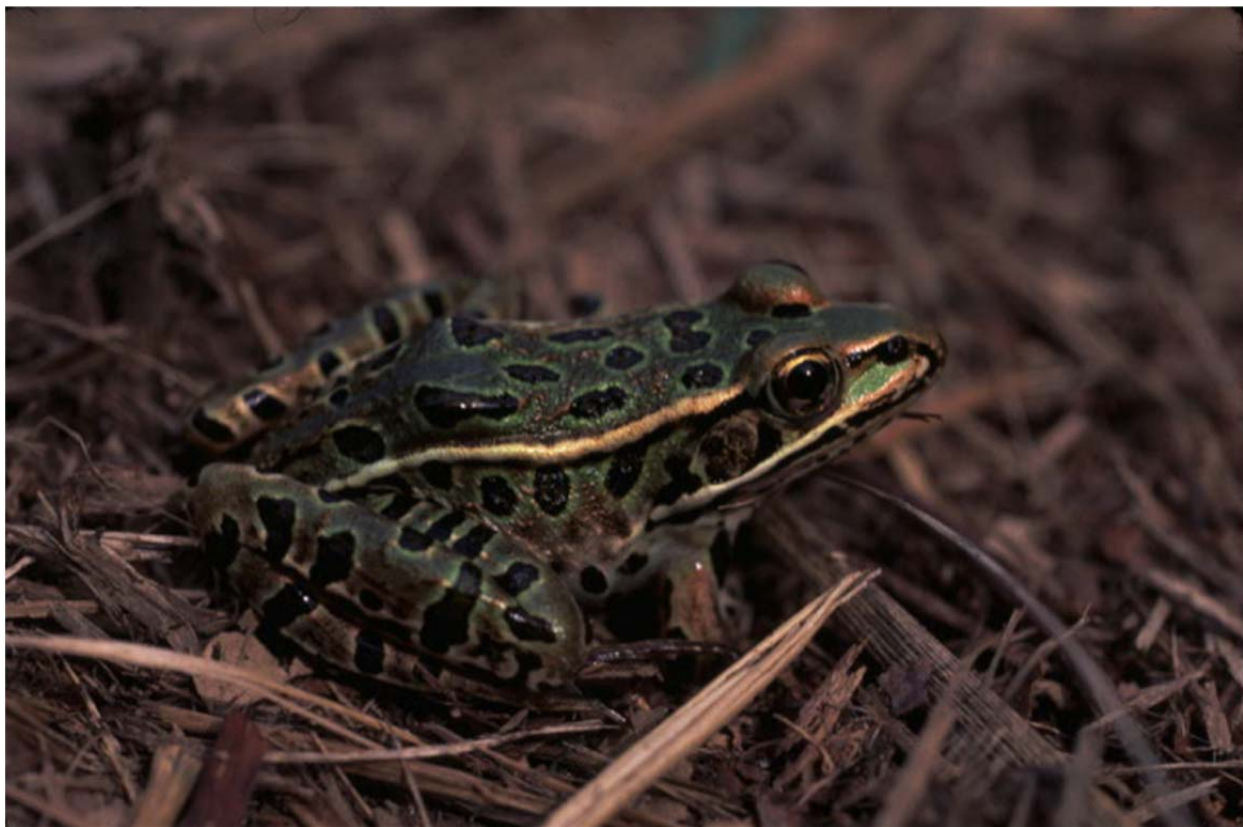




Minute Man National Historical Park Amphibian and Reptile Inventory

March-September 2001

Natural Resource Technical Report NPS/NETN/NRTR—2011/505



ON THE COVER

Northern Leopard Frog (*Lithobates pipiens*).

NPS Photo.

Minute Man National Historical Park Amphibian and Reptile Inventory

March-September 2001

Natural Resource Technical Report NPS/NETN/NRTR—2011/505

Robert P. Cook

National Park Service
Cape Cod National Seashore
Wellfleet, MA 02667

David K. Brotherton and John L. Behler

Department of Herpetology
Wildlife Conservation Society
Bronx Zoo
Bronx, NY 10460-1099

Brad C. Timm

Department of Environmental Conservation
University of Massachusetts, Amherst
Amherst, MA 01003

November 2011

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

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

The Natural Resource Technical Report Series is used to disseminate results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service mission. The series provides contributors with a forum for displaying comprehensive data that are often deleted from journals because of page limitations.

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

This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from <http://science.nature.nps.gov/im/units/NETN/index.cfm> and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>).

Please cite this publication as:

Cook, R. P., D. K. Brotherton, B. C. Timm and J. L. Behler. 2011. Minute Man National Historical Park amphibian and reptile inventory: March-September 2001. Natural Resource Technical Report NPS/NETN/NRTR—2011/505. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	vii
Tables.....	ix
Appendices.....	xi
Executive Summary	xi
Acknowledgements.....	xv
Introduction.....	1
Study Area	3
Methods.....	4
Sampling Overview	5
Marking, Measurement, and Aging/Sexing of Captured Animals	5
Anuran Calling Surveys (ACS)	9
Egg Mass Counts (EMC).....	10
Time-constrained Search (TCS)	10
Stream TCS.....	10
Woodland TCS.....	11
Field TCS.....	11
Pond TCS.....	11
Coverboards (CB)	12
Turtle Trap Surveys (TTS).....	13
Minnow Trap Surveys (MTS).....	13
Incidental Encounters (IE)	14

Contents (continued)

	Page
Quantifying Overall Abundance	14
Data Management	15
Results.....	16
Overview of Park Herpetofauna	17
Survey Method Summaries.....	26
Anuran Calling Surveys.....	27
Egg Mass Counts	27
Time-constrained Search	33
Coverboards	39
Turtle Trap Surveys	39
Minnow Trap Surveys.....	39
Incidental Encounters.....	40
Discussion.....	47
Community Analysis, Factors Affecting Species Presence, and Important Habitats	47
Species at Risk	52
Population Trends	52
Stressors	53
Recommendations for Management and Future Inventory and Monitoring	57
Species Accounts: Species currently or historically recorded at or near Minute Man NHP.....	61
Spotted Salamander (<i>Ambystoma maculatum</i>)	61
Red-spotted Newt (<i>Notophthalmus v. viridescens</i>).....	62

Contents (continued)

	Page
Eastern Red-backed Salamander (<i>Plethodon cinereus</i>)	64
Northern Two-lined Salamander (<i>Eurycea bislineata</i>)	65
Eastern American Toad (<i>Anaxyrus americanus</i>)	66
Gray Treefrog (<i>Hyla versicolor</i>)	67
Northern Spring Peeper (<i>Pseudacris c. crucifer</i>)	68
American Bullfrog (<i>Lithobates catesbeianus</i>)	69
Northern Green Frog (<i>Lithobates clamitans melanota</i>)	70
Pickerel Frog (<i>Lithobates palustris</i>)	71
Northern Leopard Frog (<i>Lithobates pipiens</i>)	72
Wood Frog (<i>Lithobates sylvaticus</i>)	73
Common snapping Turtle (<i>Chelydra s. serpentina</i>)	75
Painted Turtle (<i>Chrysemys picta</i>)	77
Stinkpot (<i>Sternotherus odoratus</i>)	78
Spotted Turtle (<i>Clemmys guttata</i>)	79
Blanding's Turtle (<i>Emydoidea blandingii</i>)	80
Northern Black Racer (<i>Coluber c. constrictor</i>)	82
Northern Water Snake (<i>Nerodia s. sipedon</i>)	83
Eastern Milk Snake (<i>Lampropeltis t. triangulum</i>)	83
Common Garter Snake (<i>Thamnophis sirtalis</i>)	84
Eastern Ribbon Snake (<i>Thamnophis sauritis</i>)	85
Northern Ringneck Snake (<i>Diadophis punctatus edwardsii</i>)	86

