps of Agius (2003) glossy buckthorn was limited to the wooded area surrounding the meadow, but not within the meadow itself, so it appears that this area may not have been invaded by any new invasive plant species.

Comparing information from Thompson and Jenkins (1992), MassGIS MA-NHESP data, and Agius (2003) it is possible that two of these three communities have been recently (within the last 15 years) invaded by invasive plant species. Thus, it is likely that invasive plant species have trended towards an increase in both abundance and number of species over the past 15 years in MIMA. This conclusion is made with caution as the field sampling effort and methods varied among investigators.

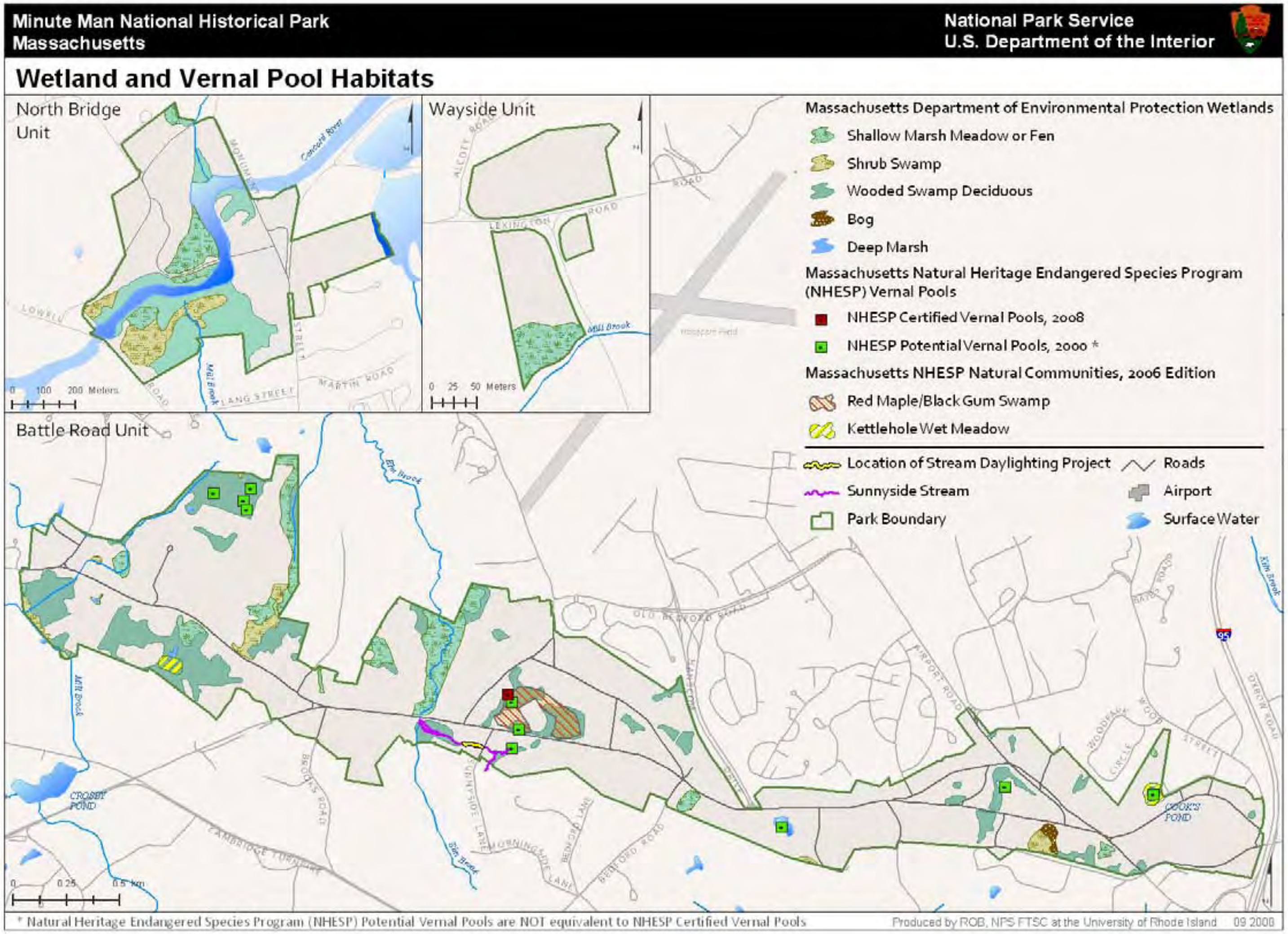

Figure 12. Wetland habitats, vernal pools, and exemplary natural communities in MIMA as mapped by the Massachusetts Natural Heritage and Endangered Species Program.

Table 13. Invasive species distribution in the 100 ft buffer around MA-NHESP natural communities and designated vernal pools. Areal estimates were calculated in GIS from the invasive species inventory of Agius (2003). [a] Indicates species was not observed by Thompson and Jenkins (1992) at this site. [b] Species not listed by Thompson and Jenkins (1992) but this species is limited to the wooded area around the meadow and was not observed within the meadow by Agius (2003). [c] Species not listed by Thompson and Jenkins (1992) but they only described the flora immediately surrounding and in the pond.

		Percent of buffer area occupied by invasive species			
Common Name	Scientific Name	Red maple-black gum swamp & certified vernal pool	Kettlehole wet meadow (west)	Kettlehole wet meadow (Fiske Hill)	Vernal Pools
Asian bittersweet	*Celastrus orbiculatus*	0.7 [a]	-	9.5 [c]	3.4
Black swallow-wort	*Cynanchum louiseae*	-	-	0.6 [c]	-
Common buckthorn	*Rhamnus cathartica*	0.1	-	8.7 [c]	0.4
Common reed	*Phragmites australis*	-	-	-	0.1
Garlic mustard	*Allaria petiolata*	<0.1 [a]	-	-	1.1
Glossy buckthorn	*Frangula alnus*	38.7	87 [b]	46 [c]	49.3
Honeysuckle species	*Lonceria* species	0.2	-	3 [c]	3.6
Japanese knotweed	*Polygonum cuspidatum*	0.3 [a]	-	-	0.2
Multiflora rose	*Rosa multiflora*	0.3	-	0.3 [c]	0.8
Norway maple	*Acer platanoides*	1.9 [a]	-	-	0.2
Purple loosestrife	*Lythrum salicaria*	0.4 [a]	8	0.1 [c]	0.8
Spotted knapweed	*Centaurea biebersteinii*	-	-	-	-
Tree of heaven	*Ailanthus altissima*	-	-	1.3 [c]	-
Percent of total area		43	95	69	60

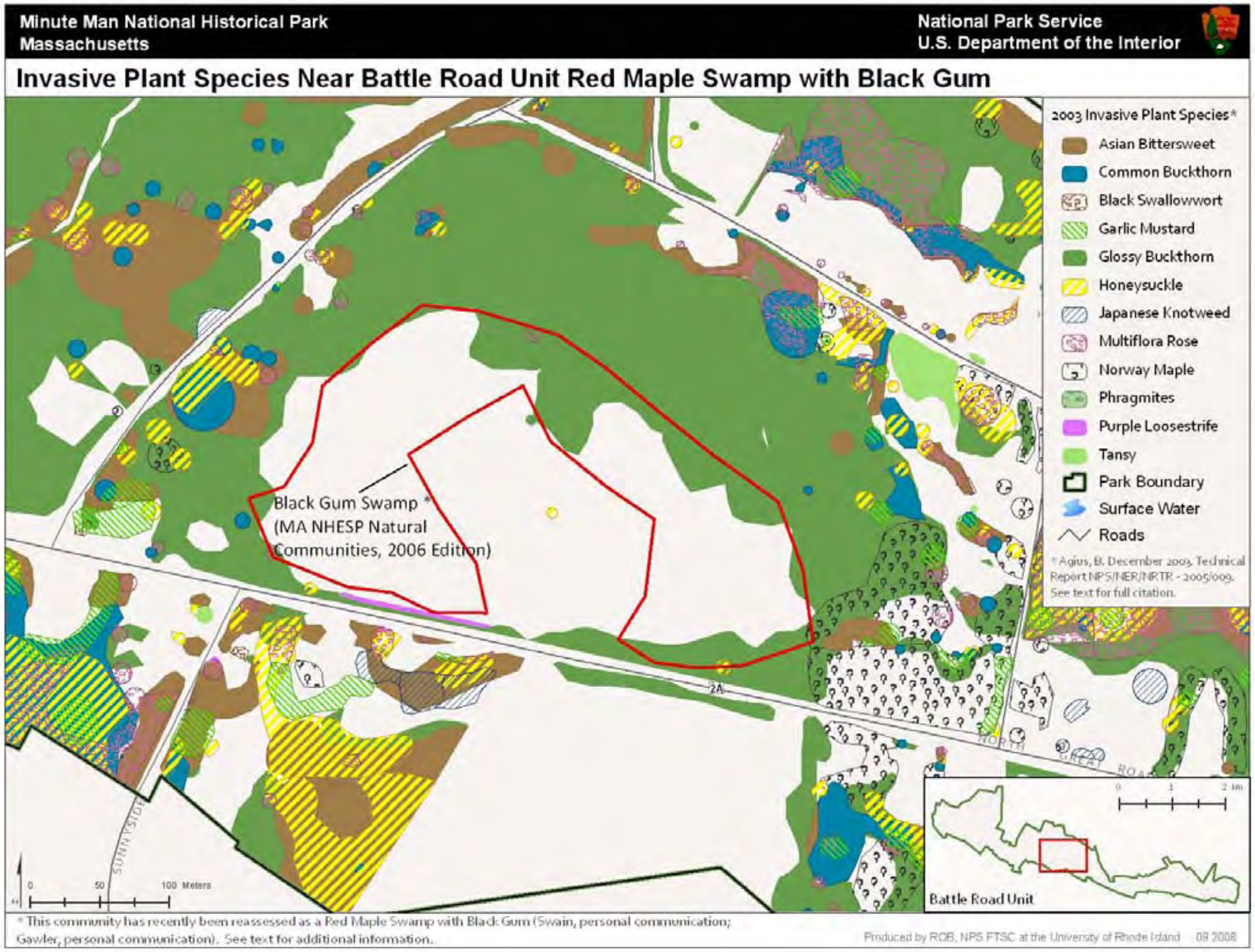

Figure 13. Invasive species (after Agius 2003) adjacent to the red maple-black gum swamp and certified vernal pool of the Battle Road Unit.

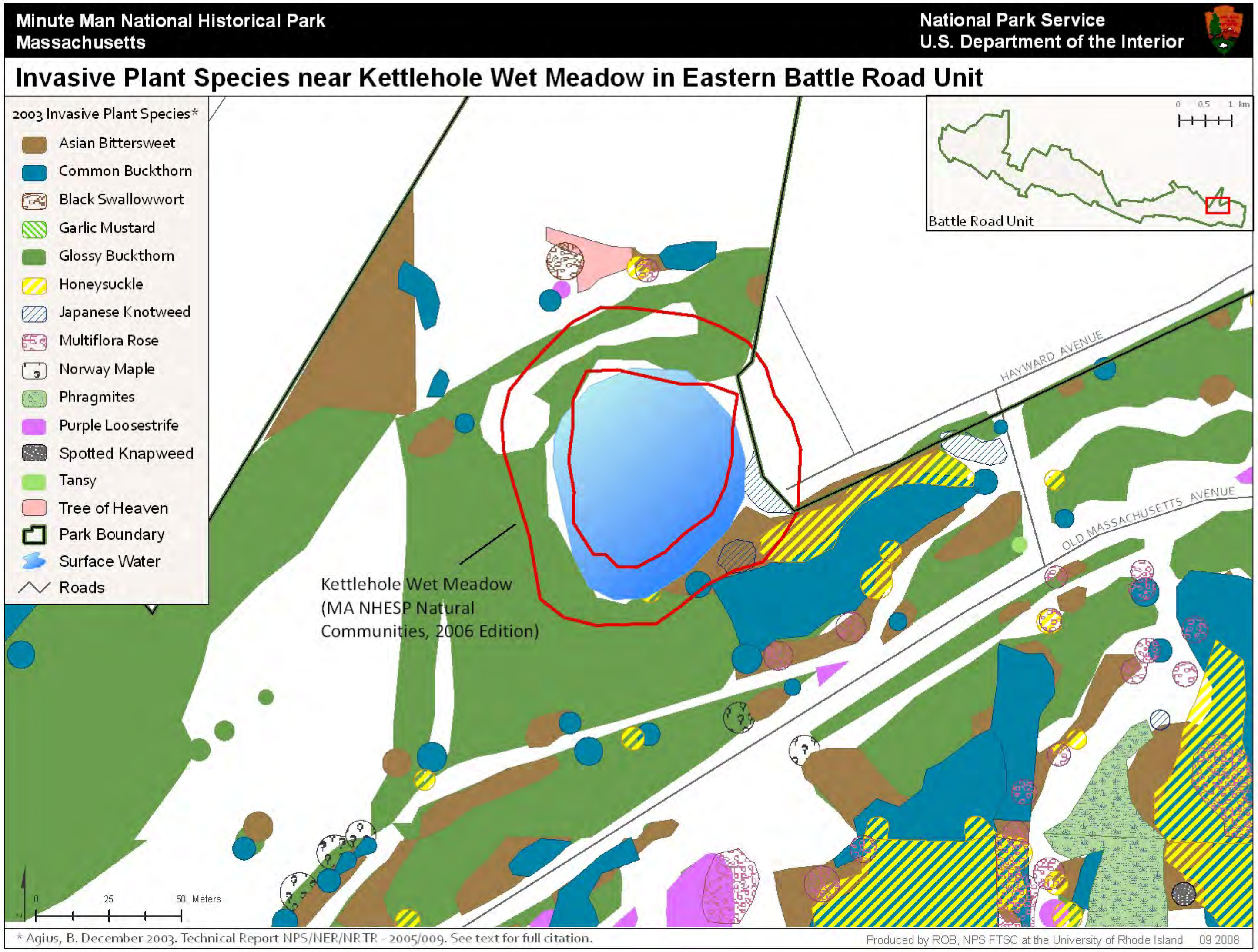

Figure 14. Invasive plant species (after Agius 2003) adjacent to the kettle hole wet meadow in the eastern portion of Battle Road Unit.

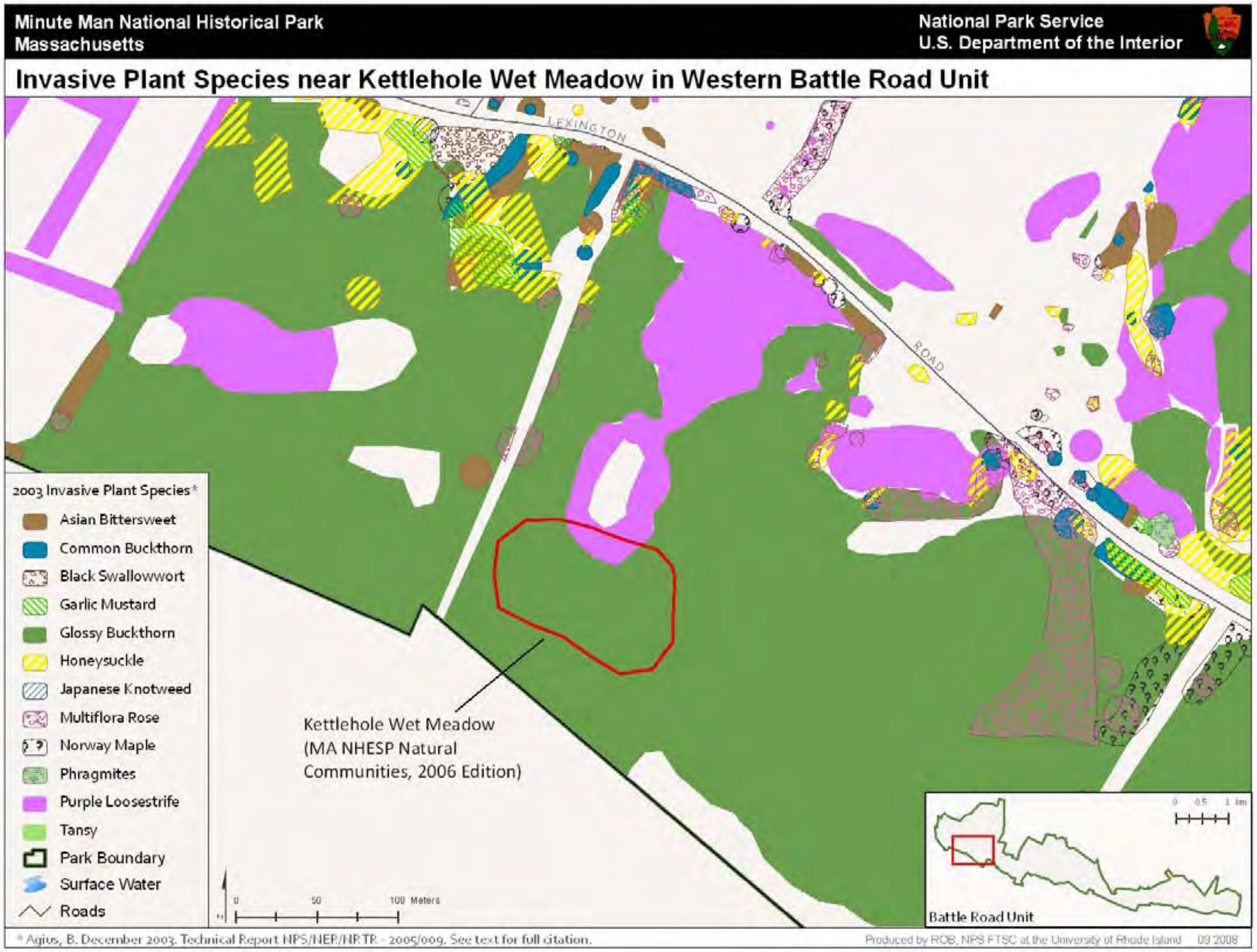

Figure 15. Invasive plant species (after Agius 2003) adjacent to the kettle hole wet meadow in the western portion of Battle Road Unit.

Vernal Pools

The MA-NHESP certifies the occurrence of vernal pools based on documented biological (e.g., presence of obligate or facultative vernal pools species) and physical (e.g., no permanently flowing outlet) criteria of the pools (MA-NHESP 2009). When a vernal pool has been certified, it automatically receives any protection afforded to vernal pools under the Massachusetts Wetlands Protection Act. Official certification provides vernal pools, in some cases up to 100 ft beyond its boundary, protection under state laws (MA-NHESP 2008a; MA-NHESP 2009). There is one certified vernal pool in MIMA, located near the Bloody Angle, in the Battle Road Unit within the red maple swamp-black gum swamp, and 10 additional potential vernal pools all located in the Battle Road Unit (Figure 12). The certified vernal pool is accessible to the public via established trails and raised walkways, which minimize the impacts of visitor use on this sensitive community.

An estimated list of species present in MIMA's vernal pools was compiled from previous surveys (Martinez 1992; Windmiller and Walton 1992; Brotherton et al. 2005). These data indicate that at least nine amphibian and reptile species and a variety of invertebrates, including the formerly state listed Mystic Valley amphipod (*Crangonyx aberrans*), utilize vernal pools in MIMA (Table 14). The most recent survey that included vernal pools was conducted by Brotherton et al. (2005) in 2001. In this study, sites listed as "Virginia Pond, Route 2A pond, and Pond O" correspond to the area where the certified vernal pool is located, with the Virginia Pond site closest to the certified vernal pool while Route 2A pond and Pond O are close to the potential vernal pools identified by MA-NHESP. Brotherton et al. (2005) reported the largest breeding population of wood frogs (*Rana sylvatica*), an obligate vernal pool species, at Virginia Pond and considered this species to have a stable population within the park. Other species utilizing Virginia Pond were American toad (*Bufo americanus*), eastern red-backed salamander (*Plethodon cinereus*), northern green frog (*Rana clamitans melanota*), spring peeper (*Pseudacris crucifer*), and spotted salamander (*Ambystoma maculatum*, an obligate vernal pool species) (Brotherton et al. 2005). Windmiller and Walton (1992) observed the American bullfrog (*Rana catesbeiana catesbeiana*) at Virginia Pond but it was absent in the most recent amphibian survey of this location (Brotherton et al. 2005). Windmiller and Walton (1992) also observed the Mystic Valley amphipod, backswimmers (*Notonecta irrorata*), mosquito larvae (*Culicidae* species), and caddisflies (*Limnephilus* species) in this vernal pool. Amphibians that were observed at other locations corresponding to potential vernal pools near the area of the Bloody Angle (Route 2A pond and Pond O) were the American bullfrog, eastern red-backed salamander, gray tree frog (*Hyla versicolor*), northern green frog, spring peeper, spotted salamander, and wood frog. An index of biotic integrity for these areas rated the Virginia Pond site as "good" and the Route 2A pond and Pond O sites as "fair" based on the amphibian communities (refer to *Faunal Communities* section and Table 21 for more detail).

Martinez (1992) also surveyed locations in MIMA for vernal pools in 1992. Based on field notes, aquatic species (including amphibians and aquatic invertebrates) were present at 16 sites, with amphibians detected at nine of these locations. Martinez (1992) only described other aquatic organisms in generic terms (e.g., freshwater clams, diving beetle) so a detailed list of species that were present in MIMA's vernal pools during this survey was not available. Unfortunately, the quality of the maps in the report was also poor and the locations of all sites that were surveyed could not be identified. Some of the sites do appear to coincide with the kettlehole wet meadow areas and a few of the potential vernal pools mapped by MA-NHESP.

As previously mentioned, there are several invasive species surrounding the certified vernal pool in the red maple-black gum swamp area near the Bloody Angle (Figure 13, Table 13). While individual assessments of invasive species were not calculated for each potential vernal pool, a general assessment was performed for 100 ft buffer zones around these pools. Several invasive plant species were present around the potential vernal pools occupying approximately 60% of the 100 ft buffer zones, with glossy buckthorn being the dominant invasive plant (Table 13). It has been suggested that invasive plants such as glossy buckthorn and rusty willow (*Salix cinerea* spp.) can dramatically alter the structure, and perhaps the function of vernal pools in eastern Massachusetts (Cutko and Rawinski 2007). Aggressive clonal species such as reed canary grass, common reed, and cattail (*Typha* species) can grow densely to the exclusion of other species, potentially altering habitat for both plants and animals and altering pool hydrology through increased evapo-transpiration (Vasconcelos and Calhoun 2006; Cutko and Rawinski 2007).

Water quality of the certified vernal pool has only been monitored in one year (1999) and was found to have some water quality parameters that exceeded minimum standards (Farris and Chapman not dated). This snapshot sampling revealed water quality parameters (pH, oxygen, and nitrogen) that exceeded the minimum state standards for Class B waters in two of the sampling periods (October 1998 and June 1999). The authors suggested further water quality monitoring of this area was warranted to determine if this was a result of the natural vernal pool ecosystem or if it represented a stressed environment (refer to *Water Resources* section for more detail). Only additional monitoring of the vernal pool will address these concerns.

Recent research has highlighted the potential of road-run off, particularly road salts, for negatively impacting vernal pool systems. Increased salinities in vernal pools that are within 200 m of roads have been linked to the use of de-icing road salt (Forman and Deblinger 2000; Karraker et al. 2008). Road salt may have detrimental impacts on populations of amphibians in vernal pools near roads, particularly spotted salamanders and wood frogs, where salt exposure can increase mortality and may lead to local extinction (Sanzo and Hecnar 2001; Karraker et al. 2008). At MIMA, six of the 10 potential vernal pools and the one certified vernal pool are within 200 m of Route 2A (Figure 12). The road salts used on Route 2A most likely affect these pools.

Table 14. Vernal pool communities at MIMA. Data compiled from Windmiller and Walton (1992), Martinez (1992), and Brotherton et al. (2005). [1] Indicates obligate vertebrate vernal pool species; [2] Indicates facultative vertebrate vernal pool species (Mass Nature 2008). * Species and specific location information was not available from Martinez (1992).

Common Name	Scientific Name	Virginia Pond (Certified Vernal Pool)	Other Vernal Pools
Vertebrates			
American bullfrog	*Rana c. catesbeiana*	X	X
American toad [2]	*Bufo americanus*	X	
Eastern red-backed salamander	*Plethodon cinereus*	X	X
Gray tree frog [2]	*Hyla versicolor*		X
Northern green frog [2]	*Rana clamitans melanota*	X	X
Snapping turtle [2]	*Chelydra serpentina*	X	
Spring peeper [2]	*Pseudacris crucifer*	X	X
Spotted salamander [1]	*Ambystoma maculatum*	X	X
Wood frog [1]	*Rana sylvatica*	X	X
Invertebrates			
Backswimmers	*Notonecta irrorata*	X	
Backswimmers	*Notonecta undulata*	X	X
Caddisflies	*Limnephilus* species	X	
Crawling water beetles	*Halipus* species		X
Freshwater clams*	Species unknown		X
Midges	*Chironomus* species		X
Mosquito larvae	*Culicidae* species	X	
Mystic Valley amphipod	*Crangonyx aberrans*	X	
Phantom midge	*Chaoborus* species		X
Predaceous diving beetles	*Dytiscus* species	X	X
Ramshorn and other snails*	Species unknown		X
Waterstriders	*Gerris* species	X	X

Condition Assessment for Wetland Resources

A general estimate of the condition of the Elm Brook wetland was based on three different sources of information: Rice's (1987) evaluation; Thompson and Jenkins (1992) rating; and water quality information. Rice's (1987) evaluation yielded to scores equivalent to 0.64 (CTDEP method) and 0.45 (Adamus method) in this report. The average of these was 0.54, or a rating of "caution". Five years after Rice's (1987) evaluation, Thompson and Jenkins (1992) ranked the Elm Brook wetland as "C" and a rating of "caution" (midpoint score of 0.50) was given based on this information. The Elm Brook wetland is likely impacted by the impaired water quality of the brook. The water quality of Elm Brook has been impaired by pathogens and turbidity since 1998, and more recently other habitat alterations from 2004 to 2008. In 2007, NETN monitoring detected elevated levels of nitrogen in Elm Brook (refer to *Water Quality* section for more detail). Based on the water quality information a rating of "caution" was given (midpoint score of 0.50). Therefore, the average of these three midpoint scores is 0.51 resulting in a condition assessment rating of "caution" for the Elm Brook wetland (Table 15).

Thompson and Jenkins (1992) ranked the red-maple black gum swamp area as "A" (equivalent to rating of "good" in this report). The MA-NHESP evaluation of this area mentioned that this area had invasive species present, therefore the condition rating for this wetland was determined to be "caution" (midpoint score of 0.50) for this report. The MA-NHESP has evaluated kettlehole wet meadow communities within the Battle Road Unit as excellent (community near Fiske Hill) and good (community in western portion of unit). Based on this information the kettlehole wet meadows were given a condition rating of "good" (midpoint score of 0.84) (Table 15).

There was little detailed information specifically focusing on vernal pools in MIMA. Several species have been documented in MIMA's vernal pools, including both obligate and facultative vernal pool species (Table 14). In general, there was a considerable lack of information regarding these fragile ecosystems, especially in light of the one water quality sampling event that potentially indicated an impaired or stressed system and the potential for negative impacts due to their proximity to Route 2A. An index of biotic integrity based on the amphibian communities (refer to *Faunal Communities* section for more detail) of vernal pools sites rated the majority of areas as "fair". Based on this information the condition of vernal pools was rated as "caution" (Table 15).

Trends in wetland vegetation communities were evaluated by comparing a few of the exemplary communities (as designated by MA-NHESP) with the GIS maps of the 14 primary invasive species mapped by Agius (2003), MassGIS, and matching up community species descriptions by Thompson and Jenkins (1992) to specific sites. For the three sites (black gum-red maple swamp and the two kettlehole wet meadows) compared there was an increasing number of invasive plant species present over time (from 1992 to 2003), indicating that the invasive plants were increasing in these wetland areas. Therefore, the trend for wetland resources was rated as a "declining trend" for condition based on best professional judgment (Table 15). There was little information available for trends in the condition of the vernal pools systems, and therefore, the trend for this resource was rated as "unknown".

The average condition score for wetland resources was 0.59, falling within the "caution" range for this report. The overall score for data reliability for information on MIMA's wetlands was "satisfactory" (average score of 0.50) (Table 15). Apart from Rice (1987) it appears that wetlands have only been surveyed in the context of other efforts. Monitoring of wetland ecosystems, including their water quality, should be a priority management objective.

Table 15. Conditional assessment ratings for wetland resources at MIMA. Average scores are given when more than one metric was assigned a condition rating.

Metric	Condition	Numerical Score	Comments
<u>Current Condition of Wetland Resources</u>			
Wetlands – Elm Brook	Caution	0.51	Average of ratings as evaluated by Rice (1987), Thompson & Jenkins (1992), and water quality information.
Wetlands – red maple-black gum swamp	Caution	0.50	Thompson & Jenkins 1992 gave this wetland a rank of “A”, but MA-NHESP noted invasive species around this area.
Wetlands – kettlehole wet meadows	Good	0.84	MA-NHESP rates these areas as excellent and good.
Vernal pools	Caution	0.50	Average condition of amphibian communities in vernal pools was rated as fair by the biotic integrity index (refer to *Faunal Communities* section, Table 21).
Average condition score	Caution (0.34 to 0.67)	0.59	
<u>Trend Data for Wetland Resources</u>			
Wetlands	Declining trend	0.16	Comparison of data indicate invasive plant species have increased around these fragile areas.
Vernal Pools	Unknown	-	Not enough information to evaluate trends.
<u>Data reliability for Wetland Resources</u>			
Martinez (1992)	Limited	0.16	Report is limited to field notes with only general species information. Survey locations not identified.
MA Natural Heritage and Endangered Species Program	Good	0.84	
Rice (1987)	Satisfactory	0.50	
Thompson & Jenkins (1992)	Satisfactory	0.50	
Average data reliability score	Satisfactory (034 to 0.67)	0.50	

Faunal Communities

Landbird Community

Since 1992 there have been at least four surveys that have recorded a total of 113 avian species at MIMA (Windmiller and Walton 1992; Alden 1998; Trocki and Paton 2003; B. Mitchell personal communication). In 2007, Massachusetts Audubon Society started data collection for the Breeding Bird Atlas 2 and will continue until 2011 (Massachusetts Audubon 2009). Volunteers collect data for the Breeding Bird Atlas by surveying all areas of the state for evidence of breeding birds. Long-term monitoring of avian species is also being accomplished through the NETN Forest Breeding Bird Protocol, which was first implemented at MIMA in 2006. The objective of the NETN monitoring is to determine changes in the relative abundance and composition of native and non-native forest passerine species in major habitat types during the breeding season and to establish correlations between changes in avian communities and site-specific information about park management activities (Mitchell et al. 2006).

Twenty-seven (24%) avian species that have been observed at MIMA during various surveys are listed as priority species in the Partners in Flight (PIF) Landbird Conservation Plan for Physiographic Area 9, southern New England (Dettmers and Rosenberg 2000) (Table 16). Seven of these species are listed by Partners in Flight as IA: High Continental Priority, High Regional Responsibility, indicating that conservation of these species in southern New England is critical to the overall health to species (Dettmers and Rosenberg 2000). An additional seven other species are listed by PIF as IIA: High Regional Concern, indicating that these species are experiencing declines in the core of their range and that they require short-term conservation action to reverse or stabilize trends. Partners in Flight lists several threats to these species including habitat deterioration and fragmentation, parasitism, competition with exotic and non-native species, poisoning from pesticides and other environmental contaminates, hybridization, and urbanization (Panjabi et al. 2005). While no state listed bird species have been recorded at MIMA, three state listed species were observed during Biodiversity Day in the towns of Lincoln and Concord (Alden 1998; NPS 2008d): the American bittern (*Botaurus lentiginosus*), grasshopper sparrow, and upland sandpiper. Both the American bittern and the upland sandpiper are state listed endangered species, while the grasshopper sparrow is a state listed threatened species (MA-NHESP 2008a).

MIMA breeding status (if known) and population trends for Massachusetts and southern New England are presented for the 27 PIF listed species that have been observed in MIMA (Table 16). The park breeding status was only known for five of these species (Trocki and Paton 2003). Comparison of the population trends between Massachusetts (and by extension MIMA) and the southern New England region gives a general indication of the population trends for these species as they relate to the park. Twelve of these species had population trends in Massachusetts that were better than the southern New England trend while another 12 had trends that were worse in Massachusetts when compared to southern New England. Eight of the 27 PIF species showed significant negative population trends for Massachusetts (Table 16) (Sauer et al. 2007). Only two species showed slightly positive population trends for Massachusetts, but neither trend was significant. Three of the eight species exhibiting negative population trends

Table 16. Significant population trend estimates for avian species observed at MIMA and in the vicinity of MIMA that are considered priority species by Partners in Flight (PIF). Population trend estimates are from Breeding Birds Surveys, 1966-2006, for the Massachusetts and the southern New England region (Sauer et al. 2007). "+" or "-" indicates the Massachusetts rate was either more positive or more negative compared to the southern New England rate. * Indicates significant trend. PIF Status: IA= High Continental Priority, High Regional Responsibility; IB= High Continental Priority, Low Regional Responsibility; IIA= High Regional Concern; III= Additional US National Watch List; V= Additional State list. n/a indicates population trend information was not available. B: breeds in park; L: local breeder, park breeding status unknown; U: breeding status unknown (after Trocki and Paton 2003). [a]: Species was only observed during Biodiversity Day in the towns of Lincoln and Concord (Alden 1998; NPS 2008d) and may not be present in MIMA.

Common Name	MIMA Breeding Status	PIF Status	MA Trend	S. NE Trend	MA vs. S. NE Trend
American bittern [a]	U	V	0.22	-3.77	+
American black duck [a]	U	IIC	-2.16	-4.69	+
American woodcock	U	IA	-4.96	-3.92	-
Baltimore oriole	B	IA	-2.22*	-2.93*	+
Barred owl [a]	U	V	4.00	1.84	+
Black-and-white warbler	L	IIA	-2.52*	-.166	-
Black-billed cuckoo [a]	U	IA	-0.08	-7.79*	+
Black-crowned night-heron [a]	U	V	-3.25	1.58	-
Blue-winged warbler	U	IA	-1.74	-2.72*	+
Bobolink	U	III	-0.69	-2.32	-
Chimney swift	L	IIA	-2.04*	-1.45*	-
Cooper's hawk	U	V	-6.13	-3.71	-
Eastern towhee	B	IIA	-8.59*	-7.15*	-
Eastern wood-pewee	U	IIA	-0.34	-1.11	+
Grasshopper sparrow [a]	U	V	n/a	n/a	n/a
Great blue heron	U	V	-2.28	1.77	-
Great Egret [a]	U	V	-10.85	-2.32	-
Hairy woodpecker [a]	U	IIA	0.02	-2.08*	+
Northern goshawk [a]	U	V	n/a	n/a	n/a
Prairie warbler	U	IA	-1.24	-3.43*	+
Purple finch	U	IIA	-3.01*	-5.52*	+
Red-shouldered hawk [a]	U	V	-9.87*	7.70	-
Rose-breasted grosbeak	U	IIA	-1.11	-2.53*	+
Savannah sparrow [a]	U	V	-7.83*	-6.63*	-
Scarlet tanager	B	IA	-1.26*	-1.00	-
Upland sandpiper [a]	U	IB	n/a	n/a	n/a
Wood thrush	U	IA	-3.45*	-2.30*	-

for Massachusetts (Baltimore oriole [*Icterus galbula*], scarlet tanager [*Piranga olivacea*], and wood thrush [*Hylocichla mustelina*]) are listed as PIF status IA and another three are listed as PIF status IIA (black-and-white warbler [*Mniotilta varia*], chimney swift [*Chaetura pelagic*], and purple finch [*Carpodacus purpureus*]). Only two of these species (Baltimore oriole and purple finch) had population trends for Massachusetts that were better, although still negative, when compared to population trends for southern New England (Table 16). Species of particular conservation interest for MIMA may include the chimney swift and bobolink (*Dolichonyx oryzivorus*). It is likely that chimney swifts breed in the park, possibly utilizing park buildings and historic structures as nesting habitat (Trocki and Paton 2003). Bobolinks have been observed during three surveys (Windmiller and Walton 1992; Alden 1998; Trocki and Paton 2003) and the fields in MIMA could provide suitable breeding habitat but it is unknown if this species breeds in the park (Trocki and Paton 2003).

The NETN Breeding Bird Protocol has established a guild-based scorecard to assess the biotic integrity of the forest and grassland avian communities for the Northeast Temperate Network (NETN 2007a). The NETN protocol identifies 13 guilds within three biotic elements for forest community birds and four guilds associated with grassland community birds (Table 17). One of the metrics used by the NETN protocol is the percent of species in each guild or the proportional species richness, and this metric was used to assess the condition of the MIMA avian community. Only Trocki and Paton (2003) specifically surveyed in grasslands at MIMA and therefore grassland species may be underrepresented in other surveys; however, these data are presented with this caveat because they provide a general estimate of species richness in these guilds. Once calculated the percent species richness can be rated for each guild as "good", "caution", or "significant concern" based on threshold values established by the protocol (NETN 2007a) (Table 18). Since species can belong to more than one forest guild, the percentages for the forest guilds may add to more than 100%. A condition rating for each guild was estimated using the midpoint score of the three categories ("good", "caution", and "significant concern"; refer to Table 1) and an average for each biotic element was calculated for each of the avian surveys in and in the vicinity of MIMA (Table 18).

In general, very few guilds had a rating of "good" for any of the surveys (Table 18). The one guild that rated "good" for all surveys was the low proportion of nest predators and brood parasites. The majority of the average scores for the forest biotic elements rated as "caution" and the average scores for the grassland guild were all in the "significant concern" range for all surveys (although grassland species may be underrepresented in some surveys). Guilds that consistently rated as "significant concern" across all surveys were the proportion of single brooders, high canopy foragers, canopy nesters, grassland exotics, and grassland obligates. Species richness was lower than optimum for high canopy foragers, canopy nesters, and grassland obligates, while it was higher than desired for single brooders and grassland exotics. The average score for majority of the surveys rated as "caution" (only the 1992 survey rated as "significant concern"). The most recent surveys at the park (2003, 2006, and 2007) all had very similar average scores (ranging from 0.40 to 0.42) possibly indicating that the bird community of MIMA is relatively stable but in the "caution" range of condition (Table 18).

Table 17. Bird species observed at MIMA and in the vicinity of MIMA during various surveys. 1992: Windmiller and Walton (1992); 2003: Trocki and Paton (2003); 2006 & 2007: NETN Breeding Bird Survey data (B. Mitchell personal communication); 1998: Biodiversity Day in the towns of Lincoln and Concord (Alden 1998; NPS 2008d). [a] Massachusetts state listed species (refer to Table 29); [b] Partners in Flight Priority Species (refer to Table 16). Guild designations are from NETN Forest Breeding Bird Protocol (NETN 2007a): Forest Guilds: BP: bark prober forager, C: canopy nester; E: exotic; FG: forest-ground nester; GG: ground gleaner forager; HC: high canopy forager; IF: interior forest obligate nester; LC: low canopy forager; NP: nest predator; O: omnivore; R: resident; S: shrub nester; SB: single brooded; Grassland Guilds: E: exotic; EG: edge generalist; GO: grassland obligate; SD: shrub dependent; n/a: guild designation not available. * Grassland species may be underrepresented in some surveys.

				Surveys in MIMA				Surveys in Vicinity of MIMA
Common Name	Scientific Name	Forest Guild	Grassland* Guild	1992	2003	2006	2007	1998
Alder flycatcher	*Empidonax alnorum*	S, SB	n/a		X			
American bittern [a, b]	*Botaurus lentiginosus*	n/a	n/a					X
American black duck [b]	*Anas rubripes*	n/a	n/a					X
American coot	*Fulica americana*	n/a	n/a					X
American crow	*Corvus brachyrhynchos*	C, NP, O, R, SB	EG	X	X	X	X	X
American goldfinch	*Carduelis tristis*	O, R, S, SB	EG	X	X	X	X	X
American kestrel	*Falco sparverius*	n/a	n/a	X	X			X
American redstart	*Setophaga ruticilla*	C, IF, LC, SB	n/a	X	X		X	X
American robin	*Turdus migratorius*	O, S	EG	X	X	X	X	X
American woodcock [b]	*Scolopax minor*	n/a	n/a	X				X
Baltimore oriole [b]	*Icterus galbula*	C, O, SB	EG	X	X	X	X	X
Bank swallow	*Riparia riparia*	SB	EG					X
Barn swallow	*Hirundo rustica*	SB	EG	X	X			X
Barred owl [b]	*Strix varia*	n/a	n/a					X
Belted kingfisher	*Ceryle alcyon*	n/a	n/a					X
Black-and-white warbler [b]	*Mniotilta varia*	BP, FG, IF, SB	n/a	X	X			X
Black-billed cuckoo [b]	*Black-billed Cuckoo*	LC, S	n/a					X
Black-capped chickadee	*Poecile atricapilla*	LC, R, SB	n/a	X	X	X	X	X

Table 17. Bird species observed at MIMA and in the vicinity of MIMA during various surveys (continued).

				Surveys in MIMA				Surveys in Vicinity of MIMA
Common Name	Scientific Name	Forest Guild	Grassland* Guild	1992	2003	2006	2007	1998
Black-crowned night-heron [b]	*Nycticorax nycticorax*	n/a	n/a					X
Black-throated green warbler	*Dendroica virens*	C, HC, IF, SB	n/a					X
Blue jay	*Cyanocitta cristata*	C, NP, O, R	n/a	X	X	X	X	X
Blue-gray gnatcatcher	*Polioptila caerulea*	C, HC, SB	n/a		X			X
Blue-headed (solitary) vireo	*Vireo solitarius*	C, IF, LC, SB	n/a					X
Blue-winged warbler [b]	*Vermivora pinus*	LC, SB	SD	X	X	X		X
Bobolink [b]	*Dolichonyx oryzivorus*	O, SB	GO	X	X			X
Broad-winged hawk	*Buteo platypterus*	n/a	n/a	X	X			X
Brown creeper	*Certhia americana*	BP, IF, R, SB	n/a					X
Brown thrasher	*Toxostoma rufum*	O, S,	SD	X				X
Brown-headed cowbird	*Molothrus ater*	NP, O	EG	X	X	X	X	X
Canada goose	*Branta canadensis*	n/a	n/a	X	X		X	X
Carolina wren	*Thryothorus ludovicianus*	LC, R	n/a	X	X	X	X	X
Cedar waxwing	*Bombycilla cedrorum*	C, R, SB	EG	X	X	X	X	X
Chestnut-sided warbler	*Dendroica pensylvanica*	LC, S, SB	SD					X
Chimney swift [b]	*Chaetura pelagica*	SB	n/a	X	X		X	X
Chipping sparrow	*Spizella passerina*	O, S	EG	X	X	X	X	X
Common grackle	*Quiscalus quiscula*	O	n/a	X	X	X	X	X
Common yellowthroat	*Geothlypis trichas*	LC, S	SD	X	X	X	X	X
Cooper's hawk [b]	*Ardea herodias*	n/a	n/a					X
Double-crested cormorant	*Phalacrocorax auritus*	n/a	n/a					X
Downy woodpecker	*Picoides pubescens*	BP, R	n/a	X	X	X	X	X
Eastern bluebird	*Sialia sialis*	O	EG		X			X
Eastern kingbird	*Tyrannus tyrannus*	C, SB	EG	X	X	X		X

Table 17. Bird species observed at MIMA and in the vicinity of MIMA during various surveys (continued).

Common Name	Scientific Name	Forest Guild	Grassland* Guild	Surveys in MIMA				Surveys in Vicinity of MIMA
				1992	2003	2006	2007	1998
Eastern meadowlark	*Sturnella magna*	O	GO					X
Eastern phoebe	*Sayornis phoebe*	n/a	n/a	X	X	X		X
Eastern towhee [b]	*Pipilo erythrophthalmus*	FG, O	SD	X	X			X
Eastern wood-pewee	*Contopus virens*	C, SB	n/a	X	X	X	X	X
European starling	*Sturnus vulgaris*	E, NP, O, R	E	X	X			X
Field sparrow	*Spizella pusilla*	O	SD	X				X
Grasshopper sparrow [a, b]	*Ammodramus savannarum*	O	GO					X
Gray catbird	*Dumetella carolinensis*	O, S	n/a	X	X	X	X	X
Great blue heron [b]	*Ardea herodias*	n/a	n/a	X	X			X
Great crested flycatcher	*Myiarchus crinitus*	SB	n/a	X	X	X		X
Great egret [b]	*Ardea alba*	n/a	n/a					X
Great horned owl	*Bubo virginianus*	n/a	n/a					X
Green heron	*Butorides virescens*	n/a	n/a		X			X
Hairy woodpecker [b]	*Picoides villosus*	BP, IF, R	n/a			X	X	X
Hermit thrush	*Catharus guttatus*	FG, GG, IF	n/a			X		X
Herring gull	*Larus argentatus*	n/a	n/a					X
House finch	*Carpodacus mexicanus*	E, R	EG, E	X	X	X	X	X
House sparrow	*Passer domesticus*	E, R	EG, E	X	X	X	X	X
House wren	*Troglodytes aedon*	LC	EG	X	X	X	X	X
Indigo bunting	*Passerina cyanea*	O, S	SD	X	X	X	X	X
Killdeer	*Charadrius vociferus*	n/a	n/a	X	X	X		X
Least flycatcher	*Empidonax minimus*	C, SB	EG					X
Least sandpiper	*Calidris minutilla*	n/a	n/a					X
Magnolia warbler	*Dendroica magnolia*	IF, LC, S, SB	n/a		X			

Table 17. Bird species observed at MIMA and in the vicinity of MIMA during various surveys (continued).

Common Name	Scientific Name	Forest Guild	Grassland* Guild	Surveys in MIMA				Surveys in Vicinity of MIMA
				1992	2003	2006	2007	1998
Mallard	*Anas platyrhynchos*	n/a	n/a		X			X
Marsh wren	*Cistothorus palustris*	n/a	n/a					X
Mourning dove	*Zenaida macroura*	C, R	EG	X	X	X	X	X
Northern cardinal	*Cardinalis cardinalis*	O, R, S	n/a	X	X	X	X	X
Northern flicker	*Colaptes auratus*	GG	n/a	X	X	X	X	X
Northern goshawk [b]	*Accipiter gentilis*	n/a	n/a					X
Northern mockingbird	*Mimus polyglottos*	O, R, S	EG	X	X		X	X
Northern rough-winged swallow	*Stelgidopteryx ruficollis*	SB	EG	X				X
Ovenbird	*Seiurus aurocapillus*	FG, GG, IF, SB	n/a		X	X	X	X
Pileated woodpecker	*Dryocopus pileatus*	BP, IF, R	n/a					X
Pine warbler	*Dendroica pinus*	BP, C, IF, SB	n/a	X	X	X	X	X
Prairie warbler [b]	*Dendroica discolor*	LC, S, SB	SD	X				X
Purple finch [b]	*Carpodacus purpureus*	C, R	n/a	X				X
Red-bellied woodpecker	*Melanerpes carolinus*	BP, R	n/a		X		X	X
Red-breasted nuthatch	*Sitta canadensis*	BP, FG, IF, SB	n/a					X
Red-eyed vireo	*Vireo olivaceus*	HC, S, SB	n/a	X	X		X	X
Red-shouldered hawk [b]	*Buteo lineatus*	n/a	n/a					X
Red-tailed hawk	*Buteo jamaicensis*	n/a	n/a	X	X			X
Red-winged blackbird	*Agelaius phoeniceus*	O, S	n/a	X	X	X	X	X
Ring-billed gull	*Larus delawarensis*	n/a	n/a					X
Ring-necked pheasant	*Phasianus colchicus*	n/a	n/a	X				X
Rock dove	*Columba livia*	E, O, R	EG, E	X	X			X
Rose-breasted grosbeak [b]	*Pheucticus ludovicianus*	C, O, SB	n/a	X	X	X	X	X
Ruby-throated hummingbird	*Archilochus colubris*	C, O	n/a					X

Table 17. Bird species observed at MIMA and in the vicinity of MIMA during various surveys (continued).

Common Name	Scientific Name	Forest Guild	Grassland* Guild	Surveys in MIMA 1992	Surveys in MIMA 2003	Surveys in MIMA 2006	Surveys in MIMA 2007	Surveys in Vicinity of MIMA 1998
Ruffed grouse	*Bonasa umbellus*	n/a	n/a					X
Savannah sparrow [b]	*Passerculus sandwichensis*	O	GO					X
Scarlet tanager [b]	*Piranga olivacea*	C, HC, IF, SB	n/a	X	X	X	X	X
Solitary sandpiper	*Tringa solitaria*	n/a	n/a					X
Song sparrow	*Melospiza melodia*	O	EG	X	X	X	X	X
Spotted sandpiper	*Actitis macularia*	n/a	n/a					X
Swamp sparrow	*Melospiza georgiana*	O	n/a		X			X
Tree swallow	*Tachycineta bicolor*	SB	EG	X	X			X
Tufted titmouse	*Baeolophus bicolor*	LC, R, SB	n/a	X	X	X	X	X
Turkey vulture	*Cathartes aura*	n/a	n/a					X
Upland sandpiper [a, b]	*Bartramia longicauda*	n/a	n/a					X
Veery	*Catharus fuscescens*	FG, IF, SB	n/a			X	X	X
Virginia rail	*Rallus limicola*	n/a	n/a					X
Warbling vireo	*Vireo gilvus*	C, HC, SB	EG	X	X	X		X
White-breasted nuthatch	*Sitta carolinensis*	BP, IF, R, SB	n/a	X	X	X	X	X
Wild turkey	*Meleagris gallopavo*	n/a	n/a			X		X
Willow flycatcher	*Empidonax traillii*	S, SB	n/a		X			X
Winter wren	*Troglodytes troglodytes*	GG, IF, SB	n/a					X
Wood duck	*Aix sponsa*	n/a	n/a					X
Wood thrush [b]	*Hylocichla mustelina*	O, S,	n/a		X	X	X	X
Yellow warbler	*Dendroica petechia*	LC, S, SB	SD	X	X	X	X	X
Yellow-billed cuckoo	*Coccyzus americanus*	LC, S	n/a					X
Total species observed				59	63	42	39	110

Table 18. Percent species richness for avian guilds and NETN rating (in parentheses) observed during surveys in and in the vicinity of MIMA. 1992: Windmiller and Walton (1992); 2003: Trocki and Paton (2003); 2006 & 2007: NETN Breeding Bird Survey data; 1998: Biodiversity Day in the towns of Lincoln and Concord (Alden 1998; NPS 2008d). Guild designations after NETN Breeding Bird Protocol (refer to Table 17). NETN ratings (G: good; C: caution; and SC: significant concern) were based on values defined by NETN Breeding Bird Protocol (NETN 2007a). Average score for biotic elements were calculated using the midpoint value for each rating categories (refer to Table 1). *Grassland guilds may be underrepresented in some surveys.

		Percent Bird Species Richness (NETN rating)				
		Surveys in MIMA				Survey in Vicinity of MIMA
Biotic Element	Response Guild Metric	1992	2003	2006	2007	1998
Forest compositional	Exotic	7 (C)	6 (C)	5 (C)	5 (C)	4 (C)
Forest compositional	Nest predator/brood parasite	7 (G)	6 (G)	7 (G)	8 (G)	4 (G)
Forest compositional	Resident	29 (C)	27 (G)	33 (C)	41 (C)	19 (G)
Forest compositional	Single-brooded	42 (SC)	44 (SC)	43 (SC)	41 (SC)	34 (SC)
Forest functional	Bark prober	7 (C)	8 (C)	10 (C)	13 (G)	8 (C)
Forest functional	Ground gleaner	2 (SC)	3 (SC)	7 (C)	5 (C)	4 (C)
Forest functional	High canopy forager	5 (SC)	6 (SC)	5 (SC)	5 (SC)	5 (SC)
Forest functional	Low canopy forager	15 (C)	14 (C)	17 (C)	15 (C)	12 (SC)
Forest functional	Omnivore	36 (C)	35 (C)	36 (C)	41 (C)	25 (G)
Forest structural	Canopy nester	22 (SC)	21 (SC)	26 (SC)	26 (SC)	16 (SC)
Forest structural	Forest-ground Nester	3 (SC)	5 (C)	7 (C)	5 (C)	5 (C)
Forest structural	Interior forest obligate	8 (SC)	11 (C)	17 (C)	18 (C)	14 (C)
Forest structural	Shrub nester	22 (C)	24 (C)	24 (C)	28 (SC)	16 (G)
Grassland*	Edge generalist	66 (SC)	73 (SC)	39 (C)	87 (SC)	61 (SC)
Grassland*	Exotic	14 (SC)	15 (SC)	6 (SC)	13 (SC)	11 (SC)
Grassland*	Grassland obligate	3 (SC)	4 (SC)	0 (SC)	0 (SC)	11 (G)
Grassland*	Shrub dependant	28 (SC)	19 (C)	11 (C)	13 (C)	25 (C)
Forest compositional average score		0.50 (C)	0.59 (C)	0.50 (C)	0.50 (C)	0.59 (C)
Forest functional average score		0.36 (C)	0.36 (C)	0.43 (C)	0.50 (C)	0.43 (C)
Forest structural average score		0.25 (SC)	0.42 (C)	0.42 (C)	0.33 (SC)	0.50 (C)
Grassland average score		0.16 (SC)	0.25 (SC)	0.33 (SC)	025 (SC)	0.42 (C)
Overage average score		0.32 (SC)	0.41 (C)	0.42 (C)	0.40 (C)	0.49 (C)

Amphibian and Reptile Communities

The most recent inventory of amphibian and reptiles was conducted at MIMA from March through September 2001 (Brotherton et al. 2005). There have been several previous surveys of amphibians and reptiles at MIMA (Martinez 1992; Thomas 1992; Windmiller and Walton 1992) and one survey in the vicinity of MIMA (Alden 1998; NPS 2008d). These surveys indicate that 23 species of amphibians and reptiles have been documented in or around the park (Table 19). The most recent survey documented 17 (74%) of these species (Tables 19 and 20). Only one species, the Blanding's turtle, is listed as a state threatened species, although the spotted turtle (*Clemmys guttata*) was a state listed species up until 2006 when it was de-listed (MA-NHESP 2004a, 2004b; Brotherton et al. 2005; MA-NHESP 2008a). All of the amphibian species observed fall under the "least concern" status of the Global Amphibian Assessment (IUCN, Conservation International and NatureServe 2006).

In the most recent survey (Brotherton et al. 2005) anurans composed 94% of the individuals recorded with salamanders (4%), snakes (1%), and turtles (1%) composing the remainder of the taxa. For individual taxa, spring peepers, eastern red-backed salamanders, snapping turtles (*Chelydra serpentina*), and eastern garter snakes (*Thamnophis sirtalis sirtalis*) represented the most abundant species for each group. Folly Pond had the greatest species richness with nine species present; while Cook's Pond had the greatest total number of individuals (1067) recorded (Tables 19 and 20).

Sixteen of the 23 species (70%) that occurred historically at or in the area around MIMA appeared to be stable in terms of their population status, six species (26%) have declined or have disappeared since 1992, and the status of one species (ring-necked snake, *Diadophis punctatus*) was undetermined (Brotherton et al. 2005) (Table 19). The six species identified to be in decline were pickerel frog (*Rana palustris*), red-spotted newt (*Notophthalmus viridescens viridescens*), Blanding's turtle, spotted turtle, eastern ribbonsnake (*Thamnophis sauritus*), and northern black racer (*Coluber constrictor constrictor*) (Brotherton et al. 2005) (Table 18). The pickerel frog and red-spotted newt are relatively sensitive species to disturbance (Micacchion 2004) and the spotted turtle and Blanding's turtle are either presently (Blanding's turtle) or previously (spotted turtle) listed by the MA-NHESP. The decline of these species may be an indication of less than favorable conditions. Windmiller and Walton (1992) noted that the abundance of pond-breeding amphibian species appeared to be skewed in favor of species that were broadly tolerant of habitat fragmentation and human intrusion (e.g., green frog, bullfrog, and spring peeper). They also noted that the two obligate vernal pools species, the spotted salamander and the wood frog, were not abundant. Brotherton et al. (2005) similarly classified the spotted salamander as uncommon, but considered the wood frog as common (Table 19).

The Ohio State Environmental Protection Agency has developed an Amphibian Index of Biotic Integrity (AmphIBI) to assess wetland quality (Micacchion 2002, 2004). The AmphIBI uses five metrics related to the composition of amphibian communities that correlate well with wetland disturbance. The metrics used are: 1. The Amphibian Quality Assessment Index (AQAI); 2. relative abundance of sensitive taxa; 3. relative abundance of tolerant taxa; 4. number of species of pond-breeding amphibians; and 5. presence of spotted salamanders and/or wood frogs (Micacchion 2004). The AQAI is a weighted index that takes into account the number of individuals of each species and each species' sensitivity to disturbance. The AQAI results in a

Table 19. Amphibian and reptile species recorded at MIMA and in the vicinity of MIMA during various surveys. Relative abundance, total individuals recorded (in parentheses), and status as identified by Brotherton et al. 2005 (survey was conducted in 2001). Status: C=common, R=rare, U=uncommon, ↓ in decline, n/a indicates abundance estimate was not available. * Cited as personal communication in Brotherton et al. (2005). [1] Indicates species that are native-transplant species (USGS-NAS 2008).