Contents (continued)

	Page
Species Accounts: Potentially-occurring species never recorded at or adjacent to Minute Man NHP	89
Blue-spotted Salamander (<i>Ambystoma laterale</i>) complex.....	89
Four-toed Salamander (<i>Hemidactylium scutatum</i>)	90
Northern Dusky Salamander (<i>Desmognathus fuscus</i>)	91
Fowler’s Toad (<i>Anaxyrus fowleri</i>)	92
Eastern Box Turtle (<i>Terrapene c. carolina</i>)	92
Wood Turtle (<i>Gleptemys insculpta</i>).....	94
Smooth Green Snake (<i>Liochlorophis vernalis</i>).....	94
Northern Brown Snake (<i>Storeria d. dekayi</i>)	95
Northern Red-bellied Snake (<i>Storeria o. occipitomaculata</i>)	96
Literature Cited	97

Figures

	Page
Figure 1. Location of standardized sampling sites and time-constrained search areas used in herpetofaunal inventory at Minute Man National Historical Park.	8
Figure 2. Location of salamander detections at Minute Man National Historical Park. Points represent central location of survey sites where a given species was recorded, not actual location of each individual.	22
Figure 3. Location of frog and toad detections at Minute Man National Historical Park. Points represent central location of survey sites where a given species was recorded, not actual location of each individual.	23
Figure 4. Location of reptile detections at Minute Man National Historical Park. Points represent central location of survey sites where a given species was recorded, not actual location of each individual. Open symbol represents incidental encounter site.	24
Figure 5. Species richness of areas sampled for amphibians and reptiles at Minute Man National Historical Park.	25

Tables

	Page
Table 1. Overview of standardized survey sites at Minute Man National Historical Park and sampling methods used at each site.	6
Table 2. Number of adult amphibians and reptiles encountered during all standardized surveys and incidental encounters listed by habitat category, at Minute Man National Historical Park. Within-order relative abundance (RA) is the number of individuals of a species divided by total number of adults of species within each taxonomic order, expressed as a percentage.	18
Table 3. Distribution by habitat category and frequency of occurrence for the 17 species of amphibians and reptiles recorded at Minute Man National Historical Park. Frequency of Occurrence (FO) = the number of sites where a species was detected divided by the total number of sites surveyed (37). Number of localities includes both standardized survey sites (32) and incidental encounter locations (5).	19
Table 4. Number of adults recorded and species richness (S) at each of 32 standardized survey sites and 5 incidental encounter locations at Minute Man National Historical Park. Frequency of occurrence (FO) is the number of locations where a species was detected, divided by the total number of locations surveyed (37). L=larvae.	20
Table 5. Number and species richness (S) of amphibians recorded by survey method at Minute Man National Historical Park. A species was determined as being present for a given survey method if at least one individual of any age-class was detected by that method.	28
Table 6. Number and species richness (S) of adult-form reptiles recorded by survey method at Minute Man National Historical Park.	29
Table 7. Percentage of adult-form individuals of each species detected by each survey method at Minute Man National Historical Park. Derived from Tables 5 and 6.	30
Table 8. Results of anuran calling surveys at Minute Man National Historical Park.	31
Table 9. Number of egg masses recorded during egg mass counts at Minute Man National Historical Park.	32
Table 10. Time constrained search effort and dates by habitat at Minute Man National Historical Park.	34

Tables (continued)

	Page
Table 11. Number of amphibians and reptiles recorded during stream time-constrained search at Minute Man National Historical Park. The capture rate (CR) is the number of individuals divided by total search hours.....	35
Table 12. Number of amphibians and reptiles recorded during woodland and field time-constrained search at Minute Man National Historical Park. The capture rate (CR) is the number of individuals divided by search hours.....	36
Table 13. Number of amphibians and reptiles recorded during pond time-constrained search at Minute Man National Historical Park. The capture rate (CR) is the number of individuals divided by search hours.....	37
Table 14. Number of reptiles and amphibians recorded during woodland and field coverboard surveys at Minute Man National Historical Park. Capture rate (CR) is the number of captures per 100 board checks. Board checks are number of boards per site, multiplied by number of site visits.....	41
Table 15. Seasonal variation in snake captures during coverboard surveys at Minute Man National Historical Park, April to June versus August to September 2001. Board checks are the number of boards per site, multiplied by the number of site visits.	42
Table 16. Number of snakes captured under metal versus plywood during coverboard surveys at Minute Man National Historical Park.....	42
Table 17. Number of unique individuals (Inds) and turtle captures (Caps) during turtle trapping at Minute Man National Historical Park. Capture rate (CR) is the number of captures per 100 trap nights.	43
Table 18. Number of amphibians captured in minnow traps at Minute Man National Historical Park. Capture rate (CR) is the number of captures per 100 trap nights.	44
Table 19. Number of adult-form amphibians and reptiles recorded as incidental encounters at 18 localities at Minute Man National Historical Park.	46
Table 20. Status of amphibians and reptiles of Concord area in early 20 th century, mid-1990's, and current survey. Long term trend is from early 20 th century to the end of the 20 th century. Species in bold have been recorded in or very close to Minute Man National Historical Park (MIMA) since 1990. Others species historically occurred in Concord, and most likely occurred on lands now MIMA.	54

Appendices

	Page
Appendix A. Historic and current records of amphibians and reptiles from Minute Man National Historical Park and vicinity. Herp Atlas data are for blocks that MIMA falls within, i.e. Quad 67, blocks 1, 2, 5.	111
Appendix B. Cross-reference of the names used to identify Minute Man National Historical Park wetland survey sites in this report and three reports published in 1992.....	112
Appendix C. Habitat categories and types surveyed at Minute Man National Historical Park.	114
Appendix D. Coordinates for 32 standardized amphibian and reptile survey sites and five incidental encounter (IE) localities at Minute Man National Historical Park. For streams and coverboards (CB), the pair of coordinates are start and end points of linear features. For fields and ponds, the single point is a central point in what is actually a polygon feature.	116
Appendix E. Summary of measurements for snakes captured at Minute Man National Historical Park in 2001.	119
Appendix F. Summary of measurements for turtles captured at Minute Man National Historical Park in 2001.	120

Executive Summary

Under a National Park Service/Wildlife Conservation Society Cooperative Agreement, the amphibians and reptiles of Minute Man National Historical Park (MIMA) were inventoried from March through September 2001. Monthly sampling periods generally lasted six days and five nights, and employed six standard sampling methods: anuran calling surveys, egg mass counts, time-constrained search, coverboards, turtle trap surveys, and minnow trap surveys. In addition, animals encountered outside of standardized surveys (temporally or spatially), including rare species observed by MIMA staff and other scientists, were recorded as incidental encounters.