				Surveys in MIMA				Survey in Vicinity of MIMA
Common name	Scientific Name	Percent Relative Abundance (Total Individuals)	MIMA Status	Martinez (1992)	Thomas (1992)	Windmiller & Walton (1992)	Brotherton et al. (2005)	Alden (1998)
FROGS								
American bullfrog [1]	*Rana c. catesbeiana*	1.8 (80)	C	X		X	X	X
American toad [1]	*Bufo americanus*	0.4 (17)	U			X	X	X
Gray treefrog	*Hyla versicolor*	13.5 (615)	C			X	X	X
Northern green frog	*Rana clamitans melanota*	12.8 (583)	C	X		X	X	X
Northern leopard frog [1]	*Rana pipiens*	0.6 (27)	U				X	X
Pickerel frog	*Rana palustris*	0.1 (5)	U ↓			X	X	X
Spring peeper	*Pseudacris crucifer*	59.8 (2727)	C	X		X	X	X
Wood frog	*Rana sylvatica*	5.7 (258)	C	X		X	X	X
SALAMANDERS								
Eastern red-backed salamander	*Plethodon cinereus*	1.7 (77)	C	X	X	X	X	X
Northern two-lined salamander	*Eurycea bislineata*	0.6 (25)	R		X	X	X	
Red-spotted newt	*Notophthalmus v. viridescens*	<0.1 (2)	R ↓		X	X	X	X
Spotted salamander	*Ambystoma maculatum*	1.3 (61)	U	X	X	X	X	X
TURTLES								
Blanding's turtle	*Emydoidea blandingii*	n/a	R ↓				X*	X
Common musk (stinkpot) turtle	*Sternotherus odoratus*	n/a	R			X		X
Common snapping turtle	*Chelydra serpentina*	0.5 (22)	C			X	X	X
Painted turtle	*Chrysemys picta*	0.4 (16)	C			X	X	X
Spotted turtle	*Clemmys guttata*	<0.1 (1)	R ↓				X	X

Table 19. Amphibian and reptile species recorded at MIMA and in the vicinity of MIMA during various surveys (continued).

				Surveys in MIMA				Survey in Vicinity of MIMA
Common name	Scientific Name	Percent Relative Abundance (total individuals)	MIMA Status	Martinez (1992)	Thomas (1992)	Windmiller & Walton (1992)	Brotherton et al. (2005)	Alden (1998)
SNAKES								
Eastern gartersnake	*Thamnophis s. sirtalis*	0.9 (42)	C			X	X	X
Eastern milksnake	*Lampropeltis t. triangulum*	<0.1 (2)	R			X	X	X
Eastern ribbonsnake	*Thamnophis sauritus*	n/a	R ↓				X	
Northern black racer	*Coluber c. constrictor*	n/a	R ↓				X	
Northern watersnake	*Nerodia sipedon*	n/a	R				X*	X
Ring-necked snake	*Diadophis punctatus*	n/a	n/a					X

score that provides information on the overall condition of the amphibian community. The AQAI assigns a coefficient of conservatism (C of C) to wetland breeding amphibian species based on their varying sensitivities to disturbance and other habitat requirements. The C of C ranges from 0 to 10, with lower C of C's assigned to species that are adapted to a greater degree of disturbance and a broader range of habitat requirements. Species assigned higher C of C's are sensitive to disturbance and have narrower habitat requirements (Micacchion 2004). The total number of individuals for each species is multiplied by the corresponding C of C to yield a subtotal for the species. Subtotals for all species are summed together and then divided by the total number of amphibians present to arrive at the AQAI. The AQAI, along with the other four metrics, is given a score of 0, 3, 7, or 10 based upon values established by Micacchion (2004). The sum of the five scores is the condition score. The maximum AmphIBI score is 50 (all five metrics having a score of 10). An AmphIBI score ranging from 30-50 represents an excellent amphibian community; a score ranging from 20-30 represents a community in good condition; a score from 10-20 is a community in fair condition; and score less than 10 is representative of a community in poor condition (Micacchion 2004). The AmphIBI is somewhat heavily weighted towards wetlands with moderate to long hydro-period vernal pools and semi-permanent ponds (e.g., the weighting of wood frogs and spotted salamanders), and therefore pristine permanent ponds, where these species do not breed, may not rate as high as they should using this method.

While the AmphIBI was developed for Ohio wetlands assessment, this index was used as a general guide to assess the condition of MIMA's wetland breeding amphibian community (Table 21). Only three sites (Cook's Pond, Virginia Pond, and Whittemore Pond) had an AmphIBI score of "good" condition, while the majority of the amphibian communities rated as "fair" condition. Three sites (Nelson Pond, Pond 4-121, and the vernal pool at the Visitor Center) all scored as "poor" condition. Overall, the average score for the amphibian communities sampled by Brotherton et al. (2005) was "fair" (Table 21). Metrics that ranked particularly poorly were the relative high abundance of tolerant species (eight of 12 sites had a community of 90% or greater of tolerant species) and the low number of pond-breeding species. None of the sites received an AQAI score of 10 (the highest score) and only one of the site, Whittemore Pond, received a score of 7. Nine of the 12 sites received an AQAI score of 0 indicating a depauperate community of sensitive amphibians at these sites.

The North American Amphibian Monitoring Program, coordinated by the USGS Patuxent Wildlife Research Center, initiated in 1997, conducts amphibian calling surveys throughout Massachusetts. The closest calling routes to MIMA are the Chelmsford Route (Route # 471003) and the Arlington Route (Route # 470603) (North American Amphibian Monitoring Program 2008). Unfortunately, trends cannot be discerned, as the data were limited to only two years (2003 and 2007) and one year (2007) for the Arlington and Chelmsford routes, respectively (North American Amphibian Monitoring Program 2008). The US Fish and Wildlife Service at Great Meadows National Wildlife refuge also conducts yearly anuran call surveys.

Highway mortality is potentially a large source of amphibian mortality at MIMA. Amphibians and reptiles migrate to breeding and nesting areas and frequently cross roads to reach suitable habitats (Petranka 1998). Synchronized breeding migrations by some species of salamanders (e.g., spotted salamanders), which are trigged by several environmental factors, but generally occur on the first rainy night over 45 ^{o}F after the ground has thawed, may result in mass highway mortality as they attempt to cross busy thoroughfares. The largest wetland area in MIMA, the Elm Brook wetland, is bisected by Route 2A. Given the particularly high traffic volume on Route 2A, road kill may have a major impact on the amphibian and reptile populations in the park, particularly during the breeding season (Windmiller and Walton 1992; Fahrig et al. 1995; Gibbs and Shriver 2002; Glista et al. 2007; Massachusetts Audubon 2008). Species that are most vulnerable to road mortality are those that tend to remain immobile at approach of oncoming traffic, such as amphibians (Mazerolle et al. 2005). Wildlife corridors (special tunnels under roadways), closing of specific roads on the first warm rainy night of spring, and the preservation of critical salamander habitat are actions that are promoted by Massachusetts Audubon to conserve the populations of amphibians within the state (Massachusetts Audubon 2008).

Some of the declines in amphibian and reptile abundance observed during the most recent survey are likely due to the occurrence of roads in close proximity to wetland areas, which have fragmented the landscape and left few avenues for immigration, thus limiting the likelihood of colonization or re-colonization (Brotherton et al. 2005). Habitat fragmentation and barriers to dispersal, such as Route 2A and Lexington Road, may be responsible for the restricted distribution of many amphibian and reptile species within MIMA, especially salamanders and turtles (Windmiller and Walton 1992; Brotherton et al. 2005).

Several other factors that could be negatively impacting amphibians and reptiles at MIMA include global and regional stressors such as atmospherically transported pollutants, acid precipitation, and ultraviolet-B radiation; and more localized stressors such as pesticides, fertilizers, road-run off, degraded water quality, disease, introduced species and feral cats, and habitat degradation (Sanzo and Hecnar 2001; Brotherton et al. 2005; Karraker et al. 2008). For the species in decline (as indicated in Table 19), truly “historic” data are lacking and it is impossible to know how common or rare they were at MIMA, except in recent decades. The decline of these species appears to be part of a larger regional decline affecting many of the urbanized areas of the Northeast (Brotherton et al. 2005).

Table 20. Number of adult amphibians and reptiles recorded by Brotherton et al. (2005) (some localities were combined). The AmphIBI coefficient of conservatism (Micacchion 2004) is given in parentheses after names of wetland breeding amphibian species. "-" indicates species was not observed.

Localities	Total species present	Amer. bullfrog (2)	Amer. toad (1)	E. red-backed salamander	Gray treefrog (5)	N. green frog (3)	N. leopard frog (2)	N. two-lined salamander	Pickerel frog (7)	Red-spotted newt (9)	Spotted salamander (8)	Spring peeper (2)	Wood frog (7)	Painted turtle	Snapping turtle	Spotted turtle	E. gartersnake	E. milksnake
Concord River	2	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-
Cooks Pond	7	5	-	-	270	183	-	-	-	-	25	452	130	-	2	-	-	-
Cranberry bog	6	-	-	-	60	49	-	-	-	-	1	506	-	-	3	1	-	-
Elm Brook sites	1	-	-	-	-	-	-	25	-	-	-	-	-	-	-	-	-	-
Fields (all sites)	7	-	1	-	2	-	17	-	-	-	-	-	2	1	-	-	28	2
Folly Pond	9	3	-	-	220	93	-	-	1	2	-	374	2	-	4	-	1	-
Irrigation Pond A	6	7	-	-	-	7	-	-	-	-	-	5	1	1	-	-	1	-
Mill Brook sites	8	1	1	-	-	3	8	-	2	-	-	-	1	1	1	-	-	-
Mill Brook Wayside	2	-	-	-	-	40	-	-	-	-	-	313	-	-	-	-	-	-
Nelson House	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-
Nelson Pond	8	38	3	-	2	77	-	-	1	-	-	78	-	3	1	-	-	-
Palumbo ditches and pond	7	1	1	-	-	35	1	-	-	-	-	8	-	9	8	-	-	-
Pond 4-121	3	-	1	-	-	3	-	-	-	-	-	325	-	-	-	-	-	-
Pond O (vernal pool)	4	11	-	-	-	25	-	-	-	-	1	211	-	-	-	-	-	-
Route 2A Pond (vernal pool)	7	12	-	1	58	39	-	-	-	-	15	251	4	-	-	-	-	-
Virginia Pond (vernal pool)	6	-	4	1	-	2	-	-	-	-	8	191	106	-	-	-	-	-

Table 20. Number of adult amphibian and reptiles recorded by Brotherton et al. (2005) (continued).

Localities	Total species present	Amer. bullfrog (2)	Amer. toad (1)	E. red-backed salamander	Gray treefrog (5)	N. green frog (3)	N. leopard frog (2)	N. two-lined salamander	Pickerel frog (7)	Red-spotted newt (9)	Spotted salamander (8)	Spring peeper (2)	Wood frog (7)	Painted turtle	Snapping turtle	Spotted turtle	E. gartersnake	E. milksnake
Visitor Center vernal pool	1	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-
Visitor Center pond	6	2	-	-	-	9	-	-	1	-	-	10	1	-	2	-	-	-
Whittemore Pond	4	-	1	-	2	17	-	-	-	-	11	-	-	-	-	-	-	-
Woodland areas (all sites)	7	-	5	75	1	1	1	-	-	-	-	-	11	-	-	-	7	-

Table 21. Values and scores (in parentheses) for metrics associated with the AmphIBI (Micacchion 2004) for amphibian communities sampled by Brotherton et al. (2005). Condition scores were estimated by summing the scores of the five metrics and are based on a maximum score of 50, with a score of 30-50 representing a community in excellent condition; a score of 20-30 representing communities in good condition; a score of 10-20 representing communities in fair condition; and a score <10 indicates communities in poor condition (after Micacchion 2004).

Site	AQAI [1]	Relative Abundance of Sensitive Species [2]	Relative Abundance of Tolerant Species [3]	Number of Pond Breeding Species [4]	Presence of Spotted Salamanders or Wood Frogs [5]	Condition Score
Cooks Pond	3.7 (3)	15 (7)	60 (3)	1 (0)	present (10)	good (23)
Cranberry bog	2.4 (0)	0 (3)	90 (0)	1 (0)	present (10)	fair (13)
Folly Pond	3.1 (3)	1 (3)	68 (3)	1 (0)	present (10)	fair (19)
Irrigation Pond A	2.6 (0)	5 (3)	95 (0)	0 (0)	present (10)	fair (13)
Nelson Pond	2.4 (0)	0 (0)	98 (0)	0 (0)	absent (0)	poor (0)
Palumbo complex	2.8 (0)	2 (3)	98 (0)	0 (0)	present (10)	fair (13)
Pond 4-121	2.0 (0)	0 (0)	100 (0)	0 (0)	absent (0)	poor (0)
Pond O (vernal pool)	2.1 (0)	0 (3)	100 (0)	1 (0)	present (10)	fair (13)
Route 2A Pond (vernal pool)	2.9 (0)	5 (3)	80 (3)	1 (0)	present (10)	fair (16)
Virginia Pond (vernal pool)	3.9 (3)	37 (7)	63 (3)	1 (0)	present (10)	good (23)
Visitor Center vernal pool	2.0 (0)	0 (0)	100 (0)	0 (0)	absent (0)	poor (0)
Visitor Center pond	2.8 (0)	4 (3)	91 (0)	1 (0)	absent (0)	fair (13)
Whittemore Pond	4.8 (7)	35 (7)	58 (3)	1 (0)	present (10)	good (27)
Overall score						fair (13)

1. AQAI scores: 0: <3.00; 3: 3.00-4.49; 7: 4.50-5.49; 10: ≥5.5
2. Relative abundance of sensitive species scores: 0: 0%; 3: 0.01-9.99%; 7: 10-49.99%; 10: ≥50%
3. Relative abundance of tolerant species scores: 0: >80%; 3: 50.01-79.99%; 7: 25.01-50%; 10: ≤25%
4. Number of pond-breeding salamander species: 0: 0-1; 3: 2; 7: 3: 10: >3
5. Presence of spotted salamander and/or wood frogs score: 0: absent; 10: present

Mammal Community

The only historical survey of mammals in MIMA was conducted by Jones in 1992 (Jones 1993). Observations of mammals in the vicinity of MIMA were also available from a Biodiversity Day event held in the towns of Lincoln and Concord in 1998 (Alden 1998; NPS 2008d). MIMA was also included in a study on hanta virus in small rodent populations in National Parks (no animals had the virus) (Mills et al. 1998). A recent NETN inventory of mammals was conducted in 2004 (Gilbert et al. 2008). This survey sampled MIMA during the winter/spring and during summer/fall using remote cameras, track plates, hair samples, and trapping. Pitfall traps were not used during this inventory so the abundance and/or presence of small insectivorous mammals (e.g., shrews) may have been underestimated. Of the nine parks sampled during this effort MIMA had the most species detected (24 species, not including a possible white-footed/deer mouse hybrid) (Gilbert et al. 2008). This survey did not include bats, except for limited reconnaissance and documentation using historical voucher specimens and related records. The combined total number of mammals recorded from all surveys and historical voucher specimens at MIMA (including bats) is 43, 24 of which (56%) have been recorded in the most recent survey (Table 22).

Gilbert et al. (2008) detected 24 species at MIMA and estimated that they detected 50% of the potential mammals present, not including bats, (48 potential species) at the park. The most frequently detected and widely distributed medium sized mammals at MIMA were raccoons (*Procyon lotor*), fisher (*Martes pennanti*), red fox (*Vulpes vulpes*), and striped skunks (*Mephitis mephitis*). Frequently detected small mammals were white-footed mouse (*Peromyscus leucopus*), possible white-footed/deer mouse (*P. maniculatus*) hybrid, short-tailed shrew (*Blarina brevicauda*), and meadow vole (*Microtus pennsylvanicus*). Species richness varied among the different habitat types surveyed, but no one area of the park appeared more diverse (Gilbert et al. 2008). Species that were expected but not detected were moles, mink (*Neovison vison)*, beaver (*Castor canadensis*), and river otter (*Lontra canadensis*).

White-tailed deer (*Odocoileus virginianus*) are commonly sighted at MIMA, most frequently in the area of the Ranger Station west to Lexington Road and along Lexington Road to the Old Bedford Road area. One concern among park managers is deer-vehicle collisions. As many as four to six collisions occur each year, primarily in the above mentioned areas (B. Brooks via S. Colwell personal communication). White-tailed deer herbivory does not appear to be excessive in most park habitats, but, initial data on tree regeneration, which was rated as "significant concern" (Table 6) may be suggestive of browse pressure. Only one of the forest monitoring plots had a discernable browse line (K. Miller via S. Colwell personal communication). A pilot study in 2006 (conducted by a student from the University of Massachusetts at Amherst) to estimate deer abundance yielded insufficient deer sightings to estimate deer density in the park, and suggests that the deer population may not as extreme as perceived (S. Colwell personal communication).

Beaver were absent from Massachusetts from the late 1700s to the early 1900s, due to deforestation and unregulated hunting and trapping (Jackson and Decker 2001). They were re-established in Berkshire County in the 1930s, and since then have reclaimed much of their former range in Massachusetts (Jackson and Decker 2001). Farmers near the park have stated that beavers have been around for decades, building dams and occasionally flooding property (B. Brooks via S. Colwell personal communication). Beavers have been documented in the park since 1993, and although the most recent survey did not directly observe beavers there have been recent reports of beaver activity near the North Bridge, where several trees were damaged (Gilbert et al. 2008). In the past few years, increased beaver activity has contributed to additional flooding of agricultural fields in and around MIMA, particularly in the vicinity of Meriam's Corner and Palumbo Fields. The park mapped the locations of beaver dams and lodges in 2006. Internal park memos state that no beaver dams were present in 1984; a beaver lodge may have been present in the general area of Meriam's Corner and Palumbo Fields in 1995; and by 2001, dams and lodges were in their present configuration (Figure 16). Property owners near the park have also reported flooding on their fields from beavers building dams in the park. For example, a 2006 internal park memo stated that a property owner on Old Bedford Road called to report flooding of both his property and the park field behind Meriam House due to beaver activity in the park. In 2006, the park installed a pipe into one of the dams near Meriam's Corner to regulate water levels. Shortly thereafter, beavers built another dam below the breached one. Since then no further attempts have been made to install water flow devices and drain the flooded fields (B. Brooks via S. Colwell personal communication). The issue remains a challenging one for park management. Beaver activity continues to alter agricultural fields in the park, an important cultural landscape, and flooding of properties near the park creates potential conflict with adjacent landowners.

Table 22. Mammal species observed during surveys at MIMA and in the vicinity of MIMA. [a] Indicates record from museum specimen collected at MIMA; [b] indicates record from museum specimen from the towns of Lincoln, Concord, or Lexington. * Moose are a rare vagrant to MIMA that have been historically noted by photographs, newspaper articles, and witness reports (NPS 2008d).

		Surveys in MIMA		Survey in Vicinity of MIMA
Common Name	Scientific Name	Jones (1993)	Gilbert (2008)	Alden (1998)
Beaver	*Castor canadensis*	X		X
Big brown bat	*Eptesicus fuscus*	X		X
Black bear	*Ursus americanus*			X
Common shrew	*Sorex cinereus*	X		
Coyote	*Canis latrans*	X	X	
Domestic cat (feral)	*Felis catus*	X	X	
Domestic dog (feral)	*Canis familiaris*	X		
Eastern chipmunk	*Tamias striatus*	X	X	X
Eastern cottontail	*Sylvilagus floridanus*	X	X	X
Eastern gray squirrel	*Sciurus carolinensis*	X	X	X
Eastern pipistrelle	*Pipistrellus subflavus*		X[b]	
Eastern red bat	*Lasiurus borealis*	X	X[b]	
Ermine	*Mustela erminea*		X	X
Fisher	*Martes pennanti*		X	
Gray fox	*Urocyon cinereoargenteus*	X	X	
Hairy-tailed mole	*Parascalops breweri*		X[b]	X
Hoary bat	*Lasiurus cinereus*	X	X[b]	
Little brown bat	*Myotis lucifugus*	X		X
Long-tailed weasel	*Mustela frenata*	X	X	
Masked shrew	*Sorex cinereus*		X	
Meadow jumping mouse	*Zapus hudsonius*	X	X	
Meadow vole	*Microtus pennsylvanicus*	X	X	X
Mink	*Neovison vison*	X	X[b]	X
Moose*	*Alces alces*			
Muskrat	*Ondatra zibethicus*	X		X
Northern long-eared bat	*Nyctophilus arnhemensis*	X		
Northern short-tailed shrew	*Blarina brevicauda*	X	X	X
Norway rat	*Rattus norvegicus*	X		
Pine vole	*Microtus pinetorum*		X	
Porcupine	*Erethizon dorsatum*			X
Raccoon	*Procyon lotor*	X	X	X
Red fox	*Vulpes vulpes*	X	X	X
Red squirrel	*Tamiasciurus hudsonicus*	X	X	X
River otter	*Lontra canadensis*	X		X
Snowshoe hare	*Lepus americanus*		X[b]	
Southern flying squirrel	*Glaucomys volans*		X	
Southern Red-backed Vole	*Clethrionomys gapperi*	X	X	X
Star-nosed mole	*Condylura cristata*	X	X [a,b]	
Striped skunk	*Mephitis mephitis*	X	X	X

Table 22. Mammal species observed during surveys at MIMA and in the vicinity of MIMA (continued).

		Surveys in MIMA		Survey in vicinity of MIMA
Common Name	Scientific Name	Jones (1993)	Gilbert (2008)	Alden (1998)
Virginia opossum	*Didelphis virginiana*	X	X	X
White-footed mouse	*Peromyscus leucopus*	X	X	X
White-footed/deer mouse hybrid	*Peromyscus leucopus/ maniculatus*		X	
White-tailed deer	*Odocoileus virginianus*	X	X	X
Woodchuck	*Marmota monax*	X	X	X

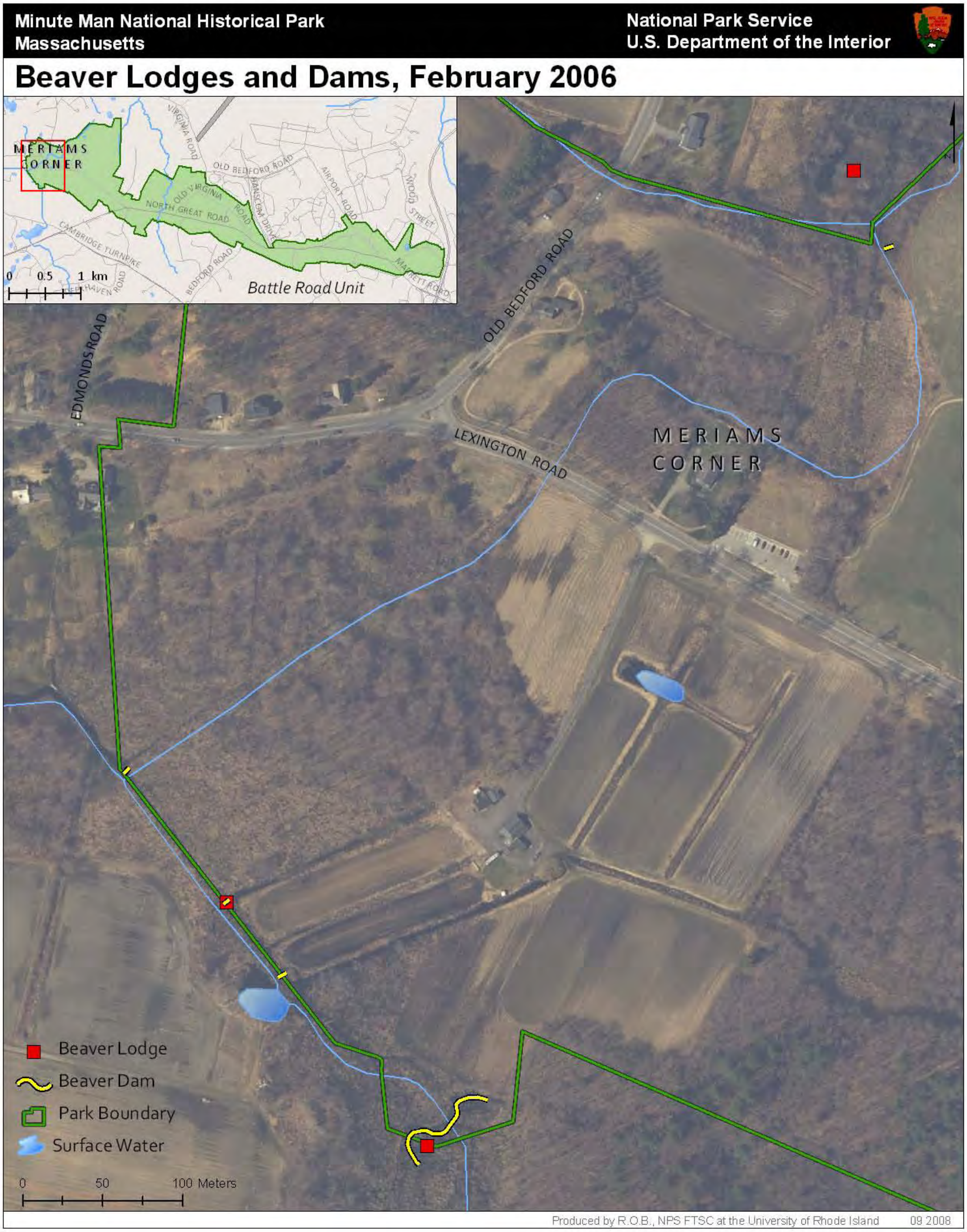

Figure 16. Existing beaver dams and lodges in and adjacent to MIMA. Maps from Natural Resource Management files, Minute Man National Historical Park, Concord, MA.

Fish Community

There have been two surveys of the freshwater fish community in MIMA, with the most recent survey occurring in 2001 (Windmiller and Walton 1992; Mather et al. 2003). Observations of fish in the vicinity of MIMA were available from a Biodiversity Day event held in the towns of Lincoln and Concord in 1998 (Alden 1998; NPS 2008d). Mill Brook was sampled by electroshocking in 2001 by Massachusetts Division of Fish and Wildlife (Commonwealth of Massachusetts 2005) downstream of Haywood Road in Concord. These surveys indicate that the freshwater fish community of MIMA is composed of at least 22 fish species, 9 (41%) of which were non-native. One of the non-native species was an exotic and the other eight were native transplants to Massachusetts (native transplants are species that are native to North America but have been introduced to areas outside of their original range) (USGS-Nonindigenous Aquatic Species Database [USGS-NAS] 2008) (Table 23). None of the fish species recorded were considered threatened, endangered, or a species of concern by Massachusetts (MA-NHESP 2008a). The only survey where estimates of relative abundances were reported was by Mather et al. (2003). Based on this report, the three non-native species that were observed during the survey (bluegill, green sunfish, and largemouth bass) composed approximately half (52%) of the fish community sampled at MIMA in 2001 (Mather et al. 2003) (Table 24). The non-native species were only found in Mill Brook and the un-named pond adjacent to the Visitor Center in the Battle Road Unit where they composed 17% and 92%, respectively, of the fish communities in these waters.

The Commonwealth of Massachusetts is currently developing an Index of Biotic Integrity for fish communities for the states' waterbodies (Massachusetts Division of Fish and Wildlife 2007a). In absence of a Massachusetts based Index of Biotic Integrity (IBI), an index developed by New Jersey Department of Environmental Protection was used as a general indication of the condition of MIMA's fish community (Vile 2008). The New Jersey IBI is consistent with Karr et al. (1986) in its use of several biological metrics to assess fish community richness, trophic composition, abundance, and condition. The New Jersey method scores 10 metrics based upon the degree of deviation from appropriate reference conditions and is scored as: 5 (none to slight deviation); 3 (moderate deviation); and 1 (significant deviation). The scores are summed and assigned to a condition category based on the score. The maximum score for these 10 metrics is 50, with a score of 45 to 50 representing excellent biotic integrity. A score of 37 to 44 indicates a good community; a score of 29 to 36 a fair community; and a score of 10 to 28 is indicative of poor biological integrity (Vile 2008). Nine of the 10 metrics used by Vile (2008) could be estimated for the fish community of MIMA using the data available from Mather et al. (2003) (Table 25). The ranges for the condition ratings were modified for nine metrics, but still adhered to Vile's (2008) rating system, yielding a maximum score of 45 (40 to 45: excellent, 33 to 39: good, 26 to 32: fair, and 9 to 26: poor). The condition of all four waterbodies sampled by Mather et al. (2003) in 2001 rated as "poor" using the IBI metrics of Vile (2008) (Table 25). In general, the fish community of MIMA ranked low due to depleted species richness, absence of benthic insectivores, low diversity of trout and sunfish species (not including green sunfish or bluegill), low number of intolerant species, and low number of individuals sampled. Elm Brook, which ranked high for low number of tolerant and generalist species and the presence of trout, had the highest score (23 points) of all waterbodies but was still rated as "poor" (Table 25).

The brook trout, the only trout native to the eastern US, composed 28% of the relative catch and was only collected from Elm Brook (Mather et al. 2003). Windmiller and Walton (1992) also reported that a native population of brook trout was present at Elm Brook. In Massachusetts, less than 11% of the subwatersheds support intact or reduced native (non-stocked) brook trout populations with the watersheds surrounding the greater Boston area having lost the greatest amount of brook trout habitat in the state (Eastern Brook Trout Joint Venture 2006). Twenty of the sub-watersheds (7% of all Massachusetts watersheds) are listed as extirpated for native brook trout, including the Shawsheen River watershed, the sub-watershed where Elm Brook is located (Eastern Brook Trout Joint Venture 2006). Stream fragmentation, either by dams or roads, is the most common form of disturbance to brook trout populations. These form barriers to trout movement and can effectively isolate populations and prevent re-establishment from larger downstream populations (Eastern Brook Trout Joint Venture 2006). Route 2A bisects Elm Brook, with the higher gradient upstream portion of the stream north of the road and the lower gradient downstream portion of the stream south of the road (Mather et al. 2003). Field notes indicated that in the upstream portion of Elm Brook a stone block forms a wall across the stream that could prevent the movement of fish further upstream (M. Mather personal communication). Brook trout were more numerous and were smaller in the upstream, high gradient portion of the stream than they were in the downstream, low gradient portion of the stream (Mather et al. 2003; M. Mather personal communication). The Commonwealth of Massachusetts stocks brook trout in the Shawsheen River in Bedford, MA, approximately 7.4 km downstream, but does not stock any of waters in or immediately adjacent to MIMA (Massachusetts Division of Fisheries and Wildlife 2008a). Stocked brook trout are typically 250 mm to 300 mm in length while wild adult brook trout range in length from 150 mm to 200 mm (Massachusetts Division of Fisheries and Wildlife 2008b). The average size of brook trout sampled by Mather et al. (2003) was 91 mm, with 85% of the individuals less than 150 mm in length (range 39 mm to 234 mm, 20 individuals sampled) (M. Mather personal communication) (Figure 17). Based on this size distribution, the population of brook trout in Elm Brook is likely a native population, or at the very least a self-reproducing population that could have been initially established by stocked individuals. The Massachusetts Division of Fisheries and Wildlife has issued conservation strategies for brook trout (Massachusetts Division of Fisheries and Wildlife 2007b) and among the priorities are the development of partnerships with other agencies and stakeholders to conduct brook trout restoration projects.

Table 23. Fish species observed during surveys at MIMA and in the vicinity of MIMA. Trophic guilds (after Vile 2008) are BI: benthic insectivore; G: generalist; I: insectivore; IS: intolerant species; P: piscivore; O: omnivore; TS: tolerant species. Nativity status from USGS-NAS (2008). * MA Division of Fish and Wildlife (MA DFW) only sampled Mill Brook in the Town of Concord, MA.

			Surveys in MIMA		Surveys in Vicinity of MIMA		
Common Name	Scientific Name	Trophic Guild	Windmiller & Walton (1992)	Mather et al. (2003)	MA DFW * (2001)	Alden (1998)	MA Nativity Status
American eel	*Anguilla rostrata*	P, TS	X	X	X		native
Banded killifish	*Fundulus diaphanus*	G, TS				X	native
Banded sunfish	*Enneacanthus obesus*	I				X	native
Black crappie	*Pomoxis nigromaculatus*	I, P				X	transplant
Bluegill	*Lepomis macrochirus*	G, TS	X	X		X	transplant
Brook trout	*Salvelinus fontinalis*	I, P, IS	X	X			native
Brown bullhead	*Ameiurus nebulosus*	G	X	X		X	native
Chain pickerel	*Esox niger*	P	X			X	transplant
Common carp	*Cyprinus carpio*	G				X	exotic
Common shiner	*Luxilus cornutus*	I	X				native
Creek chubsucker	*Erimyzon oblongus*	BI				X	native
Golden shiner	*Notemigonus crycoleucas*	O	X	X		X	native
Green sunfish	*Lepomis cyanellus*	G, TS		X			transplant
Largemouth bass	*Micropterus salmoides*	P	X	X		X	transplant
Pumpkinseed	*Lepomis gibbosus*	G	X	X		X	native
Redfin pickerel	*Esox americanus*	P	X	X	X	X	native
Smallmouth bass	*Micropterus dolomieu*	P				X	transplant
Swamp darter	*Etheostoma fusiforme*	BI, IS				X	native
White perch	*Morone americana*	I, P				X	transplant
White sucker	*Catostomus commersoni*	G, TS			X		native
Yellow bullhead	*Ameiurus natalis*	G	X				transplant
Yellow perch	*Perca flavescens*	P	X	X		X	native
Total species observed			12	10	3	16	

Table 24. Fish species and percent of total species abundance based on relative abundance for the most recent inventory in 2001 (Mather et al. 2003). Abbreviations: EB=Elm Brook; MB= Mill Brook; PFP= Palumbo's Farm Pond; UP= Un-named Pond.

Common Name	Scientific Name	Location	Percent of Total
American eel	*Anguilla rostrata*	EB	4%
Bluegill sunfish	*Lepomis macrochirus*	UP	33%
Brook trout	*Salvelinus fontinalis*	EB	28%
Brown bullhead	*Ameiurus nebulosus*	PFP	4%
Golden shiner	*Notemigonus crysoleucas*	MB	4%
Green sunfish	*Lepomis cyanellus*	MB	4%
Largemouth bass	*Micropterus salmoides*	UP	11%
Pumpkinseed sunfish	*Lepomis gibbosus*	PFP, MB, UP	6%
Redfin pickeral	*Esox americanus americanus*	PFP, MB, EB	5%
Yellow perch	*Perca flavescens*	MB	4%

Table 25. Index of Biotic Integrity metrics (after Vile 2008) for fish communities sampled in 2001. Metric values and condition score (in parentheses) were estimated for four waterbodies sampled by Mather et al. (2003). Condition scores were based on degree of deviation from a reference condition (5: none to slight; 3: moderate; and 1: significant) (Vile 2008). Condition was based on the sum of the scores modified for nine metrics: 40-45: Excellent condition; 33-39: Good condition; 26 to 32: Fair condition; 9 to 25: Poor condition.

Index of Biotic Integrity Metric	Value (condition score 1, 3, or 5)			
	Elm Brook	Mill Brook	Palumbo's Farm Pond	Un-named Pond
Total number of fish species [1]	3 (1)	5 (1)	3 (1)	3 (1)
Number of benthic insectivores [1]	0 (1)	0 (1)	0 (1)	0 (1)
Trout and/or sunfishes (not including green sunfish or bluegill) [1]	1 (1)	1 (1)	1 (1)	2 (1)
Number of intolerant species [1]	1 (3)	0 (1)	0 (1)	0 (1)
Percent of tolerant individuals [2]	6% (5)	13% (5)	0 (5)	77% (1)
Percent of individuals as generalists [3]	0 (5)	38% (3)	80% (1)	81% (1)
Percent of individuals as insectivorous cyprinids [4]	0 (1)	13% (1)	0 (1)	0 (1)
Percent of individuals as trout OR Percent of individuals as piscivores [5] (whichever gives better score)	83% (5)	50% (5)	20% (5)	19% (5)
Number of individuals in sample [6]	36 (1)	8 (1)	5 (1)	96 (3)
Sum of scores	23	19	17	15
Condition (maximum possible score of 45)	Poor	Poor	Poor	Poor

1. Refer to Vile (2008) for scoring criteria.
2. Percent of tolerant individuals score: 1: >45%; 3: 20-45%; 5: <20%
3. Percent of individuals as generalists score: 1: >45%; 3: 20-45%; 5: <20%
4. Percent of individuals as insectivorous cyprinids score: 1: <20% 3: 20-45%; 5: >45%
5. Percent of individuals as trout or piscivores (excluding American eel) score: 1: <1%; 3: 1-5%; 5: >5%
6. Number of individuals in the sample score: 1: <75; 3: 75-250; 5: >250

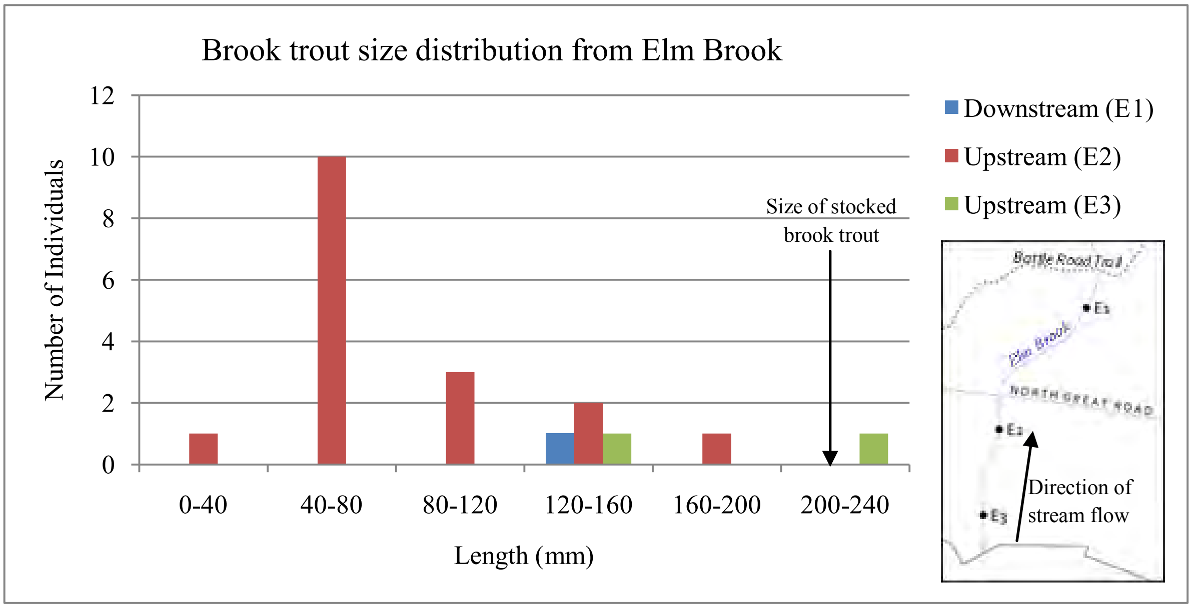

Figure 17. Size distribution of brook trout from Elm Brook upstream and downstream of Route 2A (Mather et al. 2003; M. Mather personal communication).

Invertebrate Community

Only Windmiller and Walton (1992) recorded detailed observations of invertebrates in MIMA. Observations of invertebrates in the vicinity of MIMA were also available from a Biodiversity Day event held in the towns of Lincoln and Concord in 1998 (Alden 1998; NPS 2008d). In total there have been approximately 830 species or higher taxonomic categories of invertebrates observed in MIMA or in the vicinity of MIMA, with the majority of the species being insects (Table 26). Windmiller and Walton (1992) observed 42 species of butterflies, represented by 430 individuals from nine habitats, during their 1992 survey effort. At that time this represented approximately one-third of the regularly occurring butterflies in Massachusetts and these authors stated that this proportion was a fairly good diversity for the park (Windmiller and Walton 1992).

The invertebrates species recorded in MIMA were cross referenced with several databases of known non-indigenous species, invasive species, agricultural and forest pests, and USDA regulated species (Hanson and Walker not dated; USDA Forest Service 1979; Solomon 1995; Maier et al. 2004; USDA 2008; USGS-NAS 2008). Three non-indigenous aquatic invertebrate species and 14 insects that are considered pests have been recorded in the vicinity MIMA (Table 27).

The rusty crayfish (*Orconectes rusticus*), a non-native aquatic invertebrate, was observed by Windmiller and Walton (1992) in the small pond by Cranberry Hill Office Park just outside of MIMA (Table 27). The rusty crayfish is an aggressive crustacean that often displaces native crayfish and may reduce aquatic plant abundance and diversity (Lodge and Lorman 1987; DiDonato and Lodge 1994). The main process of introduction for the rusty crayfish is by anglers using them as bait (Minnesota Sea Grant Fact Sheet 2008), so it is possible that ponds in MIMA may also have this species.

The other two non-indigenous aquatic invertebrates, the Chinese mystery snail (*Cipangopaludina chinensis*) and Japanese mystery snail (*Cipangopaludina japonica*), both exotic species, were observed during Biodiversity Day in the towns of Lincoln and Concord in 1998 (Alden 1998; NPS 2008d) (Table 27). To date, these snails have not had a detrimental impact on species of the Great Lakes and are currently considered benign (Mackie 1996). In the Boston area these snails are a host to the common native parasite *Aspidogaster conchicola*, which are first time records in North America for these gastropods acting as hosts for this parasite (Michelson 1970). Potential negative interactions with native gastropods may be possible but have not been documented (USGS-NAS 2008).

Fourteen insects that are considered pests have been observed in the vicinity of MIMA (Alden 1998; NPS 2008d). Ten species are defoliators, two are borers of wood and bark, and the remaining two either attack fruit or the stems of plants (Table 27).

Table 26. Approximate number of invertebrate species, by higher taxonomic category, that have been observed at MIMA or in the vicinity of MIMA (Windmiller and Walton 1992; Alden 1998; NPS 2008d) (numbers are approximate).

Taxonomic Category	Number of Species or Higher Taxonomic Categories
Annelids	8
Butterflies, moths and dragonflies	292
Crustaceans	15
Mollusks	23
Other Arthropods	27
Other Insects	440
Spiders and scorpions	23
Sponges	3

Table 27. Invertebrate pests and/or non-native or exotic species that occur in the vicinity of MIMA. [a] Observed by Windmiller and Walton (1992); [b] Observed during Biodiversity Day in the towns of Lincoln and Concord in 1998.

Common Name	Scientific Name	Type of Pest	Comments & Host species (if applicable)
Crustaceans (aquatic)			
Rusty crayfish [a]	*Orconectes rusticus*	Non-native	Displaces native crayfish.
Mollusks (aquatic)			
Chinese mystery snail [b]	*Cipangopaludina chinensis*	Exotic	Host to the common native parasite *Aspidogaster conchicola*. Negative interactions with native gastropods are also possible.
Japanese mystery snail [b]	*Cipangopaludina japonica*	Exotic	Host to the common native parasite *Aspidogaster conchicola*. Negative interactions with native gastropods are also possible.
Insects			
Bagworm [b]	*Thyridopteryx ephemeraeformis*	Defoliator	Many trees and shrubs, including especially eastern red-cedar and northern white-cedar (arborvitae).
Codling moth [b]	*Cydia pomonella*	Fruit pest	Fruit of apple trees.
Eastern tent caterpillar [b]	*Malacosoma americanum*	Defoliator	Primarily ornamental cherry, wild cherry, and apple, but also other shade, forest, and fruit trees.
Elm spanworm [b]	*Ennomos subsignaria*	Defoliator	Ash, hickory, and walnut are preferred, but elm, oak, cottonwood, and various other species are also heavily attacked. Yellow-poplar and sycamore are rarely attacked.
Forest tent caterpillar [b]	*Malacosoma disstria*	Defoliator	Sugar maple, birch, oak, aspen, and many other deciduous trees but never red maple.
Gypsy moth [b]	*Lymantria dispar*	Defoliator	Over 500 trees and shrubs, but especially oaks; eastern hemlock, eastern larch, eastern white pine, and other species of *Pinaceae*, particularly during outbreaks
Jack pine budworm [b]	*Choristoneura pinus*	Defoliator	Jack pine, although Scots, red, and white pines may also be attacked.
Japanese beetle [b]	*Popillia japonica*	Defoliator	Apple, cherry, maple (especially Norway), littleleaf linden, birch, elm, and many other hardwood species of trees; foliage and flowers of many shrubs are also attacked.

Table 27. Invertebrate pests and/or non-native or exotic species that occur in the vicinity of MIMA (continued).

Common Name	Scientific Name	Type of Pest	Comments & Host species (if applicable)
Large yellow underwing [b]	*Noctua pronuba*	Stem pest	This is one of the notorious "cutworms", causing fatal damage at the base of virtually any herbaceous plant.
Leopard moth [b]	*Zeuzera pyrina*	Wood borer	Attacks over 100 species of trees and shrubs such as elm, maple, ash, beech, walnut, oak, chestnut, poplar, willow, apple, pear, and plum. Except for evergreens, most woody plants of suitable size appear susceptible.
Maple callus borer [b]	*Synanthedon acerni*	Wood borer	Maple trees, but silver maple is preferred; red maple and sugar maple are readily attacked, and other maples are probably susceptible. Mountain-ash has been listed as a host, but this record needs to be confirmed.
Pale tussock moth [b]	*Halysidota tessellaris*	Defoliator	Oak, willow, poplar, hickory, grape, and hackberry.
Rose chafer [b]	*Macrodactylus subspinosus*	Defoliator	Flowers of roses and peonies, new grapes, and the leaves of grapes. Larvae feed on the roots of turf, weeds, and nursery stock.
Saddlebacked looper [b]	*Ectropis crepuscularia*	Defoliator	Many trees and shrubs including eastern hemlock, eastern larch, northern white-cedar, spruces, and probably other conifers.

Potential Major Insect Pests

The US Forest Service maps the distribution and susceptibility of forests to infestation by a variety of non-indigenous forest pest species (USDA Forest Service 2008a). Several of these insect pests have distribution ranges that include Middlesex County, MA. Additionally, there are several other pests where Middlesex County has high forest susceptibility to infestation based upon basal area of preferred host species (Table 28). Currently there is no monitoring system in place at MIMA to assess current or potential future pest infestation in the park.

US Forest Service tracks two species pest species, the gypsy moth (*Lymantria dispar*) and the Japanese beetle (*Popillia japonica*), that have been recorded in the towns of Lincoln and Concord (Alden 1998; NPS 2008d) and are likely present in MIMA. Although only these two species have been recorded in the vicinity of MIMA there are 14 of 31 insect pests (45%) that are present in Middlesex County and the forest susceptibility for the county is either extreme or high, thus these insects represent potential current threats to the MIMA forest ecosystem. There are another eight insect pests (eight of 19 or 42%) that are currently not found in Middlesex County but the forest susceptibility is either extreme or high for these pests. If the distribution of these pests extends into Middlesex County there is a high potential for infestation in the county and by extension at MIMA (Table 28).

The gypsy moth is both an APHIS-Regulated Pest (USDA 2008) and is listed by the National Agriculture Pest Information System (NAPIS 2008). The gypsy moth, an invasive insect from Europe, first became established in the United States in Massachusetts in 1869 and spread rapidly throughout the Northeast. By 1987, the gypsy moth had become established in the Northeast. It is a destructive pest of hardwood trees in the eastern United States. Since 1980, the gypsy moth has defoliated almost one million forested acres each year. In 1981, a record 12.9 million acres were defoliated (McManus et al. 1992). Feeding caterpillars prefer hardwood, such as oaks, but caterpillars will also feed on apple sweetgum, speckled alder, basswood, gray and white birch, poplar, willow, and hawthorn, although other species are also affected. Older larvae will also feed on cottonwood, hemlock, southern white cedar, and the pines and spruces native to the East. Gypsy moths avoid ash, yellow-poplar, sycamore, butternut, black walnut, catalpa, flowering dogwood, balsam fir, red cedar, American holly, and shrubs such as mountain laurel, rhododendron, and arborvitae (McManus et al. 1992). The US Forest Service has tracked infestation by gypsy moths since 1972 and has compiled information on the susceptibility of forest stands to infestation (USDA Forest Service 2008b). Susceptibility of forests in Massachusetts and in New England, in general, is very high as these forests contain high percentages of preferred host species (Figure 18). For example, the white oak (*Quercus alba*), northern red oak (*Quercus rubra*), and black oak (*Quercus velutina*) are particularly abundant in the eastern portion of Massachusetts, making this area highly susceptible to gypsy moth infestation (Figure 18) (USDA Forest Service 2008b).

Table 28. Potential and current threats to MIMA forests by non-indigenous insect pests and diseases that are tracked by the USDA Forest Service (2008a). Distribution information for Middlesex County, MA, as of 2008. Forest susceptibility based on vegetation host species volume (m^3 ha^{-1}).

Common Name	Pest Species or Disease	Pest Presence in Middlesex Cty as of 2008	Forest Susceptibility in Middlesex Cty as of 2008
Ambermarked birch leafminer	*Profenusa thomsoni*	no	low
Amylostereum rot	*Amylostereum areolatum*	no	extreme
Asian longhorned beetle	*Anoplophora glabripennis*	no	low
Asiatic oak weevil	*Cyrtepistomus castaneus*	yes	extreme
Beech bark disease	*Cryptoccocus fagisuga*	yes	low
Birch leafminer	*Fenusa pumila*	yes	low
Black vine weevil	*Otiorhynchus sulcatus*	yes	high
Browntail moth	*Euproctis chrysorrhoea*	no	low
Calico scale	*Eulecanium cerasorum*	yes	medium
Cherry bark tortrix	*Enarmonia formosana)*	no	low
Chestnut blight	*Cryphonectria parasitica*	yes	extreme
Columbian timber beetle	*Corthylus columbianus*	yes	low
Dutch elm disease	*Ophiostoma novo-ulmi*	yes	low
Elm leafbeetle	*Xanthogaleruca* (=*Pyrrhalta*) *luteola*	yes	none
Elm leafminer	*Fenusa ulmi*	yes	low
Elongate hemlock scale	*Fiorinia externa*	yes	high
Emerald ash borer	*Agrilus planipennis*	no	high
European bark beetle	*Hylastes opacus*	no	low
European mistletoe	*Viscum album*	no	low
European pine sawfly	*Neodiprion sertifer*	yes	extreme
European pine shoot moth	*Rhyacionia buoliana*	yes	extreme
European spruce needleminer	*Epinotia nanana*	yes	none
Gypsy moth	*Lymantria dispar*	yes	high
Hemlock woolly adelgid	*Adelges tsugae*	yes	high
Imported willow leaf beetle	*Plagiodera versicolora*	no	medium
Introduced basswood thrips	*Thrips calcaratus*	no	high
Introduced pine sawfly	*Diprion similis*	yes	high
Japanese beetle	*Popillia japonica*	yes	low
Japanese cedar longhorn beetle	*Callidiellum rufipenne*	no	none
Juniper scale	*Carulaspis juniperi*	yes	none
Larch sawfly	*Pristiphora erichsonii*	yes	none
Maple petiole borer	*Caulocampus acericaulis*	no	low
Mediterranean pine engraver beetle	*Orthotomicus erosus*	no	high
Mountain ash sawfly	*Pristiphora geniculata*	yes	low
Oak wilt	*Ceratocystis fagacearum*	no	high
Oystershell scale	*Lepidosaphes ulmi*	yes	low

Table 28. Potential and current threats to MIMA forests (continued).

Common Name	Pest Species or Disease	Pest Presence in Middlesex Cty as of 2008	Forest Susceptibility in Middlesex Cty as of 2008
Peach twig borer	*Anarsia lineatella*	no	medium
Pear thrips	*Taeniothrips inconsequens*	yes	low
Phytophthora root rot	*Phytophthora cinnamomi*	yes	high
Pine bark adelgid	*Pineus strobi*	yes	extreme
Pine false webworm	*Acantholyda erythrocephala*	yes	extreme
Pine shoot beetle	*Tomicus piniperda*	yes	extreme
Pitch canker	*Fusarium circinatum*	no	extreme
Poplar and willow borer	*Cryptorhynchus lapathi*	yes	medium
Red-haired pine bark beetle	*Hylurgus ligniperda*	no	extreme
Sirex woodwasp	*Sirex noctilio*	no	extreme
Smaller European elm bark beetle	*Scolytus multistriatus*	yes	low
Sudden oak death	*Phytophthora ramorum*	no	medium
White pine blister rust	*Cronartium ribicola*	yes	extreme
Winter moth	*Operophtera brumata*	yes	low

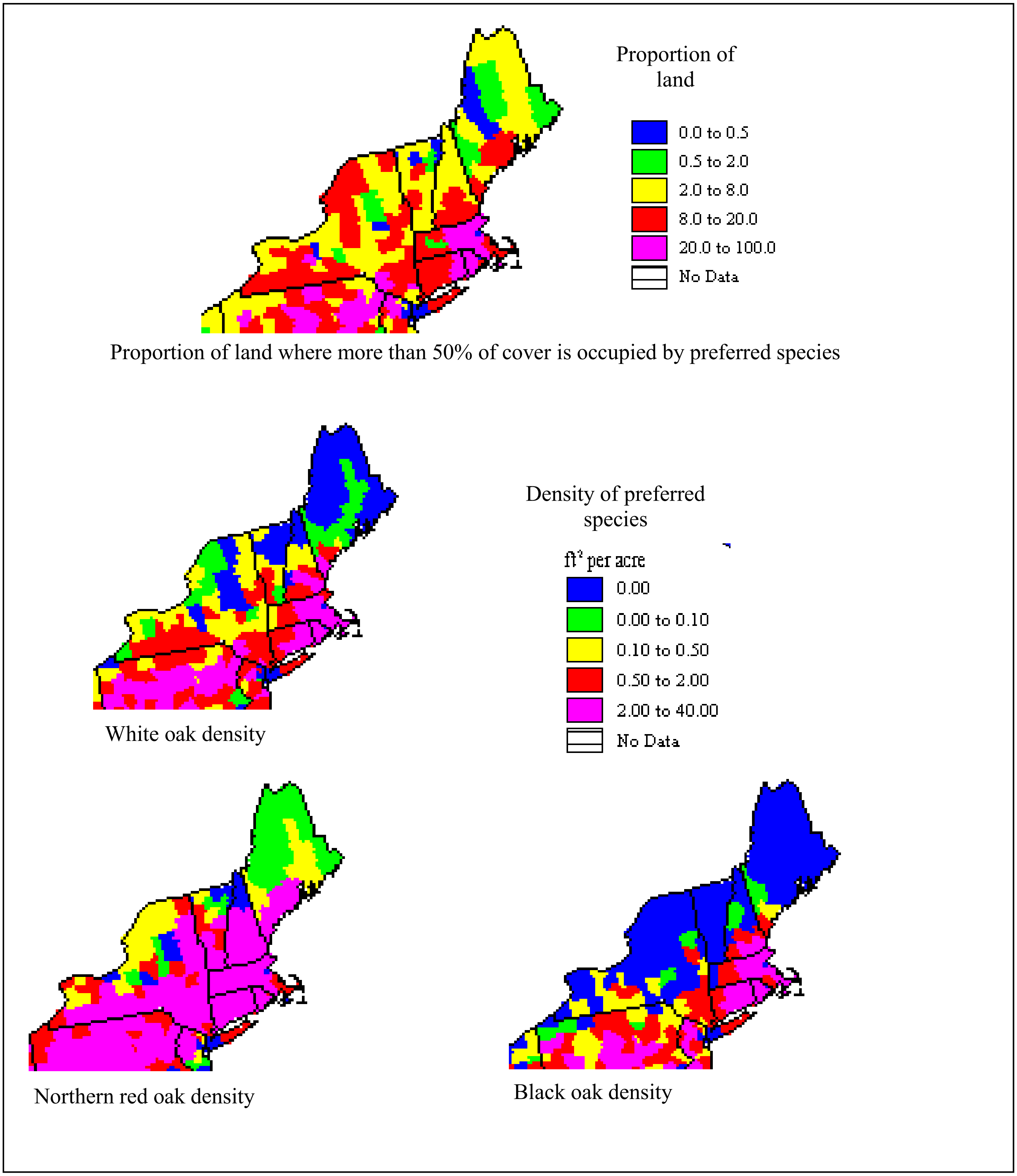

Figure 18. Forest susceptibility to gypsy moth infestation and density of preferred host species in Northeastern US. Maps from USDA Forest Service (2008b).