We recorded 17 species in the course of this survey. Two additional species, northern water snake and Blanding's turtle, were recorded subsequently. These 19 species of amphibians and reptiles known to occur at MIMA represents 59% of 32 species present in Concord in the early 20th century, and 83% of the 23 species documented at or near MIMA in the mid-1990's. Based on numbers of adults and sites recorded from in 2001, the most abundant and widespread species in each taxonomic group were northern spring peeper (anuran), eastern red-backed salamander (salamander), painted and snapping turtle (most abundant and widespread respectively), and common garter snake (snake). We recorded nine species as incidental encounters, eight during pond time-constrained search (TCS), seven each during stream TCS, woodland TCS, and minnow trap surveys, six during anuran calling surveys, four each during field TCS, coverboard surveys, and turtle trap surveys, and two species with egg-mass counts.

In the 2001 survey, 15 species were documented in wetland habitats, 10 in uplands, and nine in streams. Permanent wetlands had the greatest species richness (15), and Cook's Pond, Folly Pond, Nelson Pond, Black Gum Swamp Pond, and Palumbo Ditches were the most diverse sites. Temporary ponds Virginia Road Pond and Whittemore Pond were important to spotted salamanders and wood frogs, and Elm Brook was the only site where the stream-dwelling northern two-lined salamander was recorded. Elm Brook, Mill Brook, and the adjacent Historic Fields form an important habitat complex for the northern leopard frog, eastern American toad, common garter snake, and the state threatened Blanding's turtle. This stream-field combination is important throughout MIMA and streams are also important travel corridors, especially for crossing under roads. The majority of species at MIMA require both aquatic and terrestrial habitats in close proximity, preferably unobstructed by barriers such as development and roads.

Of the 23 species that have been recorded in or around MIMA, two of four salamander, four of eight anuran, two of five turtle, and all six snake species appear to have declined during the 20th century. There are numerous stressors at MIMA such as habitat loss and fragmentation, water pollution, invasive species, and road kill, and the herpetofaunal community of MIMA is dominated by urban-tolerant species. Local protected areas like MIMA provide important habitat for species currently experiencing local and regional decline such as Blanding's turtle (MA "Threatened"), spotted turtle, eastern milk snake, northern leopard frog, grey treefrog, wood frog, and spotted salamander. The park needs to remain engaged in efforts to promote the protection of the adjoining landscape and watershed. Future work at MIMA should include more detailed surveys focused on snakes and aquatic turtles, and monitoring of pond and stream-dwelling amphibians.

Acknowledgements

Funding for this project was provided by the National Park Service, and many people helped with fieldwork and logistics. Tami Ransom and Eric Leibgold spent long days and many hours in the field, as well as recording and inputting field data. Minuteman NHP Natural Resource Managers Bill Fuchs and Chris Davis provided critical logistic support and background information, and/or contributed important observations. Dennis Skidde, Adam Kozlowski, and Tim Shepherd helped with data review and created the maps used in this report.

We are also grateful to a number of Massachusetts biologists who graciously shared their data, observations, and insights into the herpetofauna in and around MIMA and Great Meadows NWR. In particular, Bryan Windmiller shared his extensive knowledge of this area. Others include: Eileen McGourty and Stephanie Koch, U.S. Fish and Wildlife Service; Brian Butler, Oxbow Associates.

Preliminary drafts of this report were improved as a result of critical review and comments by Adam Kozlowski and Brian Mitchell.

Introduction

Minute Man National Historical Park (MIMA) is the area where, on April 19, 1775, American colonists took up arms against British soldiers and sparked the American Revolution. The park was established by Congress in 1959 to preserve and interpret significant historic structures and properties associated with the American Revolution. MIMA is located in Concord, Lincoln, and Lexington, Massachusetts (42° 27' N, 77° 18' W) and is approximately 61 m (200') above sea level. Geologically, the park is within the Boston Area Bedrock Formation. These well-drained substrates are composed of gneiss, schist, and granite with sand, gravel and siltstone (Godfrey et al. 1996). MIMA's 393 ha (971 ac) are predominately deciduous forest but also include open fields, shrub-land, and a mixture of permanent and temporary ponds and streams, and the Concord River which flows through the western portion of the park.

In 1998, a Cooperative Agreement between the National Park Service (NPS) and the Wildlife Conservation Society was established to assess amphibian and reptile assemblages within the parks of the "New England Cluster" of the National Park Service. Since information was lacking or inadequate for the amphibians and reptiles of MIMA, a comprehensive, broad-based inventory was conducted in 2001 using a number of survey techniques. As part of this inventory project, MIMA was surveyed monthly from March through September 2001. While the goals of the project varied between parks, they generally were as follows:

- Assist the park service in documenting at least 90% of the species currently estimated to occur in the park.
- Determine the occurrence and status of species of management concern (e.g., state and federal *Threatened*, *Endangered*, and *Special Concern* species, and other declining species).
- Determine abundance categories, distribution, and habitat use of documented species.
- Identify critical habitats of *Threatened*, *Endangered*, and *Special Concern* species.
- Provide a basis for the future development of a long term monitoring program.
- Analyze species occurrence against historical occurrence and evaluate the state of the park's herpetofauna, on a site and regional scale.

The herpetofauna of MIMA is moderately well known from surveys conducted for the NPS in 1992 (Martinez 1992, Thomas 1992, Windmiller and Walton 1992), and data from the Massachusetts Herp Atlas collected in the 1990's (Jackson et al. 2010). For Herp Atlas data, we considered species recorded in Quad 67, blocks 1, 2, and 5 (the Herp Atlas blocks that MIMA lies in) as present or likely present at MIMA. Although Martinez (1992) and Thomas (1992) focused on vernal pools and amphibians, sampling by Windmiller and Walton (1992) was broader, consisting of turtle trapping, egg mass searches, anuran calling surveys, dip netting, road surveys, minnow trap surveys, active search, and drift fence surveys. Nearly all of the species found in these surveys were considered fairly common statewide, although Windmiller and Walton (1992) and Thomas (1992) found that some species (e.g. northern two-lined salamander (*Eurycea bislineata*), spotted salamander (*Ambystoma maculatum*), stinkpot (*Sternotherus odoratus*), eastern milk snake (*Lampropeltis t. triangulum*), northern water snake (*Nerodia sipedon*), northern black racer (*Coluber c. constrictor*), and eastern ribbon snake (*Thamnophis sauritus*)) were not very abundant at MIMA. Also during this same period, a spotted turtle (*Clemmys guttata*) (listed as a state "Special Concern" species at the time of the

survey, but de-listed in 2006) was recorded in the Palumbo Farm ditches in 1994 (pers. comm., Bryan Windmiller, independent consultant, 3 March 2011), bringing the total number of species found specifically at MIMA to 19 species. An additional four species were recorded near MIMA by the MA Herp Atlas (Jackson et al. 2010), including two Blanding's turtles (*Emydoidea blandingii*), a state "Threatened" species, at Great Meadows National Wildlife Refuge (NWR), which abuts MIMA. Thus during the mid-1990's, a total of 23 species including four species of salamander, eight species of anurans, five species of turtles, and six species of snakes were recorded at or near MIMA (Appendix A, Appendix B).

Determining the "historic" herpetofauna of MIMA is challenging, due to a lack of MIMA-specific historic data and limited knowledge of some species during the "historic" period. Thirty native species of amphibians and reptiles were recorded in Concord, MA in the early 20th century (Ricketson 1911, Carnegie 1914). Two additional native species, four-toed salamander and northern two-lined salamander, also occur in Concord and vicinity (Greer et al. 1973) and were likely present in the early 20th century. In our experience, early 20th century naturalists often missed four-toed salamanders (e.g. see Cook et al. 2010a) and Greer et al. (1973) suggested their apparent rarity was due to "want of looking". Two-lined salamanders were recorded at MIMA in 1992 (Thomas 1992) and in the current survey. In our view, there is no reason to believe these two species were not also present in Concord in the early 20th century, bringing the total historic herpetofauna of Concord to 32 native species.