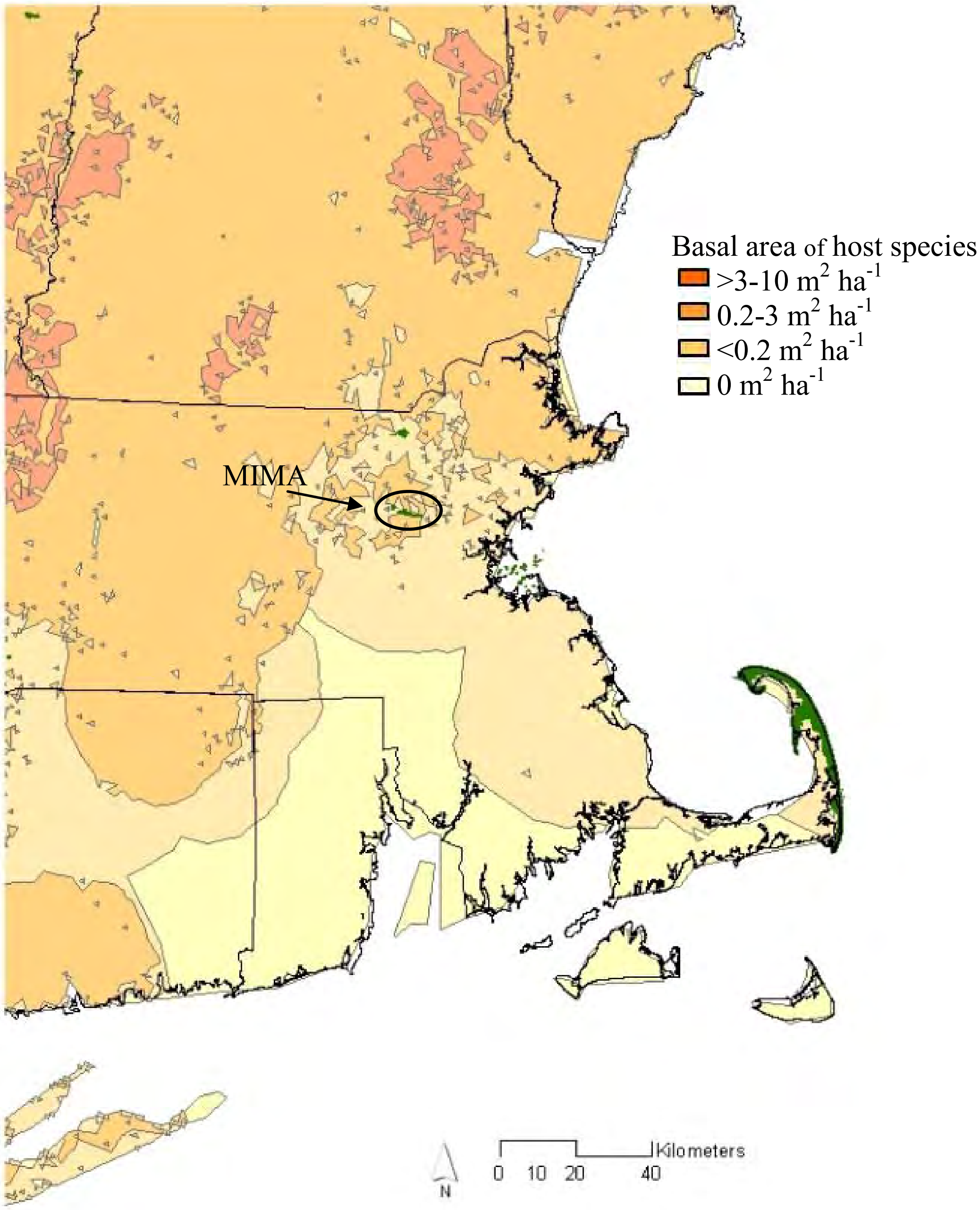

Figure 19. Forest susceptibility to infestation by hemlock woolly adelgid based on basal area of host species (eastern hemlock and Carolina hemlock) in the Northeastern US. Map from USDA Forest Service (2008a).

The hemlock woolly adelgid (*Adelges tsugae*), an Asian invasive insect, attacks eastern and Carolina hemlock trees. The hemlock woolly adelgid was first reported in the eastern United States in 1951 near Richmond, Virginia, and by 2005 it was established in portions of 16 states from Maine to Georgia (USDA Forest Service 2005). Decline and mortality of hemlocks typically occur within four to 10 years of infestation in the southern New England region (USDA Forest Service 2005). In Massachusetts, the hemlock woolly adelgid is a major concern, as five new counties in the state became infested in 2006 (the most recent year of data from the US Forest Service) (USDA Forest Service 2007). The first infestation in Massachusetts occurred in the early 1990's and Middlesex County has recorded infestations since 1991 (USDA Forest Service 2007). Although this insect pest has not been officially recorded in MIMA it is most likely present in the park. Forest susceptibility in and around MIMA has been rated as moderate based on the average basal area of eastern hemlock and Carolina hemlock (Figure 19, USDA Forest Service 2007). The state is currently monitoring predator release sites of the ladybird beetle and *Laricobius nigrinus* (a beetle) in an effort to biologically control this pest (USDA Forest Service 2007).

There have been two recent forest pest alerts for Massachusetts, the Asian longhorned beetle (*Anoplophora glabripennis*) and the viburnum leaf beetle (*Pyrrhalta viburni*) (Massachusetts Introduced Pest Outreach Project 2008). The Asian longhorned beetle was first detected in Massachusetts in Worcester County in August 2008 (Massachusetts Introduced Pests Outreach Project 2008). The Asian longhorned beetle is a pest of hardwood trees including maple, birch, horse chestnut, plane-tree, poplar, willow, and elm trees. Other susceptible trees include ash (especially green ash), silk tree, hackberry, and mountain-ash. This invasive insect is a native of China and was first discovered in New York in 1996, and has also been found in New Jersey and Chicago. The beetle causes damage by tunneling into the trunk and branches of trees, disrupting sap flow that weakens and eventually kills infected trees (Massachusetts Introduced Pest Outreach Project 2008). Forest susceptibility in Middlesex County is rated as low (Table 28); however, this could be an emerging threat to trees in MIMA.

The viburnum leaf beetle was first discovered in Massachusetts in 2004 in Berkshire County. In July of 2008 new sightings were recorded in Bristol, Franklin, and Middlesex Counties (Massachusetts Introduced Pest Outreach Project 2008). This insect is a pest of *Viburnum* species. The adult beetle, which is active in late summer and fall, feeds on viburnum leaves and damage can be seen as irregular circular to elliptical holes. Heavy infestations can defoliate shrubs, cause dieback, and eventually kill plants. The distribution of the beetle appears to be spreading throughout Massachusetts and native viburnums, as well as ornamental plantings and nursery stock, could be at risk (Massachusetts Introduced Pest Outreach Project 2008). Several *Viburnum* species susceptible to infestation are present in MIMA (e.g., arrowwood viburnum, *V. dentatum*; European cranberry bush, *V. opulus;* mapleleaf viburnum, *V. acerifolium*; nannyberry, *V. lentago*; possum-haw, *V. nudum*, [Thompson and Jenkins 1992; Alden 1998; NPS 2008d; Gawler et al. in review]) including a state listed endangered species, Rafinesque viburnum (*V. rafinesquianum*) that was observed by Thompson and Jenkins (1992). This insect pest could also pose a potential emerging threat to vegetation in the park.

State Listed Animal Species

The towns of Lincoln, Concord, and Lexington collectively list a total of 30 rare faunal species that could be present in the area based on historic records (Table 29). Two species, the Blanding's turtle and the frosted elfin (*Callophrys irus*, a butterfly) have been observed in MIMA (Windmiller and Walton 1992; Brotherton et al. 2005). Eight species were observed in the vicinity of MIMA during the Biodiversity Day event (Alden 1998; NPS 2008d). Three of the observed species (frosted elfin, pine barrens zanclognatha, *Zanclognatha martha;* and spatterdock darner dragonfly, *Aeshna mutate*) could be new records for these towns for a net total of 33 town listed species. Therefore, 6% (two species) of the possible state listed species have been recorded in MIMA, and 24% (eight species) have been observed in the vicinity of the park (Table 29).

No state listed bird species have been officially recorded in MIMA. Three state listed bird species have been observed in the towns of Lincoln and Concord during Biodiversity Day held in 1998 (Table 17, Alden 1998; NPS 2008d). Two species, the American bittern and the upland sandpiper, are listed by the State of Massachusetts as endangered, and the third, the grasshopper sparrow, is listed as threatened (MA-NHESP 2008a) (Table 29). Three other state listed bird species: king rail (*Rallus elegans*), least bittern (*Ixobrychus exilis*), and common moorhen (*Gallinula chloropus*) are known to occur in Great Meadows National Wildlife Refuge (NPS 2008d).

The American bittern (state endangered species) inhabits freshwater marshes, meadows, fens, and bogs dominated by emergent vegetation such as cattails, bulrushes, sedges, and grasses. Destruction or degradation of these habitats would negatively impact this species. Since 1980, there have been reports of American bitterns at 75 locations throughout Massachusetts during the breeding season (MA-NHESP 2006). The American bittern was observed during Biodiversity Day (Alden 1998; NPS 2008d) in the towns of Concord and Lincoln

The upland sandpiper (state endangered species) inhabits large expanses of open grassy uplands, wet meadows, old fields, and pastures. In Massachusetts, it is restricted to open expanses of grassy fields, hay fields, and mown grassy strips adjacent to runways and taxiways of airports and military bases. It is threatened by habitat loss from development and the succession of open lands to forest. As of 1985, only 25 to 27 breeding pairs were found to be nesting at only seven sites statewide (MA-NHESP 2008b). The upland sandpiper was observed during Biodiversity Day (Alden 1998; NPS 2008d) in the towns of Concord and Lincoln.

The grasshopper sparrow (state threatened species) is found in sandplain grasslands, pastures, hayfields, and other fields characterized by bunch grasses (as opposed to sod-forming grasses). It requires patchy grasslands with less than 35% shrub cover. Bare ground is especially important for escape and foraging behaviors (MA-NHESP 2008c). In Massachusetts this species is known to nest at fewer than 20 sites, with habitat loss due to development and the succession of abandoned lands to forest being the major threats and causes of this species decline (MA-NHESP 2008c). The grasshopper sparrow was observed during Biodiversity Day (Alden 1998; NPS 2008d) in the towns of Concord and Lincoln.

Observations of Blanding's turtles (state threatened species) have been recorded during the Biodiversity Day survey (Alden 1998; NPS 2008d) and by Brotherton et al. (2005) (Tables 19 and 29). This species was observed within the complex of farm ponds and irrigation ditches associated with Mill Brook, just south of Palumbo Farm (Brotherton et al. 2005). Blanding's turtles use a variety of wetland and terrestrial habitat types such as seasonal pools, marshes, scrub-shrub wetlands, and open uplands. The primary cause of adult mortality is by road kill as these turtles travel to multiple wetlands throughout a single year. Habitat fragmentation is also a concern for this species. In Massachusetts, only a few nesting sites are currently known (MA-NHESP 2007). The spotted turtle, which has been recorded in MIMA, was formerly a state listed species of special concern but was removed as a rare species in 2006 (MA-NHESP 2004a, 2004b). The blue-spotted salamander (*Ambystoma laterale*), a Massachusetts state species of special concern, is known to occur in Great Meadows National Wildlife Refuge (NPS 2008d).

No Massachusetts state listed mammal or fish species have been observed in MIMA (Table 29).

One state listed invertebrate species has been observed in MIMA, the frosted elfin, a butterfly, was observed by Windmiller and Walton (1992). Four other state listed invertebrate species: the pine barrens zanclognatha (a moth); spatterdock darner dragonfly; the eastern pondmussel (*Ligumia nasuta*); and the triangle floater, a mussel (*Alasmidonta undulate*), (Table 29) were all observed during Biodiversity Day in the towns of Lincoln and Concord (Alden 1998; NPS 2008d).

The frosted elfin butterfly (state species of special concern) inhabits xeric and open, disturbance-dependent habitats on sandy soil, especially heath and grassy openings in pitch pine-scrub oak barrens, but also in human disturbed habitats such as powerline cuts, railways, old sand/gravel pits, and airports. The frosted elfin is widely distributed throughout eastern North America, but colonies are rare and localized throughout its range. In Massachusetts, it is primarily restricted to sandplain habitats on the coastal plain and Connecticut River Valley (Nelson 2007a). Windmiller and Walton (1992) observed the frosted elfin and provided some information as to the location in terms of "polygon reference numbers". There was no map to reference the polygon number included in the report and therefore the location of this sighting is unknown. This may be a new record for the towns of Concord, Lincoln, and Lexington (MA-NHESP 2008a).

The pine-barrens zanclognatha moth (state threatened species) inhabits sandplain pitch pine-scrub oak barrens. It is sparsely distributed from Maine south to New Jersey and west to New York. In Massachusetts, it is restricted to inland barrens (Nelson 2007b). This may be a new record for the towns of Concord, Lincoln, and Lexington (MA-NHESP 2008a).

The spatterdock darner dragonfly (state endangered species) occupies boggy ponds with emergent and floating vegetation, but has also been observed in ephemeral wetlands. Its range extends from southwestern Maine south to Virginia and west to Missouri, Michigan, and Ontario. Throughout its range it is scarce and local in occurrence. In Massachusetts, the spatterdock darner appears to be one of the rarer members of its genus in eastern North America. Most spatterdock darner sites in Massachusetts are fragile wetlands, and the greatest threat to this species is the destruction or degradation of these wetlands (MA-NHESP 2003). This may be a new town record for the towns of Concord, Lincoln, and Lexington (MA-NHESP 2008a).

The eastern pondmussel (state species of special concern) is a medium- to large-sized freshwater mussel that occurs in the protected areas of lakes, in slackwater areas of rivers, and in canals. It prefers sand, silty-sand, and to a lesser extent gravely substrates in slow moving to standing water. Like all freshwater mussels, the larvae attach to the gills or fins of a host fish species to complete the juvenile stage, but the specific host fish species for the eastern pondmussel is unknown (MA-NHESP 1998). Habitat alteration and destruction are currently the most common threats to this species. Additionally, any factors that negatively impact its host fish species will also detrimentally impact the eastern pondmussel. Currently there are only 21 known populations from 18 towns in Massachusetts.

The triangle floater (state species of special concern) is a small freshwater sessile mussel that resides in rivers, streams, lakes, and ponds. Recent data indicate that the triangle floater is widely distributed in Massachusetts but many populations are sparse and the long-term viability of low-density populations is poorly understood (Nedeau 2007). Common host fish species are the common shiner, blacknose dace, longnose dace, white sucker, pumpkinseed sunfish, fallfish, largemouth bass, and slimy sculpin (Nedeau 2007). At least three of these fish species are found in the waters in and in the vicinity of MIMA. Triangle floaters are vulnerable to a variety of anthropogenic alterations and degradations of waterways, such as nutrient enrichment, sedimentation, non-point source pollution, flow alteration, and water withdrawals. The MA-NHESP has developed habitat assessment and survey guidelines for freshwater mussels so that conservation and restoration efforts, as well as regulatory protection, can be effectively targeted (Nedeau 2007).

Previous documents have listed the Mystic Valley amphipod (*Crangonyx aberrans*) and the elderberry long-horned beetle (*Desmocerus palliatus*), both which have been recorded in MIMA, as Massachusetts state listed species (Windmiller and Walton 1992, Agius 2003). These species were listed as of 2004, but are no longer listed by the state (MA-NHESP 2004a, 2004b, 2008a).

Wildlife Corridors

Route 2A bisects the Battle Road Unit of MIMA and potentially forms a barrier to wildlife movement. A recent study in the vicinity of MIMA investigated the effectiveness of underpasses to provide safe passage for wildlife under Route 2 in Concord (Sudbury Valley Trustees 2008). Over the past two years, the Concord Wildlife Passages Task Force has been monitoring wildlife use of four box culverts under Route 2. The data collected from automatically triggered cameras, winter tracking, and tracking beds have shown that a wide variety of species utilize the underpasses regularly (Sudbury Valley Trustees 2008, Figure 20).

The installation of wildlife corridors could be considered by the park, especially in areas where roads bisect large areas of natural or important habitat, such as that surrounding the Elm Brook wetlands.

Table 29. State listed rare faunal species for the towns of Lincoln, Concord, and Lexington (status in parentheses) and records of observations in MIMA or in the vicinity of MIMA (as of 2008). State status: SC= special concern, T=threatened, E=endangered. [1] Indicates species observed by Brotherton et al. (2005); [2] Indicates species observed by Windmiller and Walton (1992); Species observed in the vicinity of MIMA were recorded during the July 4, 1998 Biodiversity Day in the towns of Lincoln and Concord (Alden 1998; NPS 2008d). * Indicates species is state listed but this could be a new record for these towns.

Common Name	Scientific Name	Observed in or in Vicinity of MIMA
Amphibians		
Blue-spotted salamander (SC)	*Ambystoma laterale*	No
Jefferson salamander (SC)	*Ambystoma jeffersonianum*	No
Beetles		
Purple Tiger Beetle (SC)	*Cicindela purpurea*	No
Twelve-spotted Tiger Beetle (SC)	*Cicindela duodecimguttata*	No
Birds		
American bittern (E)	*Botaurus lentiginosus*	Vicinity of MIMA
Barn owl (SC)	*Tyto alba*	No
Common moorhen (SC)	*Gallinula chloropus*	No
Golden-winged warbler (E)	*Vermivora chrysoptera*	No
Grasshopper sparrow (T)	*Ammodramus savannarum*	Vicinity of MIMA
Henslow's sparrow (E)	*Ammodramus henslowii*	No
King rail (T)	*Rallus elegans*	No
Least bittern (E)	*Ixobrychus exilis*	No
Northern harrier (T)	*Circus cyaneus*	No
Pied-billed Grebe (E)	*Podilymbus podiceps*	No
Sedge Wren (E)	*Cistothorus platensis*	No
Sharp-shinned hawk (SC)	*Accipiter striatus*	No
Upland sandpiper (E)	*Bartramia longicaud*	Vicinity of MIMA
Dragonfly/Damselfly/Butterfly/Moth		
Arrow Clubtail (T)	*Stylurus spiniceps*	No
Brook Snaketail (SC)	*Ophiogomphus aspersus*	No
Frosted elfin (SC)*	*Callophrys irus (Incisalia irus)*	In MIMA[2]
Kennedy's Emerald (E)	*Somatochlora kennedyi*	No
Mocha Emerald (SC)	*Somatochlora linearis*	No
New England Bluet (SC)	*Enallagma laterale*	No
Pine barrens zanclognatha (T)*	*Zanclognatha martha*	Vicinity of MIMA
Spatterdock darner dragonfly (SC)*	*Aeshna mutata*	Vicinity of MIMA
Umber Shadowdragon (SC)	*Neurocordulia obsoleta*	No

Table 29. State listed rare faunal species (continued).

Common Name	Scientific Name	Observed in or in Vicinity of MIMA
<u>Invertebrates- Mollusca</u>		
Creeper (SC)	*Strophitus undulatus*	No
Eastern pondmussel (SC)	*Ligumia nasuta*	Vicinity of MIMA
Triangle floater (SC)	*Alasmidonta undulata*	Vicinity of MIMA
<u>Reptiles</u>		
Blanding's turtle (T)	*Emydoidea blandingii*	In MIMA[1] and Vicinity of MIMA
Eastern box turtle (SC)	*Terrapene carolina*	No
Wood turtle (SC)	*Glyptemys insculpta*	No

Figure 20. Wildlife corridor under Route 2 in Concord. Photos (clockwise from top left): corridor under Route 2; animal tracks in underpass; fisher; coyote; fox (Photos courtesy of Sudbury Valley Trustees).

Condition Assessment for Faunal Communities

The condition of the landbird community was assessed using threshold values for four biotic elements (forest compositional, forest functional, forest structural, and grassland guilds [although not all surveys specifically sampled in grasslands]) established for avian guilds by the NETN Breeding Bird Protocol (NETN 2007a). The overall average score for the majority of the surveys rated as "caution", with the most recent surveys at the park (2003, 2006, and 2007) all having very similar average scores (ranging from 0.40 to 0.42) (Table 18). Therefore, the condition of the landbird community was rated as "caution". Fifty percent of PIF listed bird species have population trends in Massachusetts that are lower than regional trends (Table 16). The guild analyses the landbird community indicated a stable trend but with a score of "caution" for the three most recent surveys. Based on these two metrics the trend for landbird communities was rated as a "declining trend" (Table 30).

The AmphIBI gave an overall rating of "fair" for the amphibian communities sampled by Brotherton et al. (2005) (Table 21). Based on this assessment the current condition of amphibian communities in MIMA was rated as "caution" and was given a midpoint score of 0.50 (Table 30). Twenty-six percent of the species present in MIMA were judged to be in decline by Brotherton et al. (2005) (Table 19). Since amphibians are a relatively sensitive faunal group it is assumed that any decline in amphibian species would be an indication of unfavorable conditions. Additionally, the amphibian species that were in decline, the pickerel frog and red-spotted newt, had relatively high coefficients of conservatism indicating that these species are sensitive to disturbance. The Blanding's turtle, a state listed species, and the spotted turtle, a formerly state listed species, were also in decline. Therefore, the trend for amphibian and reptile communities, based on this information and best professional judgment, was assessed as a "declining trend" and given a midpoint score of 0.16 (Table 30).

Although there has been a recent survey of mammals at MIMA (e.g., Gilbert et al. 2008), it was estimated that only 50% of the potential mammal species were detected (24 species actually observed) and bats were not included in this survey. Therefore, the current condition of mammal communities at MIMA was assessed as "unknown" condition (Table 30) since it appears that more information is needed before this community can be accurately assessed. Additionally, there were not enough data available to evaluate trends in mammal communities so the trend in mammal community was assessed as "unknown". Issues regarding the white-tailed deer population and beaver activities in the park are management concerns for MIMA. There were no quantitative park specific data related to either of these species, which would be useful for future management actions.

The current condition of freshwater fish communities was assessed as "significant concern" based on the Index of Biotic Integrity score of "poor", the lowest possible rating, given for all four waterbodies sampled in 2001 (Table 25). There were not enough data available to evaluate trends in fish communities. It is possible that a native, self-reproducing population of brook trout exists in Elm Brook. Establishing the true origin of this population could be a management objective as native brook trout are presumed to be extirpated from the watersheds in the eastern portion of Massachusetts. If this is a native population, conservation and preservation efforts could be initiated.

There was little specific information on the invertebrate communities (aquatic or terrestrial) of MIMA. Most information on invertebrates was from one study (Windmiller and Walton 1992) that surveyed several faunal communities. Due to the lack of information the condition or trend for invertebrate communities could not be determined and was assessed as "unknown".

The towns of Lincoln, Concord, and Lexington collectively list 30 state listed species. An additional three species (frosted elfin, pine barrens zanclognatha, and spatterdock darner dragonfly) have also been observed in the area of the park for a net total of 33 listed species that are likely to occur in the area of MIMA. Two of these species (6%) have been recorded in MIMA and total of eight species (24%) have been recorded in the vicinity of the park, for a net total of nine listed species occurring in the area of the park (Table 29). Compared to the area in the vicinity of the MIMA, the observations of rare species in the park is much lower (6% versus 24% observed); however, since there has not been a focused effort to search for rare fauna in the park it is not known whether this is a reflection of a paucity of rare species in MIMA or a lack of information on the presence of these species in the park. Therefore, the condition assessment for the presence of rare species was assessed as "unknown" (Table 30).

The threat of infestation from insect pests is a real and emerging threat for MIMA. In that regard, the potential threat from insect pests was included within the faunal community assessment of condition. Data on the actual degree of insect pest infestation at MIMA was lacking, therefore the condition of this metric was assessed as "unknown" (Table 30).

Overall, the reliability of information used to assess the condition of faunal communities in MIMA was satisfactory (average score of 0.70) (Table 30).

Table 30. Condition assessment scores for faunal communities at MIMA. Average scores are given when more than one metric was assigned a condition rating.

Metric	Condition	Numerical Score	Comments
Current Condition of Faunal Communities			
Landbird community	Caution	0.41	Average NETN scores based on proportional species richness by guild for recent surveys (2003, 2006, 2007) (Table 18).
Amphibian and reptile communities	Caution	0.50	Overall AmphIBI rating of "fair" for amphibian communities (Table 21).
Mammal community	Unknown	-	Insufficient information to evaluate condition.
Fish community	Significant concern	0.16	Index of Biotic Integrity for most recent survey rated as "poor" (Table 25).
Invertebrate community	Unknown	-	Too few surveys to evaluate condition.
Potential insect pest infestation	Unknown	-	More information is needed to assess condition of insect pest infestation.
State listed species	Unknown	-	Unknown if lack of rare species in park is related to detection of species or a true lack of species.
Overall condition score	-	-	Since only three of seven metrics could be assessed, an average condition score would not be appropriate.
Trend Data for Faunal Communities			
Landbird community	Declining trend	0.16	50% of PIF listed bird species had population trends that were worse for Massachusetts compared to southern New England & community is stable but in "caution" range (Table 16).
Amphibian and reptile communities	Declining trend	0.16	Decline in sensitive and/or state listed species, based on best professional judgment (refer to Table 19).
Mammal community	Unknown	-	Insufficient data to evaluate trends.
Fish community	Unknown	-	Insufficient data to evaluate trends.
Invertebrate community	Unknown	-	Insufficient data to evaluate trends.

Table 30. Condition assessment scores for faunal communities at MIMA (continued).

Metric	Condition	Numerical Score	Comments
Insect pest infestation	Unknown	-	Insufficient data to evaluate trends
Overall trend score	-	-	Since only two of six metrics could be assessed for trends, an average trend score would not be appropriate.
Data Reliability for Faunal Communities			
Biodiversity Day data (Alden 1998; NPS 2008d)	Satisfactory	0.50	Information on specific species locations were lacking.
Brotherton et al. (2005)	Good	0.84	Report has not yet been finalized and peer-reviewed, but expected to of "good" quality.
Gilbert et al. (2008)	Good	0.84	
Jones (1993)	Satisfactory	0.50	Unpublished park report.
Mather et al. (2003)	Good	0.84	
Martinez (1992)	Limited	0.16	Report was limited to field notes of observations of vernal pools. Survey locations were difficult to determine. Most species observations were very generic in terms of taxonomic identification.
MA Natural Heritage & Endangered Species Program	Good	0.84	
NETN Inventory & Monitoring (Landbird data)	Good	0.84	Data collection just recently initiated, no long-term data available, but data were of "good" quality.
Thomas (1992)	Limited	0.16	Specific locations of surveys were difficult to identify.
Trocki and Paton (2003)	Good	0.84	
Windmiller and Walton (1992)	Good	0.84	
Overall Data Reliability Score	Satisfactory (0.34 to 0.67)	0.67	

Water Resources

The aquatic habitat in MIMA includes both lentic (standing water) and lotic (flowing water) habitats (Mather et al. 2003) (Figure 3). The Concord River flows through the park as well as several small streams and brooks. The lentic waters include three small ponds, all less than 10 acres in size. The ponds are low-flow impoundments formed by human-made dams with little inflow or outflow. The lotic waters include 1.9 km of lower gradient stream and rivers characterized by slower moving water, soft bottoms with pool habitats, moderate gradient streams or rivers characterized by faster moving waters, gravel and cobble bottoms with riffle and run habitats, and higher gradient streams or rivers characterized by extremely fast moving water, rock to boulder bottoms and cascade (runs, falls, and plunge pools) habitats (Mather et al. 2003).

The Concord River, which is formed by the confluence of the Assabet and Sudbury Rivers in the town of Concord, traverses the North Bridge Unit of MIMA. Eight miles of the Concord River, from the confluence of the Sudbury and Assabet Rivers to its confluence with the Merrimack River, was designated as a Wild and Scenic River in 1999 for its recreational value (National Wild and Scenic Rivers System 2008).

Water Quantity

MIMA lies in the Concord River Basin, which drains the northeastern portion of Massachusetts. Precipitation amounts for the area average approximately 9.5 cm yr^{-1} with peak precipitation generally occurring during the spring (Figure 21). Massachusetts, in general, has adequate water supplies, but withdrawals of water in urbanized eastern Massachusetts have approached and in some cases exceeded the capacity of local water resources (Bratton and Parker 1995). The primary local water resources are generally from narrow, thin, and discontinuous stratified-drift aquifers. When ground water withdrawals exceed local capacity streamflow can decrease or even cease, possibly causing degradation to wildlife habitat (Bratton and Parker 1995).

The 1993 Resource Management Plan for the park stated that there were no water quantity issues for the park and that flow levels were adequate to preserve the natural process and cultural features (NPS 1993); however, the Sudbury-Assabet-Concord (SuAsCo) watershed has been designated as a medium stressed basin by the state (Commonwealth of Massachusetts 2001). A stressed basin is defined as a basin or sub-basin where the quantity of stream flow has been significantly reduced, the quality of streamflow is degraded, or other key habitat factors are impaired. Low flows in most of Massachusetts reflect ground water levels. Most rivers and streams in Massachusetts have low flows in the summer that are maintained by groundwater discharge in the absence of rainfall amounts. There are two USGS stream gage stations upstream of MIMA: one on the Assabet River at Maynard, MA (gage number 01097000, Latitude: 42.431944, Longitude: -71.450278) and one on the Sudbury River at Saxonville, MA (gage number 01098530, Latitude: 42.325278, Longitude: -71.398056) (USGS National Water Information System 2008) (Figure 22). Both the Assabet River and the Concord River have been

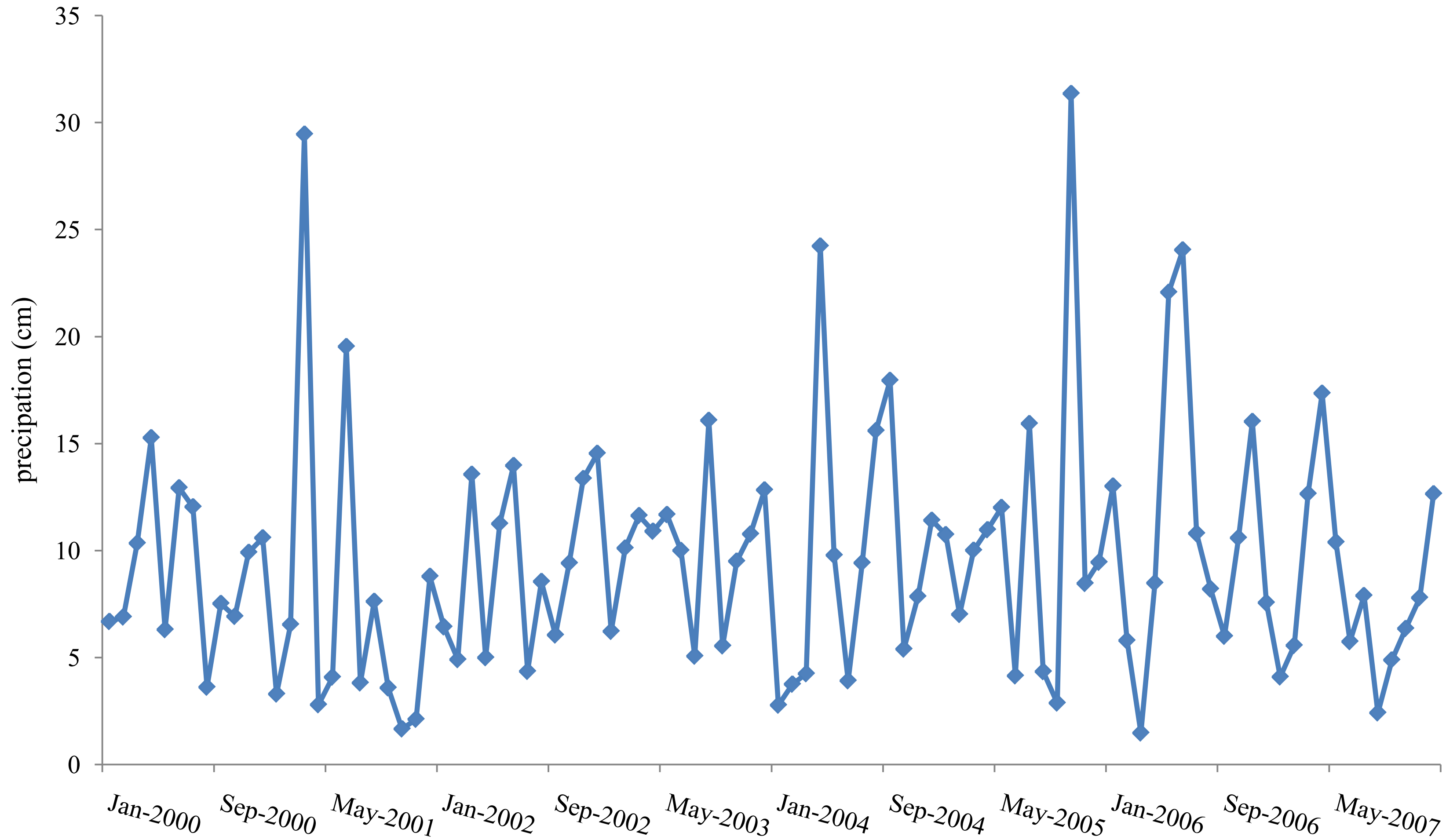

Figure 21. Monthly precipitation (cm) for MIMA. Data from the National Atmospheric Deposition Program/National Trends Network monitoring station located in Lexington, MA (MA13). Only data from 2000 to December 2007 (most recent record) are shown for clarity.

classified as medium stressed based on the historical flow conditions for these gages (Commonwealth of Massachusetts 2001). The Massachusetts Department of Conservation and Recreation (MDCR) considers the Sudbury basin to be a stressed basin due to increased water withdrawals from the shallow, valley-fill aquifers of the basin (Weiskel and Zarriello 2008). Peak stream flow generally occurs in the spring months, while low stream discharge occurs during the summer (Figure 23). The NETN also monitors stream discharge at Elm Brook and Mill Brook as part of the NETN water quality monitoring (Figure 24). Extreme low flow events have been recorded for the SuAsCo watershed. For example, in August and September of 1999 the Sudbury River ran dry near Hopkinton, MA, for approximately 15 days (Massachusetts Department of Fish and Game 2008). Low flow events can also negatively impact the wetlands of the MIMA by altering surface water hydroperiods. There is no information on surface water hydroperiods at the park as this resource is not currently monitored.

Groundwater Contamination

Hanscom Air Force Base and the civilian L.G. Hanscom Field occupy approximately 453 ha in the towns of Bedford, Concord, Lexington, and Lincoln. The airfield was constructed in 1941 and military operations were present from 1942 to 1973. In the early 1970's the airfield and surrounding land were given to the Massachusetts Port Authority (MassPort) which currently operates a civilian airport as L.G. Hanscom Field (MassPort 2008). The Air Force still occupies approximately 162 ha and operates the Electronic Systems Division of the Air Force Systems Command at Hanscom Air Force Base. During the 32 years that the Air Force occupied the facility numerous hazardous substances were used, generated, and disposed of on what is now MassPort property and on the Air Base (US EPA 2008d). The site is considered a Superfund site by the U.S. Environmental Protection Agency (US EPA) (US EPA ID: MA8570024424) (US EPA 2008d). L. G. Hanscom Field ranks 9th of 27 contamination sites throughout Massachusetts and 6th of 12 contamination sites within Middlesex County in terms of overall site contamination. On a scale of 0 to 100%, with 100% being the most hazardous, the US EPA has ranked both the overall site and the ground water migration at L.G. Hanscom Field/Hanscom Air Force Base at 60-70% and 90-100%, respectively (ScoreCard.org 2008). The substances present include chlorinated solvents, gasoline, jet fuel, aromatic solvents, tetraethyllead, and PCBs. Contaminates detected within groundwater at L.G. Hanscom Field are 1,1,1-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethylene, 1,2-dichloroethane, 1,2- dichloroethylene, tetrachloroethylene, trichloroethylene, and vinyl chloroide (ScoreCard.org 2008; US EPA 2008d).

In 1984, three of the Bedford town wells were closed when they were found to be contaminated with volatile organic compounds (VOCs) with the airfield the likely source of the groundwater contamination. Since 1991, contaminated ground water in the vicinity of the airfield has been extracted and treated; however, the source of the contamination remains unknown (US EPA 2008d). Numerous remediation efforts have taken place on both the Air Force and MassPort properties to address contamination issues, with the final remediation completed in September of 2007 (US EPA 2008d). The US EPA currently monitors the site and submits reports every five years, with the most recent review in 2007 that found that the all implemented remedies "are currently protective of human health and the environment" (US EPA 2007; US EPA 2008d).

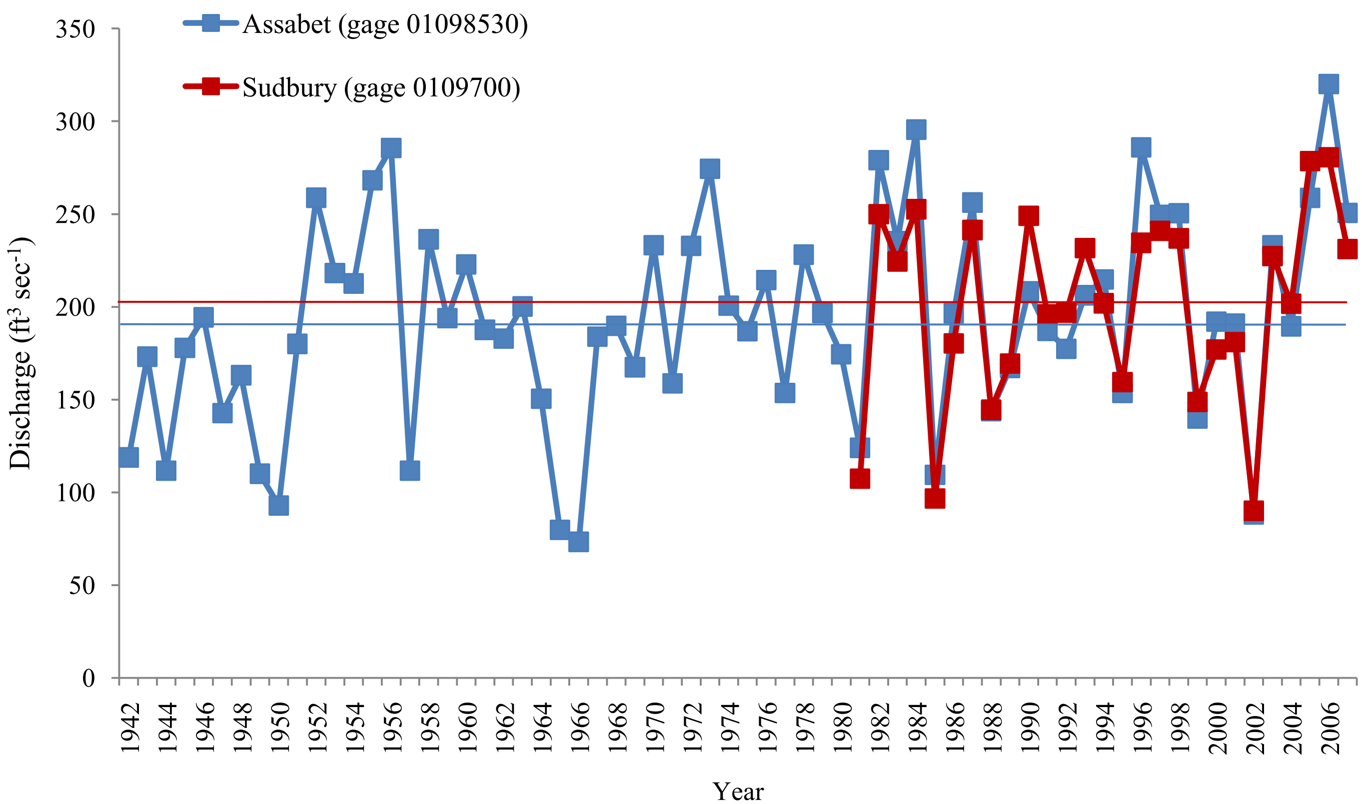

Figure 22. Average annual streamflow ($ft^3\ sec^{-1}$) for USGS stream gage stations upstream of MIMA on the Assabet and Sudbury Rivers. Horizontal lines indicate median streamflow over the period of record for each gage (USGS National Water Information System, data retrieved September 2008).

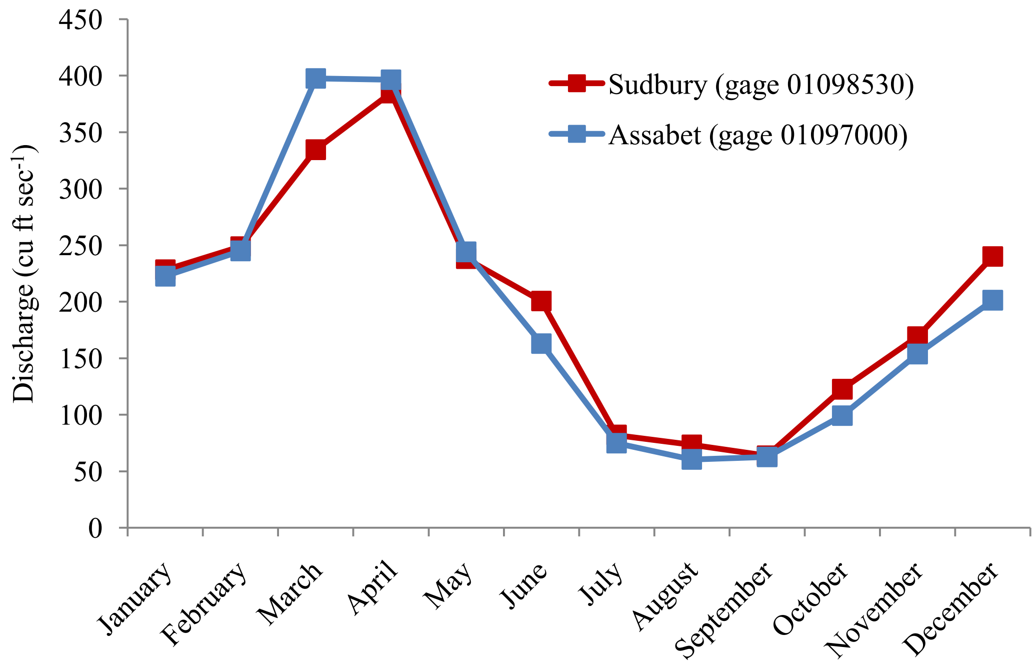

Figure 23. Average monthly stream discharge (cu ft sec^{-1}) for USGS stream gage stations upstream of MIMA on the Assabet and Sudbury Rivers. Period of record: Assabet gage: 1941-2007; Sudbury gage: 1979-2007 (USGS National Water Information System, data retrieved March 2009).

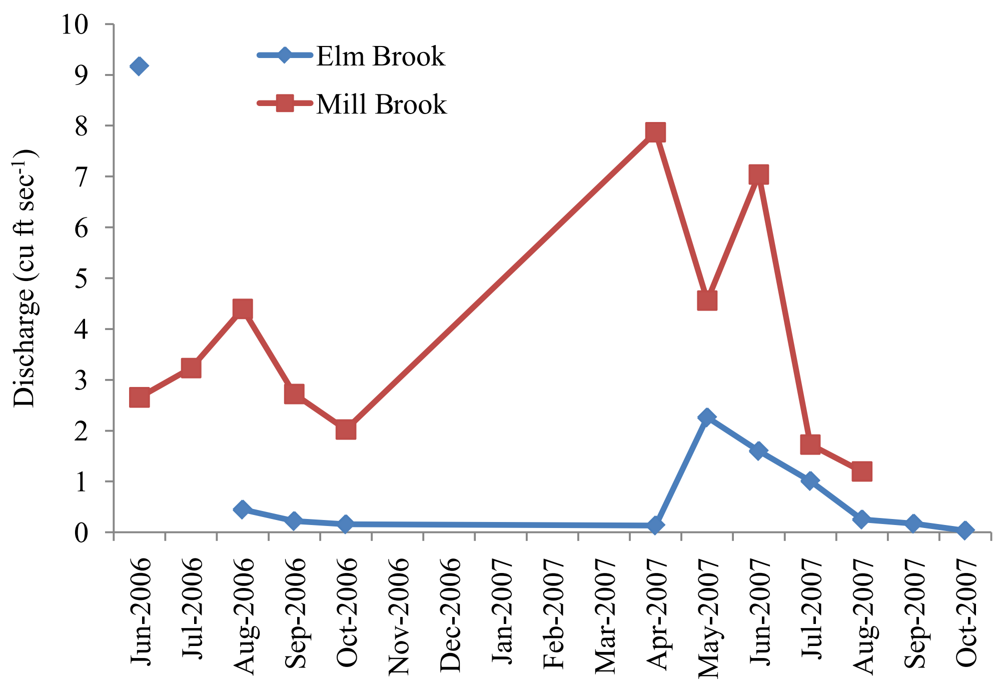

Figure 24. Stream discharge (cu ft sec^{-1}) for Elm Brook and Mill Brook. Data from NETN water quality monitoring (B. Mitchell personal communication).

Water Quality

Water quality is assessed throughout Massachusetts on a regular basis as part of the requirement of the Clean Water Act (CWA). Section 305(b) of the CWA outlines the process whereby waters are evaluated for their ability to support each state's designated use water quality standards. Designated uses include aquatic life support, fish and shellfish consumption, drinking water supply, and primary (swimming) and secondary (boating) contact recreation. The 303(d) section of the CWA requires states to identify those waterbodies that do not meet or are not expected to meet surface water quality standards and to schedule them for development of a Total Maximum Daily Load (TMDL). The goal of a TMDL is to bring the waterbody into compliance with water quality standards by establishing the maximum amount of a pollutant that can be present while still meeting public health water quality standards and maintaining the designated beneficial uses for those waters. CWA distinguishes between "pollutants" such as nutrients, metals, pesticides, solids and pathogens that all require TMDLs and "pollution" such as low flow, habitat alterations, or non-native species infestations (e.g., aquatic macrophytes) that do not require TMDLs. The restoration of these waters requires measures other than TMDL development and implementation. In Massachusetts, the term "pathogens" as an impairment directly corresponds to fecal coliform bacteria (Commonwealth of Massachusetts 2002). Waters are evaluated every two years and a report is provided to the US EPA. State's can categorize each waterbody or waterbody segment into one of the following five categories (Commonwealth of Massachusetts 2006):

1. Unimpaired and not threatened for all designated uses;
2. Unimpaired for some uses and not assessed for others;
3. Insufficient information to make assessments for any uses;
4. Impaired or threatened for one or more uses but not requiring the calculation of a TMDL; or
5. Impaired or threatened for one or more uses and requiring a TMDL.

Three waterbodies or stream/river segments that have portions in MIMA have been routinely evaluated for water quality by the Commonwealth of Massachusetts: the Concord River at the confluence with the Sudbury and Assabet Rivers (segment ID MA82A-07) (North Bridge Unit); Mill Brook from the outlet of Crosby Pond to the confluence with the Concord River (segment ID MA82-20) (Battle Road Unit); and Elm Brook from the headwaters to confluence with Shawsheen River (segment ID MA83-05) (Battle Road Unit). One of the sampling stations for Elm Brook (Merrimack River Watershed Council ID EB0.5) is inside the park boundary on the north side of the Route 2A crossing, in Lincoln, just before the Concord Line. The baseline water quality assessment for MIMA (NPS 1996b) found no historic water quality monitoring stations in the park, and those in the study area (within three miles upstream and one mile downstream) represented only one time or intensive single-year sampling prior to 1996. A Level I Water Quality Inventory sampled five stations at MIMA once per season from October 1998 to October 1999 (Farris and Chapman not dated). The NETN initiated water quality monitoring at MIMA in 2006 at the Concord River, Elm Brook, and Mill Brook (Lombard et al. 2006) (Figure 3). These sites are monitored from April through October for temperature, dissolved oxygen, and pH. In addition, water samples are taken twice per year (May-June and August-September) to test for additional water quality parameters (B. Mitchell personal communication; NETN 2007b).

In 1994, the Massachusetts Department of Public Health (DPH) issued a statewide advisory for fish consumption for all fresh waterbodies due to concerns of mercury contamination. This advisory was further revised in 2001 to include pregnant women, women of childbearing age who may become pregnant, nursing mothers, and children less than 12 years of age to avoid eating fish from all freshwater bodies. Because the statewide advisory encompasses all freshwaters, these waters cannot be considered as “fully supporting” the fish consumption use (Commonwealth of Massachusetts 2006).

The segment of the Concord River (segment ID MA82A-07) that flows through the North Bridge Unit has been assessed for water quality by the state since 1998. This is a Class B, warm water fishery, and is a treated water supply river. Class B waters are designated as habitat for fish, other aquatic life, and wildlife and for primary and secondary contact recreation. They are also suitable as a water supply with appropriate treatment, irrigation, and for compatible industrial cooling processes, and have good aesthetic value (Commonwealth of Massachusetts 2005). This segment is listed by the state as impaired or threatened and needing TMDL (category 5) and was most recently assessed in 2008 as impaired for metals, nutrients, and pathogens (fecal coliform) and exotic species (non-native aquatic macrophytes) (Commonwealth of Massachusetts 2008) (Table 31). The exotic species assessment parameter (non-native aquatic macrophytes) may be a recent addition to assessment criterion, rather than a reflection of recent invasion by macrophytes as non-native macrophytes were documented as early as 2001 in this segment (Commonwealth of Massachusetts 2005). The pollutants requiring TMDLs for this segment of the Concord River are metals (other than mercury), pathogens, and nutrients (Commonwealth of Massachusetts 2006). As of 2008, no TMDLs have been reported by the state to the US EPA. The 305(b) Assessment for 2002 listed this segment of the Concord River as “not supporting” for the designated use category of “fish consumption” due to metals and total toxics from contaminated sediments and legacy/historical pollutants (US EPA 2008c). The Baseline Water Quality Data Inventory and Analysis (NPS 1996b; Lombard 2004) indicated that sites outside the park’s boundaries, on the Concord River and its tributaries, periodically exceeded the US EPA criteria for dissolved oxygen, pH, and dissolved copper. Screening limits for freshwater bathing were exceeded by both total coliform and fecal coliform (NPS 1996b; Lombard 2004). There are legacy data for two stations on the Concord River and its tributaries (Assabet and Sudbury Rivers) which were monitored for short periods (e.g., one year) (NPS 1996b). The snapshot water quality sampling conducted in 1999 showed water quality parameters of the Concord River that fell within the minimum standards for Class B waters, with chlorophyll, total N and P levels that were representative of a mesotrophic water body (Farris and Chapman not dated).

Mill Brook (segment ID MA82-20), a tributary of the Concord River, flows adjacent to the Battle Road Unit and through the North Bridge Unit, is a Class B water and is designated as habitat for fish, other aquatic life, and wildlife and for primary and secondary contact recreation. It is suitable as a water supply with appropriate treatment, irrigation, and for compatible industrial cooling processes, and has good aesthetic value (Commonwealth of Massachusetts 2005). Mill Brook was most recently assessed in 2008. It has been designated a category 4c waterbody indicating that the waterbody is impaired by the non-pollutant stressor of “other

Table 31. Historical and current US EPA water quality assessments for waterbodies at MIMA. "X" indicates the waterbody was listed as impaired for that parameter.

Assessment Year	Metals	Nutrients	Pathogens (fecal coliform)	Turbidity	Exotic species	Other habitat alterations
MA82A-07 Concord River (segment ID 8246500)						
2008	X	X	X		X	
2006	X	X	X		X	
2004	X	X	X			
2002	X	X	X			
1998	X	X	X			
MA82A-20 Mill Brook (segment ID 8246750)						
2008						X
2006						X
2004						X
2002						X
MA83-05 Elm Brook (segment ID 8349375)						
2008			X	X		X
2006			X	X		X
2004			X	X		X
2002			X	X		
1998			X	X		

habitat alterations" (Commonwealth of Massachusetts 2008) (Table 31). Other habitat alterations are defined as the degradation, loss, or alteration of aquatic habitat due to physical degradation, riparian alteration, channel modification, or hindrance of fish passage or migration. The 305(b) Assessment for 2002 listed Mill Brook as "not supporting" for the designated aquatic life use category of "fish, shellfish, and wildlife protection and propagation" due to "other habitat alterations" from municipal sources (e.g., urbanized high density area) and urban-related runoff and stormwater (US EPA 2008c). There are no legacy data available for this station (NPS 1996b; US EPA 2008c). In 1999, water quality parameters for Mill Brook fell within the minimum standards for Class B waters, except for one sample date in October 1999, when oxygen levels fell below the minimum. This could have been a temporary effect of a severe drought followed by a substantial rainfall in October of 1999 (Farris and Chapman not dated). The NETN water monitoring program (2006 and 2007 monitoring) detected elevated levels of total phosphorus in Mill Brook. All other sampled parameters (total nitrogen, maximum temperature, minimum dissolved oxygen, pH, and acid neutralizing capacity) were within designated US EPA ranges (NETN 2007b).

Elm Brook (segment ID MA83-05) is listed as a category 5 waterbody (impaired or threatened and needs a TMDL) and was most recently assessed in 2008 (Commonwealth of Massachusetts 2008) (Table 31). The headwaters of Elm Brook lie just outside MIMA's boundary. Elm Brook is impaired by pathogens, turbidity, and other habitat alterations. The 305(b) Assessment for 2002 listed Elm Brook as partially supporting "fish, shellfish, and wildlife protection and propagation", "secondary contact recreation" (e.g., boating), and "aesthetics" and not supporting for "primary contact recreation" (e.g., swimming). The causes of these impairments were pathogens and turbidity due to unknown sources and municipal sources (e.g., urbanized high density area) and urban-related runoff and stormwater (US EPA 2008c). There are two historic water quality monitoring stations on Elm Brook, but neither had any associated legacy data (NPS 1996b). Water quality parameters fell within the minimum standards for Class B waters in 1999 (Farris and Chapman not dated). The NETN water monitoring program (2006 and 2007 monitoring) detected elevated levels of total nitrogen in Elm Brook. All other sampled parameters (total phosphorus, maximum temperature, minimum dissolved oxygen, pH, and acid neutralizing capacity) were within designated state or US EPA ranges (NETN 2007b).

The bacterial TMDL for Elm Brook was developed in 2002. At Elm Brook, violations of the bacterial standard were regularly observed during both wet and dry weather events and this waterway has violated water quality standards for every period in which data are available (Commonwealth of Massachusetts 2002). The bacterial problem occurs throughout the Shawsheen River watershed, including the Shawsheen River and its three tributaries, Elm Brook, Roger's Brook, and Vine Brook. Elm Brook, along with several other waterbodies within the watershed, had exceedingly high bacteria concentrations (>5000#/100 ml) in 1997, with some samples having concentrations as high as 26,000#/100 ml (Commonwealth of Massachusetts 2002). The sources of fecal coliform contamination have been identified as leaking septic systems and stormwater runoff. A possible sewer leak was detected at one of the water quality stations on Elm Brook (station EB 4.0) but this station is downstream of the portion of Elm Brook that is in MIMA (Commonwealth of Massachusetts 2002). Urban storm water runoff appears to be a significant wet weather source of bacteria to Elm Brook (Commonwealth of Massachusetts 2002).

The water quality of the palustrine wetland near the Bloody Angle of the Battle Road Unit (red maple-black gum swamp and vernal pool area, Figure 12) was also sampled in 1999 (Farris and Chapman not dated). This snapshot sampling revealed water quality parameters that exceeded the minimum standards for Class B waters in two of the sampling periods (October 1998 and June 1999). Oxygen and pH values were below minimum standards; however, negative alkalinities could be expected in water bodies such as these due to the humic-rich litter bottom layer (Farris and Chapman not dated). Total nitrogen was the highest of all sites sampled during this effort, implying substantial nutrient input. The source of the nutrient input could not be ascertained and the authors suggested the collection of additional data was needed to determine whether the levels observed were indicative of a seasonally stressed habitat or an artifact of a drought year (Farris and Chapman not dated). Farris and Chapman (not dated) also sampled an un-named pond near the Visitor Center in the Battle Road Unit (Figure 3). Water quality parameters (oxygen and pH) of this site also fell outside the minimum parameters for Class B waters during some of the sampling periods. Farris and Chapman (not dated) noted that this pond was actually a palustrine wetland and that the observed trends in oxygen, pH, and chlorophyll might be expected because of the high natural nutrient regeneration rates (similar to the sample site near the red maple-black gum swamp and vernal pool area).

Nutrient loading from adjacent residential and industrial areas to critical waterways and wetland habitats is a primary water quality concern for MIMA (Farris and Chapman not dated). As of 2007 only 30% to 35% of the developed parcels in Concord were connected to the town sewer system (Town of Concord, Massachusetts 2007). It is anticipated that the town's wastewater treatment plant will soon reach its maximum capacity of 1.2 million gallons per day. The remaining developed parcels rely on some form of on-site septic system (Town of Concord, Massachusetts 2007).

Populations of amphibians that utilize Mill Brook, such as the spring peeper, northern green frog, wood frog, American bullfrog, northern leopard frog, American toad, pickerel frog, snapping turtle, and painted turtle may be impacted by the degraded water quality of Mill Brook. Water quality of the Concord River is impaired by metals, nutrients, pathogens, and exotic aquatic plant species all of which could negatively impact the population of snapping and painted turtles that are found in the river. Two state listed freshwater mussel species (triangle floater and eastern pondmussel) have been observed in the towns of Lincoln and Concord (Alden 1998; NPS 2008d). These species may be adversely affected by the degraded water quality and habitat alterations if they are present in these waterways.

The presence of brook trout in Elm Brook indicates that at least a portion of the brook is capable of supporting a species that is sensitive to impaired water quality and habitat alterations, but also indicates that these impairments could threaten this population. Additionally, Elm Brook is listed as the only breeding area for the northern two-lined salamander and a decline in water quality could also negatively impact this species. The Massachusetts Division of Fisheries and Wildlife (2007b) cites physical habitat alteration and declines in water quality and quantity as factors leading to the restriction and reduction of brook trout populations, impairments for which Elm Brook has been listed for by the US EPA. Verification of the origin of this brook trout population (native vs. introduced) should be a priority for the park. If the population is truly native, it would be the only native population of brook trout within the Shawsheen River watershed and management plans to protect and preserve the population should be formulated.