Although the early 20th century herpetofauna of Concord, MA included 32 native species, the landscape encompassed by these early reports is much larger and diverse than MIMA. It is not known if all 32 species occurred on the lands that now comprise MIMA. In contrast, the surveys from the 1990's provide MIMA-specific occurrence data, but because they occurred after most of the region's urbanization had occurred, they probably do not represent the "historic" condition. Thus, the 23 species recorded in and adjacent to MIMA in the 1990's is likely an underestimate of the "historic" herpetofauna of MIMA whereas the 32 species present in Concord in the early 20th century may be an overestimate. However, most of the nine species present in Concord in the early 20th century but not recorded at MIMA in the 1990's, are or were once fairly widespread species found in habitats present at MIMA. It is therefore likely that most of these species occurred on the lands that now comprise MIMA. Thus, we consider the "historic" baseline herpetofauna of MIMA to be the 32 native species listed by Greer et al. (1973).

The target species of this inventory were all of MIMA's historically known herpetofauna. These are broad in terms of taxonomic groups and habitat affinities and the inventory employed six standardized methods in a variety of habitats. In addition, incidental encounters were recorded to provide additional information on species' presence and distribution in the park. The habitat type of all sites where amphibians and reptiles were found was described, and the species and the habitat types they occupied were analyzed.

Study Area

MIMA is located in Middlesex County, Massachusetts, approximately 24 km (15 miles) northwest of Boston. The park consists of 393 ha (971 ac), divided into three units: the North Bridge Unit, the Wayside Unit, and the Battle Road Unit. The North Bridge Unit, 47 ha (115 ac), contains extensive lawns and landscaping in the historic core, but also contains woodland and wetland habitats. This unit is bisected by the Concord River, and also contains the confluence of the smaller Mill River with the Concord River. Buttonbush (*Cephalanthus occidentalis*) and silky/red osier dogwood (*Cornus stolonifera*) occupy the floodplain and backwater areas of the Concord River (August et al. 1992). The Wayside Unit, 2 ha (6 ac), is primarily steep-sided forest, but also contains impounded stream wetlands associated with the Mill River along its southern boundary. The Battle Road Unit, 344 ha (850 ac), is the largest unit, and the most significant in terms of natural resource values. It contains sections of two streams, Mill Brook and Elm Brook, as well as three permanent ponds, a bog, approximately 12 vernal/temporary pools, several farm ponds and drainage/irrigation ditches, and extensive emergent and forested wetlands. Collectively, this complex of ponds, streams, and ditches provides widespread aquatic habitat. The remainder of this unit is a mixture of forest, old-field, and agriculture. Deciduous forests in the park are typically red oak (*Quercus rubra*) and black oak (*Quercus velutina*), sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), and young beech (*Fagus grandifolia*) on slopes (August et al. 1992). Coniferous forest is predominately white pine (*Pinus strobus*) with less common species including pitch pine (*Pinus rigida*), Norway spruce (*Picea abies*), and eastern hemlock (*Tsuga canadensis*) (August et al. 1992). The wetlands of MIMA are vegetatively diverse with red maple swamp being the most common. The understory of these wetlands includes highbush blueberry (*Vaccinium corymbosum*), northern arrowwood (*Viburnum recognitum*), and swamp laurel (*Rhododendron viscosum*). Cranberry bog, located at the southeast end of the park, includes leatherleaf (*Chamaedaphne calyculata*) and sedges with dogwood (*Cornus* sp.), buttonbush (*Cephalanthus occidentalis*) and other shrubs (August et al. 1992).

Most of MIMA is bisected by the Route 2A, a high volume road. It is nonetheless one of the larger tracts of relatively undeveloped land within a heavily suburbanized landscape. The park is bordered by Hanscom Civilian Air Field and Air Force Base, privately held land, and several public and conservation lands, including Great Meadows National Wildlife Refuge, which abuts the North Bridge Unit.

Methods

Sampling Overview

We sampled MIMA with a two person crew as part of an effort to survey the herpetofauna of four NPS sites over the course of the 2001 field season. Because the herpetofauna of most sites in the Northeast United States consists of a variety of species, each with differing periods of greatest activity and detectability (which can also vary somewhat annually), the sampling plan called for distributing the sampling effort over the course of the spring and summer activity season. Given this, and the logistics of sampling at four sites (located in Cornish, NH; Stillwater, NY; Lexington, MA; and Saugus, MA), we sampled sites in bouts that varied in duration in proportion to a site's size and presumed faunal/zoogeographic complexity. Over the course of a month the crew sampled a site and moved on to the next, such that a full round of sampling was conducted each month during the months of April, May, June, August, and September. There was also a short sample period in March. The time periods we sampled MIMA during 2001 were: 24 to 25 March, 14 to 21 April, 15 to 20 May, 18 to 23 June, 23 to 28 August, and 13 to 17 September.

The general approach of sampling was to balance the need for standardized methods and quantifiable results with the primary goal of determining species presence. Since amphibians and reptiles found at MIMA are variable in habitat use and seasonal patterns of detectability, we employed a number of methods, both general and habitat/taxa specific (Table 1). These were: Anuran Calling Surveys (ACS), Egg Mass Counts (EMC), Coverboard Surveys (CB), Turtle Trap Surveys (TTS), Minnow Trap Surveys (MTS), Habitat or Area-specific Time Constrained Search (TCS) and Incidental Encounters (IE). We employed general methods (i.e. TCS) across all habitats for the entire field season, whereas habitat/taxa specific methods were employed at those times of the year when the target species/habitat were known to be most efficiently sampled. The combination of methods chosen recognized that multiple methods were necessary to detect the wide range of potentially-occurring species and that some species are difficult to detect due to rarity or behavior. Thus, a degree of redundancy was needed to increase the likelihood of encountering rare or hard to find species. Collectively, the methods we employed were designed to provide a comprehensive list of species occurrence and a reasonable estimate of relative abundance and habitat use.

Site selection for standardized surveys was designed to sample across the range of habitat types present and be spatially balanced (Table 1, Appendix C, Figure 1). We used existing maps of wetland and upland habitats, as well as field reconnaissance, to identify all of the ponds/wetlands, streams, rivers, and parcels of field and woodland habitat. We classified each potential survey site based on three habitat categories (stream, wetland, and upland) and six habitat types (Appendix C) to provide a general description of each. From these, we randomly selected sampling sites (ponds, stream sections, or discrete polygons of field or woodland) representing each habitat type in each of the three park units, and on both sides of Route 2A, which bisects much of MIMA.

Marking, Measurement, and Aging/Sexing of Captured Animals

Captured animals were treated differently (depending on species) in terms of marking and measuring, with exact details determined by data desired and the ease or difficulty of marking.

Table 1. Overview of standardized survey sites at Minute Man National Historical Park and sampling methods used at each site.