Condition Assessment for Water Resources

The Sudbury-Assabet-Concord (SuAsCo) watershed and the Assabet, Sudbury, and Concord Rivers have all been classified as stressed basins and/or rivers based on historical flow patterns. Low flow conditions may adversely affect the fragile wetlands and streams and the organisms that utilize these resources in MIMA as well as other important ecological areas outside of the park such as the Great Meadows National Wildlife Refuge (Weiskel and Zarriello 2008). Based on best professional judgment the condition assessment of quantity of water was rated as "caution" and the trend in water quantity was rated as a "declining trend" (Table 32). Stream flow data for Mill Brook and Elm Brook have only been collected since June 2006, and there were not enough data available to date to assess the condition of this resource and therefore the status of this resource was assessed as "unknown".

The Concord River has been assessed as impaired due to metals, nutrients, and pathogens (fecal coliform) from 1998 to 2004. In 2006 and 2008, "exotic species" was added as a fourth impairment (Table 31). Non-native aquatic species were documented as early as 2001 in the river and the addition of exotic species as an impairment in 2006 and 2008 may represent a new impairment category rather than a recent degradation of the Concord River. Mill Brook has consistently been assessed as impaired by "other habitat alterations" since 2002. Elm Brook was listed in 1998 and 2000 with only two water quality impairments, pathogens (fecal coliform) and turbidity, while in 2004 to 2008 the impairment of "other habitat alterations" was added (Table 31), indicating that this waterbody is possibly declining in condition. Based on these water quality assessments and best professional judgment, all waters were given a condition assessment rating of "significant concern". It also appears that these waterways are deteriorating or at the very least not improving in terms of water quality, therefore the condition assessment for water quality trend was rated as a "declining trend" (Table 32).

It is possible that ground water at the park may be contaminated from L.G. Hanscom Field/Hanscom Air Force Base, but currently there is no ground water monitoring at MIMA to address this potential problem. Similarly, surface water hydroperiods are not currently monitored at the park. Therefore, the current status of these resources was assessed as "unknown".

In general, the data reliability for water resources was rated as "good" (Table 32).

Table 32. Condition assessment scores for water resources at MIMA. Average scores are given when more than one metric was assigned a condition rating.

Metric	Condition	Numerical Score	Comments
<u>Current Condition of Water Resources</u>			
Water quantity – streamflow (river)	● Caution	0.50	The Concord River Basin is designated as stressed.
Water quantity – streamflow (streams)	○ Unknown	-	Not enough data to assess condition.
Water quality – Concord River, Elm Brook, Mill Brook	● Significant concern	0.16	All assessed as impaired by US EPA for several parameters (Table 31).
Ground water – quantity & quality	○ Unknown	-	Unknown, but contamination of nearby groundwater wells has been observed in the past.
Wetland hydroperiod	○ Unknown	-	No data available.
Overall condition score	-	-	Since only two of five resources could be assessed, an average condition score would not be appropriate.
<u>Trend Data for Water Resources</u>			
Water quantity	↓ Declining trend	0.16	SuAsCo basin is designated as a stressed basin.
Water quality	↓ Declining trend	0.16	Overall, water quality of assessed waters has not improved, and may have declined from 1998 to 2006 (Table 31).
Overall trend score	↓ Declining trend (0 to 0.33)	0.16	
<u>Data reliability for Water Resources</u>			
US EPA water quality assessment data	● Good	0.84	
NETN water quality data	● Good	0.84	Data collection just recently initiated, no long-term data available, but data are of "good" quality.

Table 32. Condition assessment scores for water resources at MIMA (continued).

Metric	Condition	Numerical Score	Comments
NETN stream gage data	Good	0.84	Data of good quality, but only monitored since June 2006.
USGS stream gage data	Good	0.84	
Level I water quality and inventory (Farris and Chapman not dated)	Limited	0.16	Only one year of data, but critical ecological habitats were surveyed.
Overall Data Reliability Score	Good (0.68 to 1.0)	0.70	

Soils

Soil chemistry is monitored as part of the NETN Forest Monitoring Protocol (Tierney and Faber-Langendoen in review). The protocol, initiated in 2006, monitors several vital signs at 20 co-located permanent plots at MIMA. Parameters that are monitored are soil horizon characteristics, presence of earthworms, and soil chemistry. Currently only data are available from the NETN on soil chemistry parameters. Soil chemistry parameters include the molar ratio of calcium to aluminum (Ca:Al) as an indicator of acid stress, and the ratio of carbon to nitrogen (C:N) as an indicator of forest nitrogen status and atmospheric deposition (Tierney et al. 2009; Tierney and Faber-Langendoen in review). The NETN Forest Monitoring Protocol assigns forest condition scores for each of these parameters as "good", "caution", or "significant concern", equivalent to the ratings in this report. Condition scores for soil chemistry metrics were estimated by averaging the NETN ratings, using midpoint scores (refer to Table 1), across all plots to attain an average score for that parameter. Soil chemistry data from 2006 indicated the ratio of Ca:Al was rated was "significant concern" and the C:N ratio was rated as "caution", yielding an overall rating for soil chemistry as "significant concern" (average score of 0.27) (Table 33).

The majority of soil types within MIMA are fine sandy loams. The dominant type, composing 15% of the soils in the park, is stony Montauk fine sandy loam (Figure 25). Other predominate soil types, representing at least 5% of the soils in MIMA are Scarboro mucky fine sandy loam, Deerfield loamy sand, Canton fine sandy loam, Windsor loamy sand, Hinckley loamy sand, and Wareham loamy fine sand (USDA NRCS 2008a, 2008b) (Figure 25).

The Soil Survey Geographic Database (SSURGO) rates the different soil types based on their importance to farmlands as well as for a variety of habitat types (e.g., conifer habitat, grassland habitat, wetland habitat) (Table 34) (USDA NRCS 2008a, 2008b). Ratings related to farmland are prime farmland (land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops), unique farmland (farmland other than prime farmland that is conducive to the production of specific high value food and fiber crops such as tree nuts, cranberries, and other fruits and vegetables), farmland of statewide importance (farmland other than prime farmland and unique farmland that is important for the production of food, feed, fiber, forage, and oil seed crops), and not prime farmland. Approximately 17% of the soils in MIMA were rated as "prime farmland" while 52% of the soils were rated as "not prime farmland". The remaining soils were distributed between "unique farmland" and "farmland of statewide importance" (6% and 26%, respectively) (Table 34).

The dominant soil type in MIMA, the stony Montauk loam which is found only within the Battle Road Unit (Figure 25), is rated good for conifer, hardwood, and herbaceous habitats, fair for woodland habitats, and is rated as not prime farmland (Table 34). The next dominant soil type, Scarboro mucky fine sandy loam, which comprises 9% of the park is rated good for wetland habitat, fair for water habitat and wetland wildlife, and is rated as not prime farmland (Table 34). The majority of the soil types in MIMA ranked "good" for habitats associated with forested and shrubland (conifer, hardwood, herbaceous, and woodland) habitats (Figure 25). This corresponds to the historical landscape of the area, prior to Colonial settlement, when the landscape was forested.

Table 33. Soil chemistry ratings from 2006 NETN forest condition monitoring (B. Mitchell, personal communication).

Forest Condition Metric	Forest Score	Average Score from NETN plots
Ca:Al ratio	Significant concern	0.16
C:N ratio	Caution	0.39
Overall average score	Significant concern	0.27

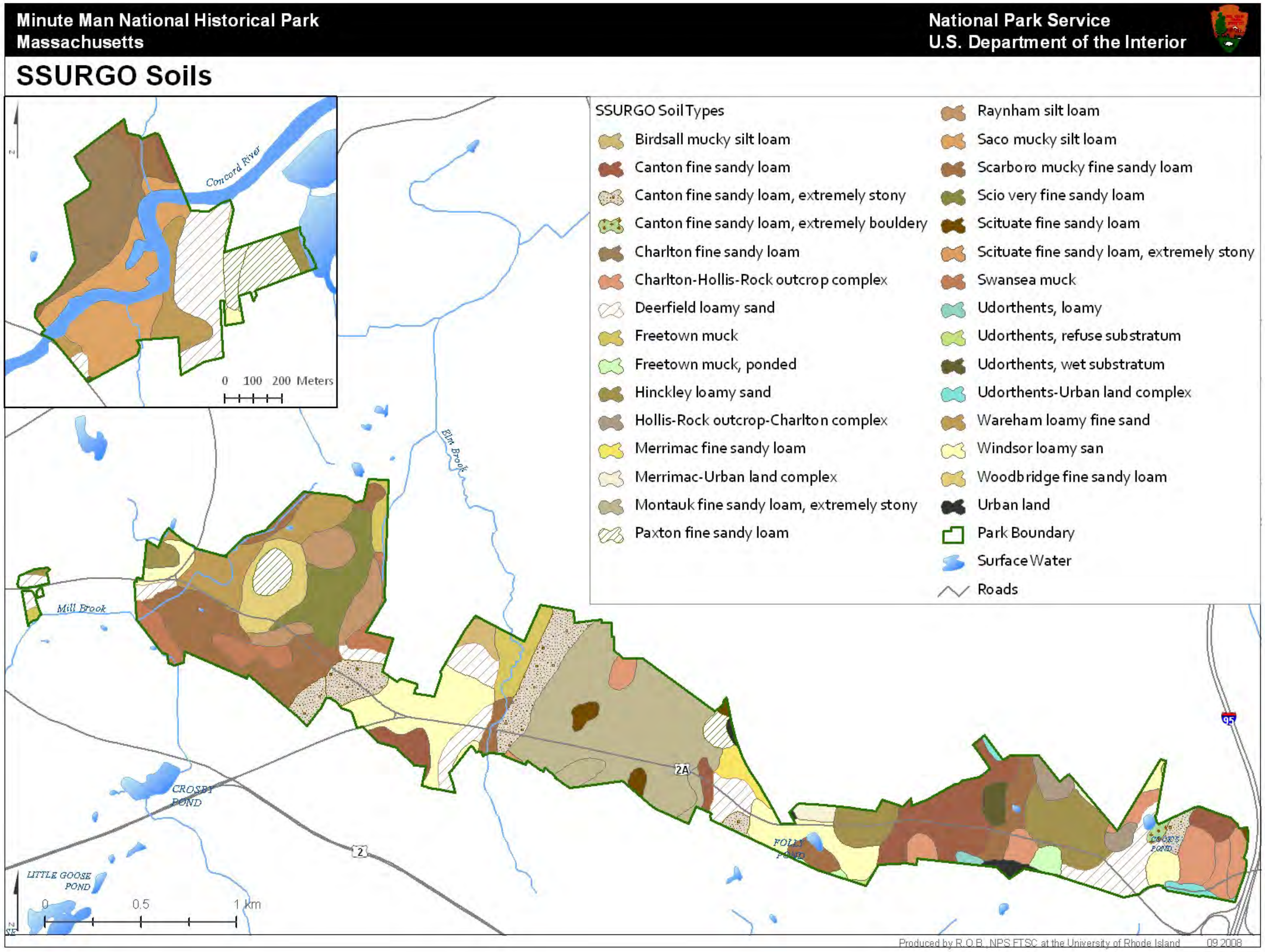

Figure 25. Soil types of MIMA based on SSURGO data. The different degrees of slope were combined for each soil type for simplification.

Table 34. Ratings for MIMA soils (only soil types that were rated by the SSURGO data are shown) for different habitat types. Farmland soil codes are: PF: Prime farmland; FS: Farmland of statewide importance; FU: Farmland of unique importance; NP: Not prime farmland. Habitat codes are A: conifer, B: grain, C: grass, D: hardwood, E: herbaceous, F: openland wildlife, G: water, H: wetland wildlife, I: wetland, J: woodland. Data from SSURGO (USDA NRCS 2008a).

Soil Type	Percent Area	Farmland Code	Good	Fair	Poor	Very poor
Birdsall mucky silt loam, 0 to 1 percent slopes	0.6%	NP	I	G, H	A, C, D, E, F, J	B
Canton fine sandy loam, 15 to 25 percent slopes, extremely bouldery	0.4%	NP	A, D, E		B, C, F	G, H, I
Canton fine sandy loam, 3 to 8 percent slopes	6.3%	PF	A, C, D, E, F, J	B	I	G, H, I
Canton fine sandy loam, 3 to 8 percent slopes, extremely stony	1.7%	NP	A, D, E	J	F, I	B, C, G, H
Canton fine sandy loam, 8 to 15 percent slopes, extremely bouldery	0.2%	NP	A, D, E		F	B, C,G, H, I
Canton fine sandy loam, 8 to 15 percent slopes, extremely stony	4.0%	NP	A, D, E		F	B, C, G, H, I
Charlton fine sandy loam, 3 to 8 percent slopes	1.6%	PF	A, C, D,E, F, J	B	I	G, H
Charlton fine sandy loam, 8 to 15 percent slopes	0.8%	FS	A, C, D, E, F,J	B		G, H, I
Charlton-Hollis-Rock outcrop complex, 3 to 8 percent slopes	3.5%	NP	A, D, E, J		C,F, I	B, G, H
Charlton-Hollis-Rock outcrop complex, 8 to 15 percent slopes	1.1%	NP	A, D, E, J		C,F	B, G, H, I
Deerfield loamy sand, 0 to 3 percent slopes	7.4%	FS		C, E, F	A, B,G, H, I, J	
Deerfield loamy sand, 3 to 8 percent slopes	3.5%	FS		C, E, F	A, B,D, I, J	G, H
Freetown muck, 0 to 1 percent slopes	2.4%	FU	G, H, I		A, C, D, E, F, J	B
Freetown muck, ponded, 0 to 1 percent slopes	0.6%	FU	G, H, I			A, B, C, D, E,F, J
Hinckley loamy sand, 25 to 35 percent slopes	1.4%	NP			A, C, D, E, F, J	B, G, H, I
Hinckley loamy sand, 3 to 8 percent slopes	4.7%	FS			A, B, C, D, E, F, J	G, H, I
Hollis-Rock outcrop-Charlton complex, 15 to 25 percent slopes	1.1%	NP		E	A, C, D, F, J	B, G, H, I
Merrimac fine sandy loam, 3 to 8 percent slopes	0.7%	PF		A, B, C, D, E, F, J		G, H, I

Table 34. Ratings for MIMA soils for different habitat types (continued).

Soil Type	Percent Area	Farmland Code	Good	Fair	Poor	Very poor
Merrimac-Urban land complex, 0 to 8 percent slopes	0.5%	NP		A, B, C, D, E, F, J		G, H, I
Montauk fine sandy loam, 3 to 8 percent slopes, extremely stony	13.8%	NP	A, D, E	J	F, I	B, C, G, H
Montauk fine sandy loam, 8 to 15 percent slopes, extremely stony	1.0%	NP	A, D, E	J	F	B, C, G, H, I
Paxton fine sandy loam, 15 to 25 percent slopes	0.3%	NP	A, D, E, J	C, F	B	G, H, I
Paxton fine sandy loam, 3 to 8 percent slopes	1.5%	PF	A, C, D, E, F, J	B	I	G, H
Paxton fine sandy loam, 8 to 15 percent slopes	0.8%	FS	A, C, D, E, F, J	B		G, H, I
Raynham silt loam, 0 to 5 percent slopes	2.9%	NP	I	A, D, E, H, J	B, C, F, G	
Saco mucky silt loam, 0 to 1 percent slopes	2.8%	NP	I	G, H	A, C, D, E, F, J	B
Scarboro mucky fine sandy loam, 0 to 3 percent slopes	9.4%	NP	I	G, H	A, C, D, E, F, J	B
Scio very fine sandy loam, 3 to 8 percent slopes	3.4%	PF	A, B, C, D, E, F, J		I	G, H
Scituate fine sandy loam, 3 to 8 percent slopes	0.7%	PF	A, C, D, E, F, J	B	I	G, H
Scituate fine sandy loam, 3 to 8 percent slopes, extremely stony	0.1%	NP	A, D, E	J	F, I	B, C, G, H
Swansea muck, 0 to 1 percent slopes	2.6%	FU	G, H, I		A, C, D, E, F, J	B
Udorthents, loamy	0.2%	NP		Not rated for habitat		
Udorthents, refuse substratum	0.1%	NP		Not rated for habitat		
Udorthents, wet substratum	0.6%	NP		Not rated for habitat		
Udorthents-Urban land complex	0.5%	NP		Not rated for habitat		
Urban land	0.5%	NP		Not rated for habitat		
Wareham loamy fine sand, 0 to 5 percent slopes	4.7%	NP		C, E, F, I	A, B, D, G, H, J	
Windsor loamy sand, 0 to 3 percent slopes	2.5%	FS		E	A, B, C, D, F, J	G, H, I
Windsor loamy sand, 3 to 8 percent slopes	5.9%	FS		E	A, B, C, D, F, J	G, H, I
Windsor loamy sand, 8 to 15 percent slopes	0.7%	NP		E	A, B, C, D, F, J	G, H, I
Woodbridge fine sandy loam, 3 to 8 percent slopes	2.3%	PF	A, C, D, E, F, J	B	I	G, H

Air Quality and Atmospheric Deposition

The Massachusetts Department of Environmental Protection Air Assessment Branch (AAB) monitors air quality and ozone throughout the state at a network of 33 monitoring stations and submits all ambient air quality data to the Air Quality System (AQS), a national database that is administered by the US EPA (Commonwealth of Massachusetts 2007). Additionally, the US EPA monitors air quality throughout the United States at over 4000 monitoring sites (US EPA 2008a). At these sites criteria pollutants, non-criteria pollutants, and meteorological parameters are measured (although not all parameters are measured at all stations). Criteria pollutants that are monitored are sulfur dioxide (SO_2), ozone (O_3), carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), lead (Pb), particulate matter ≤10 microns (PM-10), and particulate matter ≤ 2.5 microns (PM-2.5). Non-criteria pollutants that are monitored are nitric oxide (NO), total nitrogen oxides (NO_x), total reactive oxidized nitrogen (NO_y), total suspended particulates (TSP), volatile organic compounds (VOCs), black carbon, acid deposition (measured as pH and conductivity), and toxics (health relevant VOCs, aldehydes, and metals). Meteorological parameters that are measured are wind speed and direction, relative humidity, temperature, barometric pressure, solar radiation, upper air wind and temperature, total B band ultraviolet radiation, and precipitation. There are several sites in Middlesex County that provide data to the US EPA.

The closest Mercury Deposition Network site is located in Wellfleet on Cape Cod, MA (MA01 [Latitude: 41.9758; Longitude: -70.0247]). The station is approximately 110 km southeast of MIMA and is operated by the National Park Service at Cape Cod National Seashore. This station has been in operation since 2003 and collects weekly information on total mercury in wet precipitation (National Atmospheric Deposition Program/National Trends Network [NADP/NTN] 2008).

The Clean Air Status and Trends Network (CASTNET) is the nation's primary source for dry deposition data and rural ground-level ozone. The closest CASTNET station to MIMA is located in Abington, CT (station ABT147, approximately 90 km southwest of MIMA [Latitude: 41.8402; Longitude: -72.0100]). CASTNET data are used in conjunction with other monitoring programs (e.g., NADP/NTN) to evaluate the effectiveness of emission reduction programs.

The NADP/NTN has a monitoring station located in Lexington, MA (MA13 [Latitude: 42.3839; Longitude: -71.2147]) (NADP/NTN 2008). The station is located approximately 10 km southeast of MIMA and has operated since 1982. This station monitors precipitation and precipitation chemistry (pH, sulfate, nitrate, ammonium, chloride, and base cations such as calcium, magnesium, potassium, and sodium).

The National Park Service Air Resources Division (NPS ARD) has a long history of participation in partnerships with agencies such as those previously mentioned (e.g., US EPA, NADP/NTN). The NPS ARD works to preserve, protect, enhance, and understand air quality and other resources sensitive to air quality in the National Park System by ensuring compliance with the Clean Air Act and the National Park Service Organic Act (NPS 2009). Air quality-related values include visibility, flora, fauna, cultural and historical resources, odor, soil, water, and virtually all resources that are dependent upon and affected by air quality. The NPS ARD oversees the national air resource management program for the NPS and has developed materials to assist in assessing air quality conditions for Natural Resource Condition Assessments (NPS 2009). These materials include park specific estimates of interpolated air quality data for ozone, atmospheric deposition, and visibility from the most recent data (2003 to 2007), and an estimate of condition (e.g., good, moderate, significant concern) for these parameters (e.g., Table 35) (NPS 2009).

Ozone is a health and environmental hazard that is produced by the reactions of certain air pollutants (e.g., industrial and automobile emissions) in the presence of intense, high-energy sunlight during hot summer months. It is a respiratory irritant, can reduce lung function and cause asthma attacks, reduce resistance to infection, and can inhibit growth of vegetation and cause leaf damage (Commonwealth of Massachusetts 2007). Long-term data (1998 to 2004) for air quality indicated that ground-level ozone was the main pollutant affecting air quality in Middlesex County (a main pollutant is defined by the US EPA as one that has the highest value for any day's air quality index or AQI) (US EPA 2008a). The number of days when ozone was the main AQI pollutant in Middlesex County was stable from 1999 through 2004, averaging 168 days per year. In 2005 to 2007, there was a dramatic increase to above 250 days per year (US EPA 2008a). Ozone is the only air pollutant considered by the US EPA to be non-attainment status for Middlesex County, MA (Figure 26). In fact, all 14 counties in Massachusetts have a non-attainment status for the 8 hr ozone standard (current standard is 0.075 parts per million [ppm]), indicating they have persistently exceeded the national air quality standard as set by the Clean Air Act (Commonwealth of Massachusetts 2007; US EPA 2008a) (Figure 27). The NPS ARD estimated ozone concentration at MIMA (five-year average of the 4^{th} highest 8 hr ozone concentration) as 0.079 ppm falling in the significant concern range (NPS 2009) (Table 35).

Acid rain is a broad term used to describe the mixture of wet and dry deposition from the atmosphere that contains higher than normal amounts of nitric and sulfuric acids. Acid rain can form from natural processes such as decaying vegetation or volcanic eruptions, and man-made sources, such as the combustion of fossil fuels that produce emissions of SO_2 and NO_x. These gasses react in the atmosphere with oxygen, water, and other compounds to form acid rain. Normal rain is slightly acidic because carbon dioxide dissolves into it forming weak carbonic acid, giving the resulting mixture a pH of approximately 5.6 at typical atmospheric concentrations of carbon dioxide (US EPA 2008b). The NPS ARD uses the amount of wet deposition of total nitrogen (N) and total sulfur (S) as a measure of condition for atmospheric deposition. Wet deposition was calculated by multiplying N or S concentrations in precipitation by a normalized precipitation amount (NPS 2009). The estimated wet deposition for MIMA was 3.80 kg ha^{-1} yr^{-1} for total N and 5.09 kg ha^{-1} yr^{-1} for total S, both of these values fall within the significant concern range (Table 35).

Natural visibility conditions are those estimated to exist in a given areas in the absence of human-caused visibility impairment. The NPS ARD estimates scores for visibility based on the deviation of current visibility conditions from estimated natural visibility conditions using an interpolation of the five-year averages. This score is expressed in terms of a Haze Index in deciviews (dv). As the Haze Index increases, visibility worsens. The visibility score for MIMA was estimated by the NPS ARD as 7.58 dv falling in the moderate condition range, equivalent to a rating of "caution" in this report (NPS 2009) (Table 35).

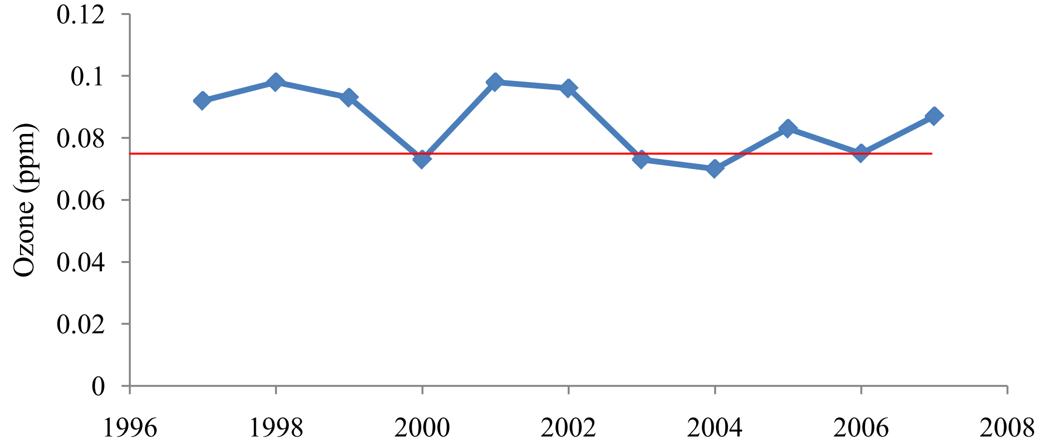

Figure 26. Ozone (8 hr averages) trends for Middlesex County, MA, from 1996 to 2008 (US EPA 2008a). US EPA standard for 8 hr ozone is 0.075 ppm (red line) (standard was previously 0.08 ppm, but was lowered in early 2008 to 0.075 ppm).

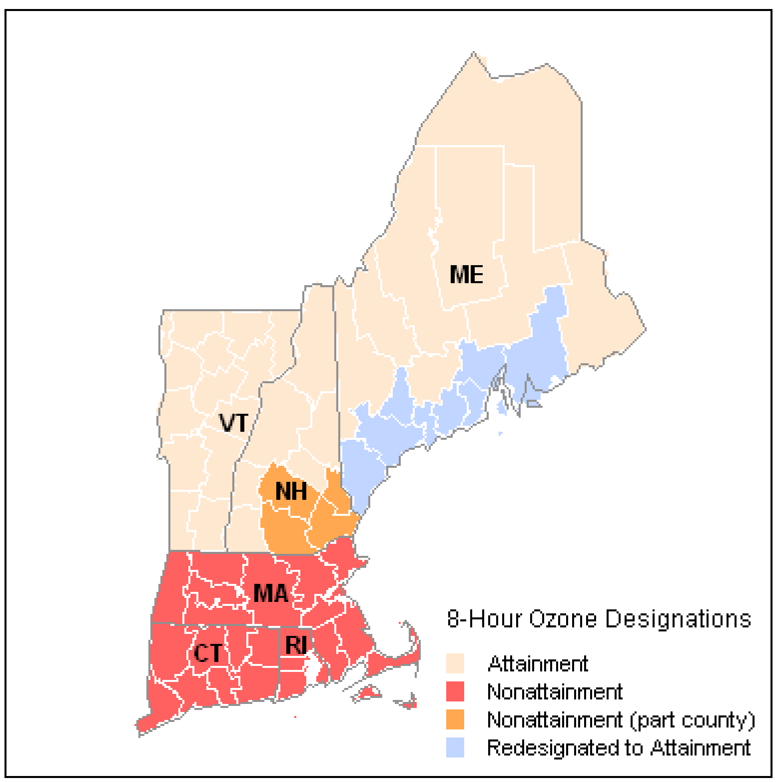

Figure 27. Attainment status for 8hr ground level ozone (1997standard of 0.08ppm) as of September 2, 2008 in US EPA Region 1. Map from US EPA (2008a), accessed February 16, 2009.

Table 35. Condition estimates for air quality parameters at MIMA as determined by the NPS ARD.

Air Quality Parameter	NPS ARD Condition Thresholds	MIMA value (estimated by NPS ARD)
Ozone	Good: ≤ 0.060 ppm Moderate: 0.061-0.075 ppm Significant Concern: ≥ 0.076 ppm	0.079 ppm (significant concern)
Total N wet deposition	Good: < 1 kg ha^{-1} yr^{-1} Moderate: 1-3 kg ha^{-1} yr^{-1} Significant Concern: > 3 kg ha^{-1} yr^{-1}	3.80 kg ha^{-1} yr^{-1} (significant concern)
Total S wet deposition	Good: < 1 kg ha^{-1} yr^{-1} Moderate: 1-3 kg ha^{-1} yr^{-1} Significant Concern: > 3 kg ha^{-1} yr^{-1}	5.09 kg ha^{-1} yr^{-1} (significant concern)
Visibility	Good: > 8 dv Moderate: 2-8 dv Significant Concern: < 2 dv	7.58 dv (moderate)

Soundscape

A soundscape refers to the total acoustic environment of an area. In the National Park setting, both natural and human sounds may be desirable and appropriate depending on the purpose and values of the park (NPS 2008c). For example, at MIMA human induced culture and historic sounds, such as cannon shots or musket fire, are appropriate and important components during re-enactment events. The soundscape, like water, scenery, or wildlife, is a valuable resource that can easily be degraded by inappropriate sounds or sound levels and as a result the soundscape requires careful management just as any other park resource (NPS 2008c).