Site	Habitat Type	Calling Survey	Egg Mass Count	TCS Stream	TCS Woodland	TCS Field	TCS Pond	Cover board	Turtle Trap	Minnow Trap
Mill Brook North	Intermittent Stream			X						
Mill Brook West	Intermittent Stream			X						
Elm Brook North	Permanent Stream			X						
Elm Brook South	Permanent Stream			X						
Mill Brook Mouth	Permanent Stream			X					X	
Mill Brook South	Permanent Stream			X						
Black Gum Swamp Pond	Permanent Pond	X	X				X		X	X
Cook's Pond	Permanent Pond	X	X				X		X	X
Cranberry Bog	Permanent Pond	X	X				X		X	X
Folly Pond	Permanent Pond	X	X				X		X	X
Irrigation Pond A	Permanent Pond	X	X				X		X	X
Mill Brook Wayside	Permanent Pond	X								
Nelson Pond	Permanent Pond	X	X				X		X	X
Palumbo Ditches	Permanent Pond		X				X		X	X
Palumbo Pond	Permanent Pond	X	X				X		X	X
Pond 4-121	Permanent Pond	X								
Pond O	Permanent Pond	X	X				X		X	X
VC Permanent Pond	Permanent Pond	X	X				X		X	X
VC Vernal Pond	Temporary Pond	X	X							
Virginia Road Pond	Temporary Pond	X	X				X		X	X
Whittemore Pond	Temporary Pond	X	X				X		X	X
Woodland #2	Deciduous Forest				X			X		
Woodland #3	Deciduous Forest				X			X		
Woodland #4	Deciduous Forest				X			X		
Woodland #6	Deciduous Forest				X			X		
Woodland #8	Deciduous Forest				X			X		
Woodland #11	Deciduous Forest				X			X		

Table 1. Overview of standardized survey sites at Minute Man National Historical Park and sampling methods used at each site (continued).

Site	Habitat Type	Calling Survey	Egg Mass Count	TCS Stream	TCS Woodland	TCS Field	TCS Pond	Cover board	Turtle Trap	Minnow Trap
Woodland #12	Deciduous Forest				X			X		
Fiske Hill Field	Field					X		X		
Historic Fields	Field					X		X		
North Bridge Field	Field					X		X		
Palumbo Field	Field					X		X		

Minute Man National Historical Park Herpetological Survey

Sampling Methods & Locations

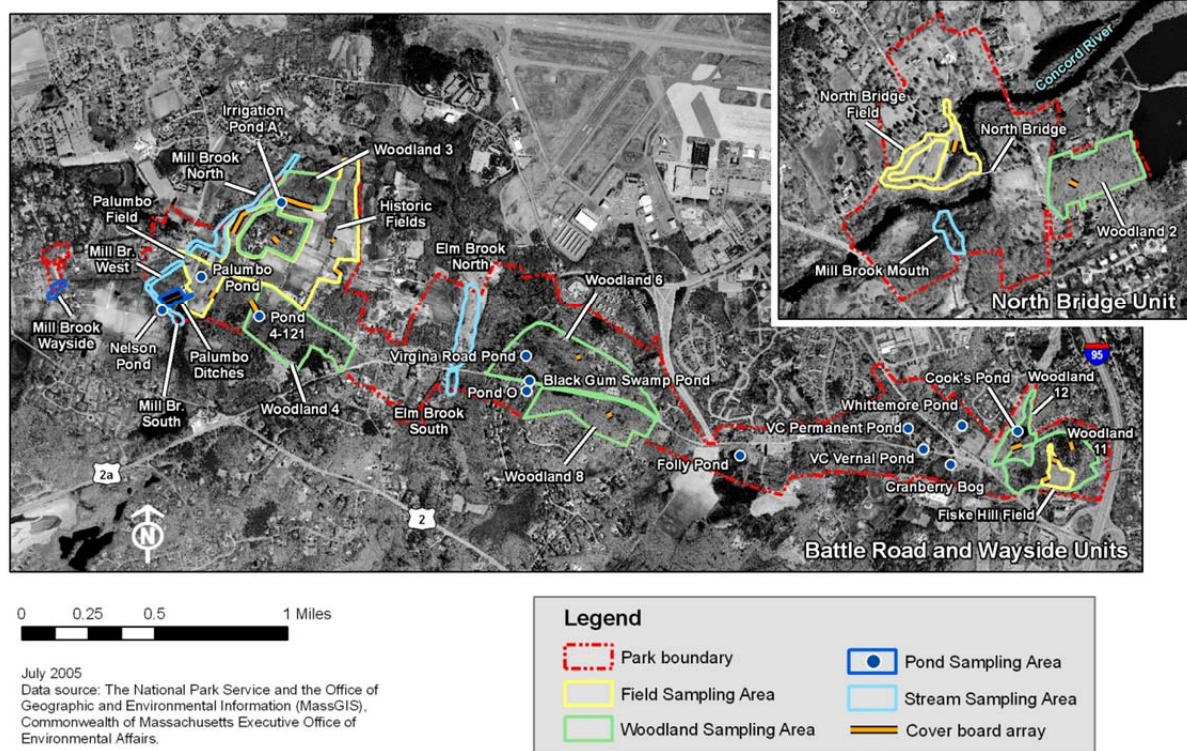


Figure 1. Location of standardized sampling sites and time-constrained search areas used in herpetofaunal inventory at Minute Man National Historical Park.

Although several different methods were used to capture animals, the details of marking and measuring were based on species, not method of capture. We classified amphibians as larvae or adult-form, and adult-form individuals into age categories (metamorph, juvenile, adults) but did not mark, measure, or weigh them. We measured snakes' snout-vent length (SVL), total length (TL), and mass, and sexed them based on degree of tail contour (Conant and Collins 1998). All snakes were given a cohort mark with a veterinary cauterizer (Jorgensen Laboratories, Loveland, CO). We marked all turtles for individual identification, with each given a unique set of notches in the marginal scutes, using a code system modified from Cagle (1939). For all turtles captured, we measured carapace length (CL), carapace width (CW), plastron length (PL), and mass. We sexed turtles based on external features for each species described in Ernst et al. (1994). Individuals were classified as adult, as opposed to juvenile, based on the following size criteria: common snapping turtles, males with CL > 210 mm and females with CL > 200 mm (Congdon et al. 1987, 1992, Ernst et al. 1994); painted turtle, males with PL > 80mm and females with PL > 110 mm (Zweifel 1989); spotted turtles, PL > 80 mm (Graham 1995).

Anuran Calling Surveys (ACS)

Anuran calling surveys were conducted at 14 ponds using the Wisconsin frog and toad survey method (Heyer et al. 1994). Anuran calling surveys record the presence of species at specific sites and provide an index of abundance based on the calling intensity of species heard. Call index values and criteria for assigning them are: 0 = no calls, 1 = individuals can be counted (no overlapping of calls), 2 = overlapping of calls (can still be counted), 3 = full chorus (calls are constant and individually indistinguishable). The surveyors arrived at each sample site at least a half-hour after dusk and listened for anuran calls for 5 minutes, recording an index value for each species heard. For each sampling occasion, the number of individuals of each species calling was also counted or estimated.

Due to variable activity patterns among anuran species, multiple calling surveys conducted throughout spring and early summer months are necessary to thoroughly document species presence at a site (Conant and Collins 1998, Crouch and Paton 2002). We sampled 14 sites once per month in April, May, and June and five of them were also sampled in late March. We sampled between 24 March and 19 June 2001.