Soundscape concerns for MIMA include aircraft associated noise from L.G. Hanscom Field and vehicular traffic from Route 2A that detract from the historic character of the park (Dietrich-Smith 2005). In the 1994 report to Congress on the effect of overflights within the National Park System, MIMA park managers were "extremely concerned" with aircraft related noise (NPS 1994). More recently, MIMA was ranked by the Coalition of National Park Service Retirees (CNPSR) as one of the top five National Parks with the most serious noise problems (CNPSR 2008; Environmental News Service 2008). Other studies have also mentioned noise as a potential negative influence on park resources. For example, Rice (1987) mentioned that species utilizing the Elm Brook wetlands may be impacted by aircraft noise from L.G. Hanscom Field. Since the late 1990's there has been a dramatic increase in the number of jet and turbo engine aircraft at the airfield (Arnold 2002) (Figure 28), which no doubt contributes to noise concerns for the park. MassPort is working cooperatively with local community and aviation groups to promote the "Fly Friendly Program", a noise abatement program aimed at reducing noise levels in and around L.G. Hanscom Field (MassPort 2008).

In 2006, MIMA began working with the NPS Natural Sounds Program to develop a Soundscape Management Plan, largely because of perceived inappropriate and excessive sound intrusions from aircraft and vehicles. Preliminary soundscape management zones, objectives, and indicators were developed for four management zones (Table 36). In 2007, MIMA initiated acoustic (attended audibility logging) monitoring at four sites (Figure 2). Attended audibility logging involved listening and logging the sources of all sounds heard during a 45-60 minute session. Metrics included identification of sources of sounds, percent time non-natural sounds were above natural ambient sounds, percent time natural/non-natural sounds were audible, noise-free intervals, duration of natural/non-natural sounds, and number of non-natural events (F. Turina via S. Colwell personal communication).

Preliminary data indicated non-natural extrinsic sounds often dominate the park's soundscape (Figure 29) and may be diminishing the park's historic character and compromising visitor experience. For example, at the three sites where useful data were returned (Route 2A Corridor, Hartwell's Tavern, and North Bridge Visitor Center) intrinsic natural sounds (birds and insects) were present, but aircraft and vehicular noise were also predominant noises (a fourth site that was monitored returned no useful data). In total, all non-natural noises were audible 80% to 95% of the time all sites, with aircraft noise audible 50% to 70% of the time at Hartwell's Tavern and the North Bridge Visitor Center (F. Turina via S. Colwell personal communication). The noise free interval, the average length of time during which no human-caused sound was heard, was on average, 1 min 40 sec at Hartwell's Tavern and 2 min 17 sec at the North Bridge Visitor Center (F. Turina via S. Colwell personal communication).

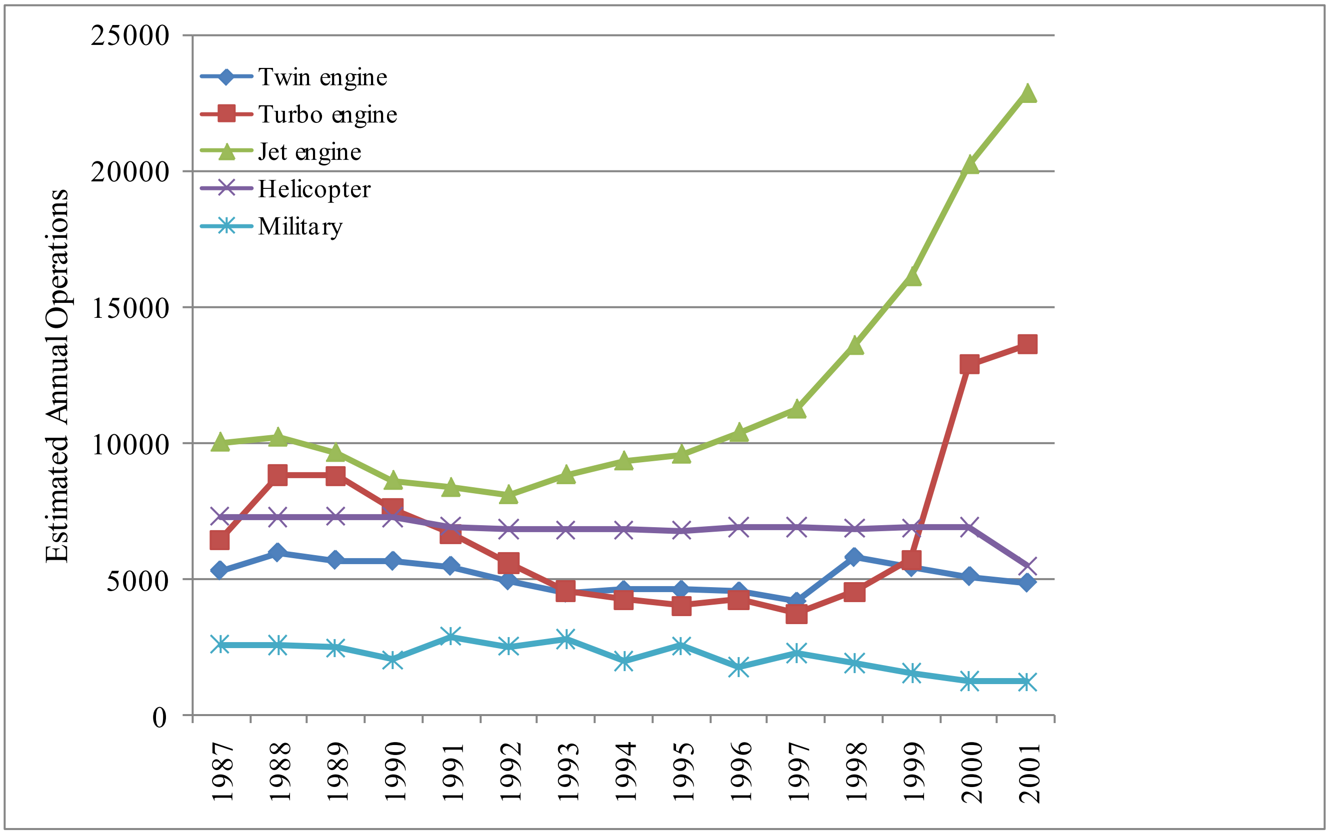

Figure 28. Estimated annual operations for selected aircraft at L.G. Hanscom Field from 1987 to 2001 (Data from Arnold 2002).

Table 36. Draft management zones and objectives for soundscape at MIMA. * 110dBA during interpretive programs (muskets, cannons), <60 dBA at other times.

Zone	Soundscape Management Objectives	Soundscape Management Indicators and Standards		
		Time Audible [1]	Time Above Ambient [2] (dBA)	Max dBA [3]
Battle Road/2A (Monitoring site: Route 2A corridor)	Human-caused sounds dominate the soundscape. However, vehicular and aircraft sounds will not diminish the commemorative character of Battle Road within the park or compromise the visitors' experience.	Up to 75%	Up to 75%	<60 dBA
Interpretive/Living History* (Monitoring site: Hartwell Tavern's)	Natural sounds dominate the soundscape. Frequent interpretive sounds can be heard. Interpretive programs and events can be conducted without interruption from noise. Sound of management and visitor activities in this zone will be mitigated to the greatest possible degree by using quiet technologies and by running vehicles and equipment the minimum time necessary.	Up to 50%	Up to 50%	<60 dBA Up to 110dBA
Developed/Visitor Facilities (Monitoring site: North Bridge Visitor Center)	Human-caused sounds are common in this zone. Natural sounds can also be heard. The sound of management and visitor activities in this zone will be mitigated to the greatest possible degree by using quiet technologies and by running vehicles and equipment the minimum time necessary for performing a function. Some noise-free intervals occur, and human-caused sound may be muted at times to accommodate the need for quality visitor experiences or sound-sensitive values to be appreciated.	Up to 75%	Up to 75%	<60 dBA
Natural/Cultural Landscape (Monitoring did not return any useful data)	The natural sounds dominate the area, although human-caused sounds are evident in some areas within the zone including areas adjacent to motorized travel corridors, open fields, and visitor use areas. The sound of management activities in this zone will be mitigated to the greatest possible degree using quiet technology and minimum impact practices.	<25%	<20%	<60 dBA

[1] Time Audible: percent time non-natural sounds are audible.
[2] Time Above Ambient: percent time non-natural sounds are greater than natural ambient.
[3] Max dBA: maximum sound level.

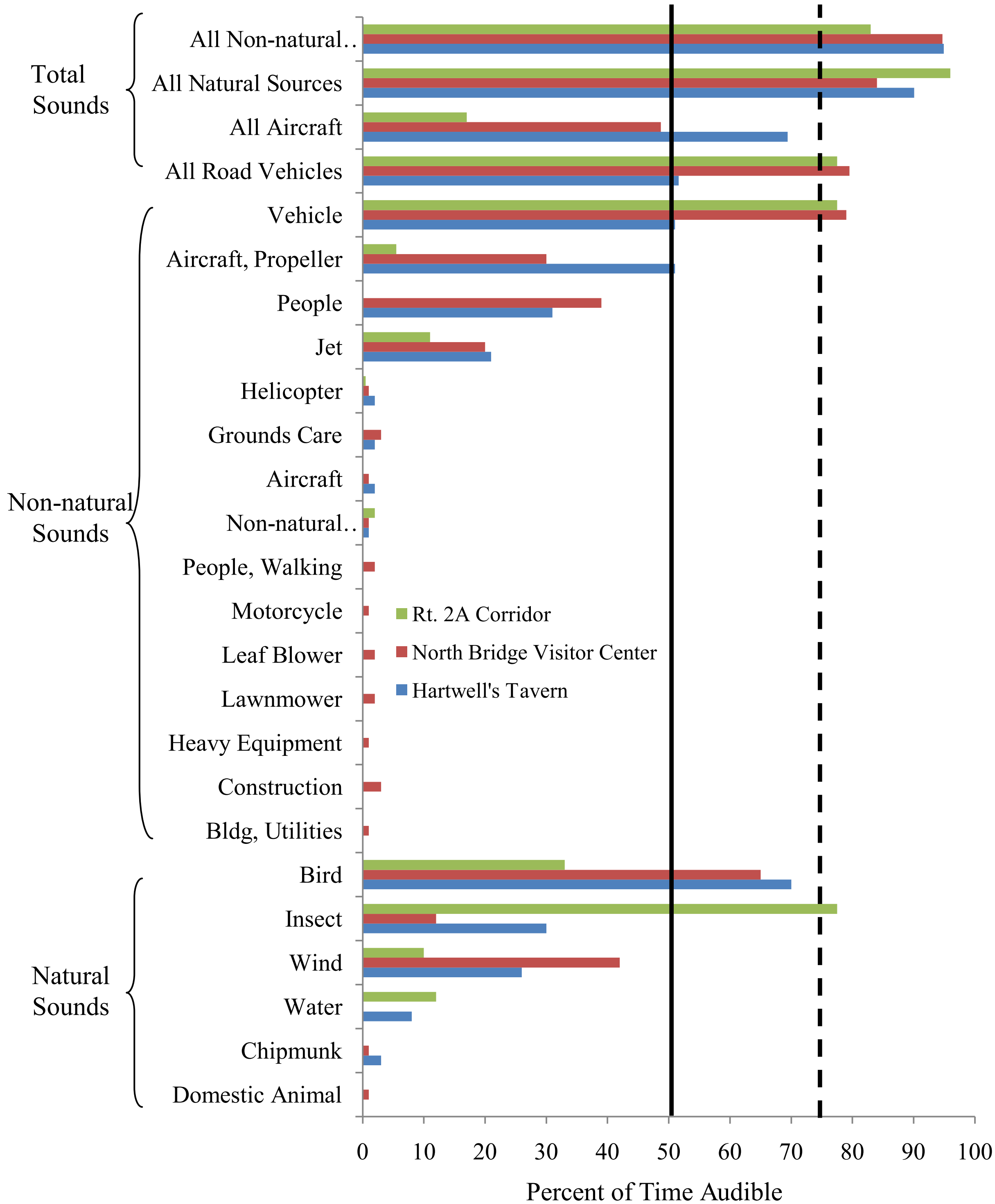

Figure 29. Percent of time non-natural and natural sounds were audible at three locations at MIMA in 2007. Lines indicate threshold values (solid line: Hartwell's Tavern; dashed line Route 2A and North Bridge sites) for non-natural sounds. Non-natural sounds above this threshold are inappropriate based on park management objectives. Draft data courtesy of F. Turina, NPS Natural Sounds Program.

Visitor Usage

Current visitation at MIMA is approximately 1 to 1.2 million visitors annually (Figure 30) (NPS 2008b). In 1996, MIMA was one of eight parks reviewed for threats caused by actives within parks borders (NPS 1996a). The report cited traffic on the roads bisecting MIMA affected the cultural resources (nearby historic structures), natural resources such as populations of small vertebrates (e.g., spotted salamander, spotted turtle), and visitor's enjoyment of the park (NPS 1996a). The roadway provides access to the park and mobility to park visitors, local residents, businesses and shoppers, and allows for speeds of up to 40 mph. Traffic on Route 2A can negatively impact the visitor experience at MIMA, manifesting itself in terms of traffic congestion, increases in travel time, traffic noise, environmental impacts, visual impacts, and safety concerns (Bryan et al. 2002). Average daily traffic volume on Route 2A has increased from 5,000 in 1960 to 20,000 vehicles daily in 2000, with only 1.4 percent of the two-way traffic related to park visitation (Bryan et al. 2002). Vehicular traffic also contributes to both air pollution and to the degradation of natural soundscape of the park (Dietrich-Smith 2005). Efforts have been made to reduce the impact of visitors on natural resources by building boardwalks through sensitive areas (e.g., certified vernal pool trail) and to positively increase the visitor experience by building trail systems (NPS 1993). Aside from the 1996 report there appears to be no further information on the impact of visitor use on the natural resources of MIMA.

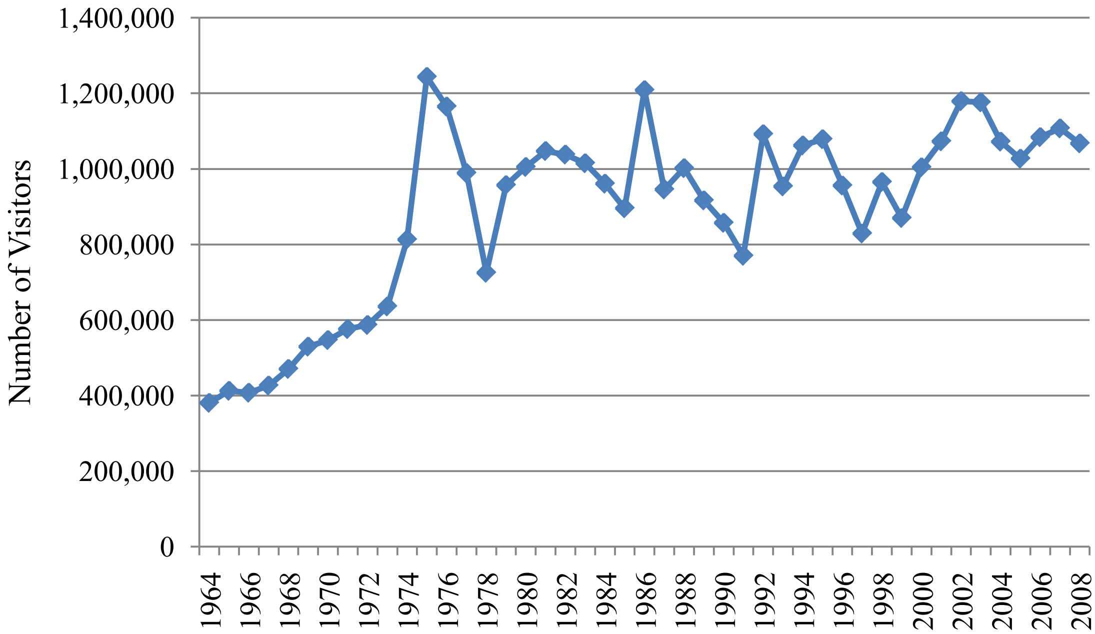

Figure 30. Number of recreational visitors at MIMA from 1964 to 2008 (NPS 2008b, data retrieved February 2009).

Condition Assessment for Parkwide Resources

The condition assessment for MIMA's soils was based on data from the NETN Forest Monitoring Protocol for the ratios of Ca:Al and C:N and was rated as "significant concern" (Table 37). Currently there are no data available on soil horizon characteristics or presence of earthworms in forest soils, and the condition of these metrics were assessed as "unknown".

The condition of air quality was based on estimates of produced by the NPS ARD for MIMA. The estimates for ozone, Total N wet deposition, and Total S wet deposition were rated as "significant concern"; while visibility was rated as "caution" (Table 37).

Preliminary soundscape data indicated that extrinsic non-natural sounds occur more frequently than the desired management objective of less than 50% to 75% of the time (Table 36; Figure 29). Additionally, the assessment by CNPSR rated MIMA as one of the top five nosiest parks in the United States (CNPSR 2008). Based on this information the condition of the soundscape at MIMA was rated as "significant concern" (Table 37).

Although visitation statistics for MIMA were available, there was little information concerning impacts of visitor use on park resources. Due to the lack of information, the condition of resources with respect to visitation could not be evaluated and was assessed as "unknown".

Trend data were only available for the ozone air quality parameter. The trend for ozone appears to be declining, or in the very least not improving, due to the continual exceedances of the ozone standard for Middlesex County, and was assessed as a "declining trend"(Table 37).

Trends for soils, soundscape, and visitor use (as it relates to natural resources) could not be evaluated due to lack of long-term data or data relevant to natural resources and these metrics were assessed as "unknown" (Table 37).

Data reliability for parkwide resources was rated a "good" with an average score of 0.77 (Table 37).

Table 37. Condition assessment scores for parkwide resources at MIMA. Average scores are given when more than one metric was assigned a condition rating.

Metric	Condition	Numerical Score	Comments
<u>Current Condition of Parkwide Resources</u>			
Air quality – ozone	● Significant concern	0.16	NPS ARD condition estimate (Table 35).
Air quality – wet deposition	● Significant concern	0.16	NPS ARD condition estimate (Table 35).
Air quality – visibility	● Caution	0.50	NPS ARD condition estimate (Table 35).
Soils - Ca:Al and C:N ratios	● Significant concern	0.16	Ratings of soil chemistry ratio parameters as assessed by NETN Forest Monitoring Protocol (Table 33).
Soils – horizon characteristics, presence of earthworms	○ Unknown	-	Currently no data are available for these metrics.
Soundscape	● Significant concern	0.16	Percent of time non-natural sounds were audible exceeds management objectives (Figure 29).
Visitor Use	○ Unknown	-	Information on visitor impacts to natural resources was lacking.
Overall Condition Score	● Significant concern	0.23	
<u>Trend Data for Parkwide Resources</u>			
Air quality - ozone	↓ Declining trend	0.16	Ozone standard has persistently been exceeded (Figure 26).
Air quality - wet deposition, visibility	○ Unknown	-	No trend data available as related to natural resources.
Soils	○ Unknown	-	No trend data available as related to natural resources.
Soundscape	○ Unknown	-	No trend data available as related to natural resources.
Visitor Use	○ Unknown	-	No trend data available as related to natural resources.
Overall Trend Score	-	-	Since only two of five resources could be assessed for trends, an average trend score would not be appropriate.

Table 37. Condition assessment scores for parkwide resources at MIMA (continued).

Metric	Condition	Numerical Score	Comments
<u>Data Reliability for Air Resources</u>			
US EPA air quality data (ozone)	Good	0.84	
NPS ARD air quality estimates	Good	0.84	
Soundscape (NPS Natural Sounds Program)	Good	0.84	Data collection just recently initiated, no long-term trend data, but data are of "good" quality.
NETN Forest Monitoring Protocol data	Good	0.84	Data collection just recently initiated, no long-term trend data, but data are of "good" quality.
Visitor Usage (NPS 2008a)	Satisfactory	0.50	Data only relate to visitation, no information was available on impacts to natural resources.
Overall Data Reliability Score	Good (0.68 to 1.0)	0.77	

Natural Resource Condition Assessment Summary

Most of natural resources at MIMA appear to be in less than desirable condition based on available data (Table 38). Urban lands occupy a considerable proportion of the park (17%) and these urban areas (roads and residential housing) can detract from the natural resources and cultural atmosphere of MIMA. Invasive plants occupy an extensive area of the park (84%). The vegetation, forest, and wetland communities of the park are under assault from these invasive species, which have persisted and increased in abundance and distribution over the years. Even areas that are considered good examples of natural native communities, such as the kettlehole wet meadows, are threatened by invasive plants. This is the legacy of disturbed lands and the opportunistic colonization of non-native species over the past few centuries.

The available data for faunal communities indicate that landbird, amphibian, and fish communities are in a less than desired condition primarily due to a loss of specialist or sensitive species and higher incidence of non-natives/exotics and/or disturbance tolerant species (Table 38). Species richness for the landbird community was lower than optimum for high canopy foragers, canopy nesters, and grassland obligates (although not all surveys specifically sampled in grasslands), while it was higher than desired for single brooders and grassland exotics. The amphibian community has a relatively high abundance of tolerant species, low abundance of sensitive taxa, and low number of pond-breeding species. The fish community has a depleted species richness, absence of benthic insectivores, low diversity of trout and sunfish species (not including green sunfish or bluegill), and a low number of intolerant species. There was insufficient information to evaluate the mammal community, invertebrate community, and the abundance of state listed species. Threats to faunal communities include habitat loss/deterioration and fragmentation, competition with non-native and/or exotic species, and environmental contaminants including impaired water quality. Concerns of possible white-tailed deer over-population and potential over browsing as well as habitat alteration by beavers are also issues that concern park management. There are potential emerging threats from several insect pests and it would be prudent to establish early detection plans for these detrimental insects.

MIMA also has had persistent degraded water quality of its streams and rivers over the past 20 years (Table 38). Metals, nutrients, and pathogens have been a persistent problem in the Concord River, and more recently, exotic macrophytes are a threat to river water quality. Pathogens and turbidity are persistent problems with Elm Brook, a sensitive and potentially important wetland area in the park for fish and amphibians (e.g., brook trout and northern two-lined salamander). Other habitat alterations (e.g., the physical degradation or loss of aquatic habitat and/or hindrance of fish passage or migration) are recent impairments (since 2002) to both Elm Brook and Mill Brook.

In terms of parkwide resources, soils, air quality, and soundscape are also of concern. Soil chemistry, assessed during forest monitoring, has been found to have undesirable ratios of Ca:Al and C:N that in turn may negatively impact forest vegetation. Three of the four air quality parameters (ozone, total N wet deposition, and total S wet deposition) were rated as “significant concern”, while the fourth (visibility) rated as “caution”. Non-natural sounds are pervasive throughout the park, especially from vehicular and aircraft traffic. There may be little that MIMA can do about these resources as they are extensively influenced by factors outside of the park's control. There was insufficient data to evaluate other metrics associated with the condition of MIMA's parkwide resources (e.g., soil horizon, impact of visitor use on natural resources) (Table 38).

The natural resources that could be evaluated for trends were found to have a declining trend of condition, primarily related to the continued, persistent presence of non-desirable conditions (e.g., invasive species, impaired water quality), and declines in species abundance (e.g., landbirds and amphibians) (Table 38).

In general, the reliability of data used in the assessment of these natural resources was "good" to "satisfactory" (Table 38).   Several data gaps exist (refer to *Suggested Research Areas* section), especially in terms of the condition of wetland resources. Important wetland ecosystems in the park include kettlehole wet meadows, a red-maple black gum swamp, Elm Brook wetlands, and vernal pools. Threats to these include invasive plants, impacts from roads (e.g., road runoff, barriers to faunal movement), and impaired water quality. Monitoring these areas (e.g., water quality, hydroperiod, presence rare and/or iconic flora and fauna) should be a priority for the park. Other data gaps include the uncertainty of the presence of state listed flora and fauna throughout the park. There are few state listed plant species that have been recorded in the park and there are other rare plant and animal species that have been recorded in the towns of Lincoln and Concord. Small urban parks, such as MIMA, can act as important biological refugia by conserving the remnants of healthy native habitats, and their associated flora and fauna, in the face of an ever increasing urban landscape (Falkner and Stohlgren 1997; Dennison et al. 2007).

Table 38. Summary of natural resource conditions for MIMA. Scores are overall average scores from each natural resource (if available).

Metric	Condition	Numerical Score	Comments
Summary of Current Conditions			
Land Use	Caution	0.50	17% of land in park is urbanized (Table 4).
Vegetation Communities	Caution	0.61	Metrics were rated as "caution" or "significant concern" (Table 10).
Wetland Resources	Caution	0.59	Most metrics rated as "caution" only one rated "good" (Table 15).
Faunal Communities	Caution	0.36	Preliminary assessment, only 3 communities were rated (Table 30).
Water Resources	Significant concern	0.33	Preliminary assessment, only 2 metrics were rated (Table 32).
Parkwide Resources	Significant concern	0.23	Most metrics were classified as "significant concern" (Table 37).
Summary of Trends			
Land Use	Declining trend	0.16	Increased urbanization, albeit small, within park's boundary (Table 4).
Vegetation Communities	Declining trend	0.16	Primarily related to persistent presence of invasive species (Table 10).
Wetland Resources	Declining trend	0.16	Possible recent invasions by invasive species and persistent degraded water quality (Table 15).
Faunal Communities	Declining trend	0.16	Preliminary assessment, trends for only 2 communities were available (Table 30).
Water Resources	Declining trend	0.33	Preliminary assessment, trends for only 2 metrics were available (Table 32).
Parkwide Resources	-	-	Since the only available trend was for air quality, an assessment of average trends would not be appropriate (Table 37).

Table 38. Summary of natural resource conditions for MIMA (continued).

Metric	Condition	Numerical Score	Comments
Summary of Data Reliability			
Land Use	Satisfactory	0.61	Refer to Table 4.
Vegetation Communities	Good	0.74	Refer to Table 10.
Wetland Resources	Satisfactory	0.50	Refer to Table 15.
Faunal Communities	Satisfactory	0.67	Refer to Table 30.
Water Resources	Good	0.70	Refer to Table 32.
Parkwide Resources	Good	0.77	Refer to Table 37.

Suggested Research Areas

Below are suggested areas where further research would benefit either the understanding of the condition of natural resources or would assist in future resource management activities.

- Monitor invasive plant species around MA-NHESP designated natural communities (e.g., kettlehole wet meadows) to determine if they are negatively impacting these areas.
- Monitor wetland ecosystems (e.g., water quality, hydroperiod, vegetation, and faunal surveys).
- Focused water quality monitoring, including salinity/conductivity and hydroperiod, of vernal pool systems with specific emphasis on systems that are potentially influenced by road runoff (e.g., those systems that are within 200 m of major roads).
- Inventory of vernal pool systems to document all species utilizing vernal pools.
- Investigate the potential for wildlife corridors under Route 2A, especially in the vicinity of the Elm Brook wetland, as a way to restore the connectiveness of fragmented wetlands.
- Determine of the nativity status, origin, and sustainability of the brook trout population in Elm Brook. Notify Eastern Brook Trout Joint Venture that a possible native population of brook trout exists in Elm Brook. Initiate restoration/conservation plans if this is a native population.
- Initiate ground water monitoring and test for possible contamination from L.G. Hanscom Field/Hanscom Air Force Base.
- Evaluate the impact/extent of road kill on amphibian populations in the park.
- Conduct survey of aquatic plants.
- Survey and measure riparian buffers. Develop protection and/or restoration plans to protect and/or repair riparian buffers.
- Develop an early detection program for invasive insect pests.
- Estimate population and carrying capacity for white-tailed deer in the park. Determine the extent, if any, that over-browsing is occurring in the park.
- Examine the issue of beaver activity on park property and influence these activities on park resources as well as surrounding landowner properties.

- Verify and document the specific localities where MA listed species were observed in the park and forward information to the MA-NHESP. Determine if these species and/or their habitats are at risk.

- Survey the park for MA listed invasive animals (e.g., rusty crayfish, Chinese mystery snail, Japanese mystery snail) to determine if these species are present. If they are present determine if they pose a threat to native species.

- Examine impacts of visitor usage on natural resources, especially in sensitive and high use areas.

- Identify indicator or "iconic" species (e.g., eastern meadowlark, pileated woodpecker, brook trout, American eel, etc), identify suitable available habitat for these species in the park, and assess these habitats using habitat suitability models.

- Examine park plantings to ensure that native species are planted. While this is not a natural resource, a reduction in non-native ornamental plantings can help to reduce the spread of invasive and exotic plant species in the park by eliminating seed sources.

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National Park Service
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U.S. Department of the Interior
National Park Service
Northeast Region
15 State Street
Boston, MA 02109

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