1. Black Gum Swamp Pond – 4 call surveys
2. Cook's Pond – 4 call surveys
3. Cranberry Bog – 3 call surveys
4. Folly Pond – 3 call surveys
5. Irrigation Pond A – 3 call surveys
6. Mill Brook Wayside – 3 call surveys
7. Nelson Pond – 3 call surveys
8. Palumbo Pond – 3 call surveys
9. Pond 4-121 – 4 call surveys
10. Pond O – 3 call surveys
11. VC Permanent Pond – 3 call surveys
12. VC Vernal Pond – 4 call surveys
13. Virginia Road Pond – 3 call surveys
14. Whittemore Pond – 4 call surveys

Egg Mass Counts (EMC)

Spotted salamanders and wood frogs migrate to ponds in the early spring to breed, depositing gelatinous egg masses attached to branches and vegetation in the water (Petranka 1998). Egg mass counts were conducted to determine presence and document evidence of breeding by these species. When counting egg masses, the observer traversed the entire pond, searching for egg masses, identifying and counting all egg masses observed and recording developmental stage and percent mortality (individual egg mortality within each egg mass). Every effort was made to count all masses in a pond, but because spawning is only loosely synchronized, counts based on a single survey may underestimate total numbers of egg masses laid. Because we only sampled each site once, on either 18 April or 19 April 2001, numbers of egg masses and species presence is likely underestimated. Sites sampled were:

1. Black Gum Swamp Pond
2. Cook's Pond
3. Cranberry Bog
4. Folly Pond
5. Irrigation Pond A
6. Nelson Pond
7. Palumbo Ditches
8. Palumbo Pond
9. Pond O
10. VC Permanent Pond
11. VC Vernal Pond
12. Virginia Road Pond
13. Whittemore Pond

Time-constrained Search (TCS)

Habitat-specific time-constrained search (TCS) was conducted in all habitats likely to support amphibians and reptiles, i.e., streams, woodlands, fields, and wetlands. Each wetland, stream section, or upland TCS area (woodlands and fields) was searched for a pre-determined period of time, which was commensurate with size. The amount of time allotted to search an area on a given occasion was not enough to search all available cover, and searchers used an approach intended to maximize the numbers and diversity of captures by moving through the area and searching under the best available cover (e.g. logs, rocks, boards, metal debris) favored by amphibians and reptiles (Bury and Raphael 1983), and by dip netting ponds (Heyer et al. 1994). Although the original plans called for sites within each habitat type to be sampled the same number of times, and sampling sessions at a given site to be the same duration each time, due to the exigencies of field work, this was not always possible. Results of TCS were standardized as a capture rate (CR) for each species, calculated by dividing the total number of individuals recorded by the total search effort (person hours) spent for each search. Person hours are the total amount of time spent searching, multiplied by the number of people participating in the search.

Stream TCS

Stream TCS was employed primarily to survey for stream salamanders at six survey sites. Investigators systematically moved upstream, using a dip net in the stream to capture amphibians as rocks were overturned. Rocks, logs, and debris in the splash zone and on the bank were overturned and searched under. Identification and life stage (adult or larva) were recorded for

each animal captured. The adult life stage was defined as any individual not in the larval stage, and the larval stage was defined as an individual with gills, showing pre-metamorphic characteristics. Starting and ending times (Eastern Daylight Time) and the number of people searching were recorded. We searched the following six stream sections once per month in April, May, June, and August, and three of them were also sampled in September. We sampled between 16 April and 15 September 2001 as follows:

1. Elm Brook North – permanent: 4 surveys, 4.0 search hours
2. Elm Brook South – permanent: 5 surveys, 3.7 search hours
3. Mill Brook Mouth – permanent: 5 surveys, 4.2 search hours
4. Mill Brook North – intermittent: 4 surveys, 5.7 search hours
5. Mill Brook South – permanent: 5 surveys, 3.8 search hours
6. Mill Brook West – intermittent: 4 surveys, 4.2 search hours

Woodland TCS

Woodland TCS was employed to survey for the broad range of species likely to occur in MIMA woodlands, especially terrestrial salamanders, several anurans, and snakes. Start and end times, number of searchers, and the identification, number, and sex of individuals found were recorded. We searched the following woodland areas at least once per month in April, May, June, August, and September, between 14 April and 16 September 2001 as follows:

1. Woodland #2 – deciduous forest: 5 surveys, 3.3 search hours
2. Woodland #3 – deciduous forest: 6 surveys, 8.3 search hours
3. Woodland #4 – deciduous forest: 5 surveys, 4.2 search hours
4. Woodland #6 – deciduous forest: 6 surveys, 5.0 search hours
5. Woodland #8 – deciduous forest: 5 surveys, 2.9 search hours
6. Woodland #11 – deciduous forest: 5 surveys, 3.3 search hours
7. Woodland #12 – deciduous forest: 5 surveys, 2.3 search hours

Field TCS

Field TCS was employed primarily to search for snakes, which are often found basking along edges. Start and end times, number of searchers, and the identification, number, and sex of individuals found were recorded. Except as noted otherwise, the following sites were surveyed once per month in April, May, June, and August, between 14 April and 27 August 2001 as follows:

1. Fiske Hill Fields – 4 surveys, 2.9 search hours
2. Historic Fields – 6 surveys (three in August), 10.2 search hours
3. North Bridge Field – 4 surveys, 2.4 search hours
4. Palumbo Field – 3 surveys (none in August), 1.8 search hours

Pond TCS

Pond TCS was conducted at night to survey primarily for amphibians. However, aquatic turtles were also often observed. Searches were conducted by traversing the entire pond, sampling with a dip-net for amphibian larvae and adults, as well as turtles and snakes. Start and end times, number of searchers, and the identification, number and sex of individuals found were recorded. Pond TCS occurred between 24 March and 14 September 2001. Except as noted otherwise

below, we sampled all ponds once per month in April, May, June, and August. Specific details of ponds surveyed are:

1. Black Gum Swamp Pond – 5 surveys (one in March), 2.7 search hours
2. Cook’s Pond – 6 surveys (one in March and September), 3.2 search hours
3. Cranberry Bog – 4 surveys, 2.5 search hours
4. Folly Pond – 5 surveys (one in September), 3.2 search hours
5. Irrigation Pond A – 4 surveys, 2.3 search hours
6. Nelson Pond – 4 surveys, 2.0 search hours
7. Palumbo Ditches – 4 surveys, 2.6 search hours
8. Palumbo Pond – 4 surveys, 2.2 search hours
9. Pond O – 4 surveys, 2.3 search hours
10. VC Permanent Pond – 4 surveys, 2.0 search hours
11. Virginia Road Pond – 5 surveys (one in September), 3.5 search hours
12. Whittemore Pond – 6 surveys (one in March and September), 3.8 search hours

Coverboards (CB)

Coverboards (Grant et al. 1992) were used primarily to inventory snakes. Coverboards located near wetlands were also expected to provide cover for terrestrial amphibians. Boards were 0.6 m x 1.2 m (2 ft x 4 ft) and made of corrugated sheet metal or plywood. In March 2001, coverboards were deployed on top of vegetation at seven woodland and four field sites. Eight boards were placed 5 meters apart in linear “arrays” consisting of alternating wood and metal boards. Coverboards were checked one time each in April, May and June, twice in August, and once in September as follows:

1. Fiske Hill Field – two arrays: 6 visits, 96 CB checks
2. Historic Fields – four arrays: 6-7 visits, 200 CB checks
3. North Bridge Field – one array: 4 visits (no April or May) , 32 CB checks
4. Palumbo Field – one array: 6 visits, 48 CB checks
5. Woodland #2 – one array: 6 visits, 48 CB checks
6. Woodland #3 – one array: 6 visits, 48 CB checks
7. Woodland #4 – one array: 6 visits, 48 CB checks
8. Woodland #6 – one array: 6 visits, 48 CB checks
9. Woodland #8 – one array: 6 visits, 48 CB checks
10. Woodland #11 – one array: 6 visits, 48 CB checks
11. Woodland #12 – one array: 6 visits, 48 CB checks

Capture rates (CR) were calculated as the number of snake captures divided by the total number of board checks for each site. Each time a board was checked constituted a “board check.” Therefore, a site with eight boards visited six times equaled 48 board checks. The number of snakes captured per 100 coverboard checks was calculated as:

$$CR = \frac{(\text{\# of snake captures})}{(\text{total \# of board checks})} \times 100$$

Turtle Trap Surveys (TTS)

Welded-wire crab traps measuring 30.5 cm x 30.5 cm x 60.1 cm (12" x 12" x 24"), with a mesh size of 1.3 cm x 2.5 cm (0.5" x 1"), were used to sample shallow areas for small aquatic/semi-aquatic turtles such as spotted turtles (*Clemmys guttata*). Funnel traps made of D-shaped metal hoops and 2.5 cm (1") nylon mesh were used to sample deeper pond areas for aquatic turtles such as painted turtles (*Chrysemys picta*) and common snapping turtles (*Chelydra s. serpentina*) (Harless and Morlock 1989). The number of traps used ranged from two to eight, depending on pond size. Traps were baited with sardines in vegetable oil and checked daily. Except as noted below, we trapped each site for two sessions, each spanning 6 days and 5 nights; May 15 thru May 20 and June 18 thru June 23.

1. Black Gum Swamp Pond – 3 traps
2. Cook's Pond – 3 traps
3. Cranberry Bog – 3 traps
4. Folly Pond – 3 traps
5. Irrigation Pond A – 3 traps
6. Mill Brook Mouth – 2 traps (23 August thru 27 August only)
7. Nelson Pond – 3 traps
8. Palumbo Ditches – 8 traps
9. Palumbo Pond – 3 traps (plus one trap set from 16 April thru 17 April)
10. Pond O – 3 traps
11. VC Permanent Pond – 3 traps
12. Virginia Road Pond – 3 traps
13. Whittemore Pond – 3 traps

We quantified turtle abundance as a capture rate, "captures/100 trap nights."

Minnow Trap Surveys (MTS)

Standard funnel-shaped wire mesh minnow traps measuring 15.2 cm x 15.2 cm x 30.5 cm (6" x 6" x 12") were used to sample ponds for adult and larval *Ambystoma* salamanders, adult and larval anurans, and aquatic snakes (Heyer et al. 1994). Except as noted below, each site had two traps and we trapped each site for four sessions, each spanning between 2-5 nights, with most trapping sessions spanning five nights during the months of March (limited; 10 total trap-nights), April (144 trap-nights), May (125 trap-nights), June (120 trap-nights), August (118 trap-nights), and September (24 trap-nights). Survey sites were:

1. Black Gum Swamp Pond – 2 to 3 traps, 5 trapping periods
2. Cook's Pond – 2 traps, 5 trapping periods
3. Cranberry Bog – 2 traps
4. Folly Pond – 2 traps, 5 trapping periods
5. Irrigation Pond A – 2 traps
6. Nelson Pond – 2 traps
7. Palumbo Pond – 2 traps
8. Palumbo Ditches – 2 traps
9. Pond O – 2 traps
10. VC Permanent Pond – 2 traps

11. Virginia Road Pond – 2 to 3 traps
12. Whittemore Pond – 2 to 3 traps

Since this method primarily captures amphibians, which were not marked for individual recognition, we quantified abundance as captures per 100 trap nights.

Incidental Encounters (IE)

Any encounter with an amphibian or reptile not recorded as data in one of the standardized surveys was considered an incidental encounter. These were recorded on observation cards (“Green Cards”) to augment data collected during formal surveys, and include credible observations made by park staff and visitors. For each incidental encounter the species, life stage, method of documentation, as well as location, habitat, and UTM coordinates were recorded. Subsequent to the 2001 field season, there was an additional significant incidental encounter at MIMA (i.e., northern water snake; pers. comm., Robert Zaremba, Ecologist, NatureServe, 17 August 2004), and more recently, two Blanding’s turtles were radio-tracked from Great Meadows NWR to wetlands in and adjacent to MIMA, along Mill Brook and Elm Brook, adjacent to the Historic Fields (pers. comm., Bryan Windmiller, independent consultant, 4 July 2011). Although not included in this report’s tables, these records have been included in our discussion of species currently present at MIMA.

Quantifying Overall Abundance

Quantifying overall abundance of the species encountered was not possible for a number of reasons. The methods used generally did not estimate actual population size, but rather provided a method-specific index of abundance, such as a capture rate (catch per unit effort). In addition, each of the seven methods used provided a sample biased towards a particular species, group of species, age or sex. Although sampling effort was divided among the different methods in an attempt to compensate for possible sampling bias, the amount of sampling bias, the extent to which the use of different methods may have balanced this bias, and the influence of other covariates, such as habitat type and breeding habits, were not estimated.

An index of overall abundance for each species was derived by summing the number of adult form individuals (as opposed to eggs or larvae) encountered during each of the seven survey methods. For time-constrained search, coverboard surveys, turtle and minnow trap surveys, and incidental encounters, the numbers of adults of a given species encountered during each sampling occasion were summed. For anuran calling surveys we used counts or estimates of numbers of calling males made when the calling index values were recorded. Although not calibrated against known numbers, the relationship between calling index value and numbers of calling males was similar to values obtained by Crouch and Paton (2002) for Rhode Island anurans (except northern spring peeper, *Pseudacris c. crucifer*) and Nelson and Graves (2004) for northern green frog (*Lithobates clamitans melanota*). When anurans were recorded calling in the course of TCS, the number of males calling was recorded in all instances, except for those involving full choruses of northern spring peeper. In these instances of full chorus, the mean number of males estimated calling during ACS occasions was used. Estimates of the number of calling males during incidents of full chorus are based on the average number of calling males estimated by multiple observers during full chorus episodes of anuran calling surveys. Because egg mass counts do not directly count adults, the numbers of females represented was estimated

as follows. For spotted salamanders (*Ambystoma maculatum*), Cook (1978) determined that, on average, each egg mass represented 0.633 females. Thus, the number of females present at a site was estimated as 0.633 times the number of egg masses. For wood frog egg mass counts, each egg mass represents one adult female (Crouch and Paton 2000). Because amphibians were not marked for individual identification, for the purposes of estimating an overall index of abundance, reptiles were also treated as though they had not been marked and, unless otherwise stated, numbers reported for reptile species represent capture events, not individuals.

Although the total numbers recorded for each species provide an index of abundance, it is an uncalibrated index and its relationship to actual abundance is unknown. These numbers, and their derivatives, are best viewed as indicating the order of magnitude of a species' abundance and providing a reasonably accurate representation of relative and ranked abundance within taxonomic orders. Although these numbers are of value for some inter-specific comparisons and community analysis, and are likely accurate in identifying abundant versus rare species, differences between species whose index of abundance are of the same order of magnitude may not reflect true differences in abundance.

Data Management

Common and scientific names and spellings are those of the Integrated Taxonomic Information System (ITIS) at the time data were collected. Data collected during the course of this study were entered into a Microsoft Access database that is associated with this report. The original data sheets are archived with the Northeast Temperate Inventory and Monitoring Network located at Marsh-Billings-Rockefeller National Historical Park in Woodstock, Vermont. Given the low-impact nature of this study, voucher specimens of live animals were not collected. The National Park Service's Northeast Temperate Network data manager can be contacted to obtain unpublished data files produced by this study.

A Garmin III Plus Global Positioning System (GPS) unit was used to record the coordinates of each survey site (Appendix D). GPS locality data were recorded as Universal Transverse Mercator (UTM) grid coordinates (zone 19 N) with X = x-axis or Easting, and Y = y-axis or Northing, using the NAD1983 datum.

Results

Overview of Park Herpetofauna

A total of 17 species (12 amphibians and five reptiles) were recorded during this survey. In addition, an adult northern water snake was found dead on Rt 2A near Cranberry Bog on August 13, 2004 (pers. comm., Robert Zaremba, Ecologist, NatureServe, 17 August 2004) and more recently, two Blanding's turtles were radio-tracked from Great Meadows NWR to wetlands in and adjacent to MIMA, along Mill Brook and Elm Brook, adjacent to the Historic Fields (pers. comm., Bryan Windmiller, independent consultant, 4 July 2011). These two species are not included in the results below, but are incorporated into the discussion section of this report.

Amphibians dominated the herpetofaunal community, accounting for 98.1% of the 4,629 individuals recorded. By order, anurans (frogs and toads) comprised 94.5% of all individuals recorded, salamanders 3.6%, turtles 0.9%, and snakes 1.0%. The most frequently recorded species in each order, based on total numbers of adults recorded, were northern spring peeper (*Pseudacris c. crucifer*), eastern red-backed salamander (*Plethodon cinereus*), common snapping turtle (*Chelydra s. serpentina*), and common garter snake (*Thamnophis sirtalis*) (Table 2).

We captured target species at all 32 standardized survey sites, plus the five incidental encounter sites (Table 3, Table 4, Figures 2-4). Based on frequency of occurrence, the most widespread species in each taxonomic group were northern green frog (found at 17, or 46.0% of sites), eastern red-backed salamander (9, or 24.3% of sites), common snapping turtle (10, or 27.0% of sites), and common garter snake (10, or 27.0% of sites, Table 3). Cook's Pond, Folly Pond, and Nelson Pond were the most species-rich sites with eight species (47.1% of all species) found at each. Cook's Pond accounted for the greatest number of individuals recorded (1,072 individuals or 23.2% of the total number of adults detected) (Table 4).

By habitat, the numbers of adults recorded was greatest in wetlands (95.2% of individuals recorded), followed by uplands (3.7% of individuals), and streams (1.1% of individuals) (Table 2). Similarly, species richness was greatest in wetlands (15 species, 88% of recorded species), followed by 10 species in uplands, and nine species in streams (Table 2). Within the six sub-habitat categories, species richness was greatest in permanent ponds (15 species, 88%), followed by permanent streams and fields (eight species each, 47%), temporary ponds and deciduous forest (seven species each, 41%), and intermittent streams (three species, 18%) (Table 2, Figure 5).

Table 2. Number of adult amphibians and reptiles encountered during all standardized surveys and incidental encounters listed by habitat category, at Minute Man National Historical Park. Within-order relative abundance (RA) is the number of individuals of a species divided by total number of adults of species within each taxonomic order, expressed as a percentage.

Species Common Name	Stream		Wetland		Upland		Total	Within-order RA % (Rank)
	Intermittent Stream	Permanent Stream	Temporary Pond	Permanent Pond	Field	Deciduous Forest		
Northern Spring Peeper			203	2,559			2,762	63.13 (1)
Gray Treefrog			2	616	2	1	621	14.19 (2)
Northern Green Frog	1	4	20	555		1	581	13.28 (3)
Wood Frog		1	106	139	2	11	259	5.92 (4)
American Bullfrog	1			83			84	1.92 (5)
Northern Leopard Frog		8		1	18	1	28	0.64 (6)
Eastern American Toad		1	5	5	5	5	21	0.48 (7)
Unknown <i>Lithobates</i> sp.		5		6		2	13	0.30 (8)
Pickerel Frog		2		4			6	0.14 (9)
Eastern Red-backed Salamander			1	1		76	78	47.27 (1)
Spotted Salamander			19	41			60	36.36 (2)
Northern Two-lined Salamander		25					25	15.15 (3)
Red-spotted Newt				2			2	1.21 (4)
Common Snapping Turtle		2		20	1		23	53.49 (1)
Painted Turtle	1	1		16	1		19	44.19 (2)
Spotted Turtle				1			1	2.33 (3)
Common Garter Snake				1	35	8	44	95.65 (1)
Eastern Milk Snake					2		2	4.35 (2)
Total # of Adults	3	49	356	4,050	66	105	4,629	
Total # of Species	3	8	7	15	8	7	17	
	9		15		10			

Table 3. Distribution by habitat category and frequency of occurrence for the 17 species of amphibians and reptiles recorded at Minute Man National Historical Park. Frequency of Occurrence (FO) = the number of sites where a species was detected divided by the total number of sites surveyed (37). Number of localities includes both standardized survey sites (32) and incidental encounter locations (5).

Species Common Name	Stream		Wetland		Upland		Total	FO (%)
	Intermittent Stream	Permanent Stream	Temporary Pond	Permanent Pond	Field	Deciduous Forest		
Northern Spring Peeper			2	12			14	37.8
Gray Treefrog			1	5	1	1	8	21.6
Northern Green Frog	1	1	2	12		1	17	46.0
Wood Frog		1	1	5	2	3	12	32.4
American Bullfrog	1			9			10	27.0
Northern Leopard Frog		1		1	4	1	7	18.9
Eastern American Toad		1	2	4	1	4	12	32.4
Pickerel Frog		1		3			4	10.8
Unknown <i>Lithobates</i> sp.		2	2	8		1	13	35.1
Eastern Red-backed Salamander			1	1		7	9	24.3
Spotted Salamander			2	4			6	16.2
Northern Two-lined Salamander		2					2	5.4
Red-spotted Newt				1			1	2.7
Common Snapping Turtle		2		7	1		10	27.0
Painted Turtle	1	1		4	1		7	18.9
Spotted Turtle				1			1	2.7
Common Garter Snake				1	4	5	10	27.0
Eastern Milk Snake					1		1	2.7
Total # of Locations with detections/ Total # of locations	2/2	5/5	3/3	12/12	7/7	8/8	37/37	

Table 4. Number of adults recorded and species richness (S) at each of 32 standardized survey sites and 5 incidental encounter locations at Minute Man National Historical Park. Frequency of occurrence (FO) is the number of locations where a species was detected, divided by the total number of locations surveyed (37). L=larvae.

Site	Northern Spring Peeper	Gray Treefrog	Northern Green Frog	Wood Frog	American Bullfrog	Northern Leopard Frog	Eastern American Toad	Pickereel Frog	Unknown <i>Lithobates</i> species	Eastern Red-backed Salamander	Spotted Salamander	Northern Two-lined Salamander	Red-spotted Newt	Common Snapping Turtle	Painted Turtle	Spotted Turtle	Common Garter Snake	Eastern Milk Snake	Total # of Adults	% of Total	S
Standardized Survey Sites																					
Mill Brook North			1												1				2	0.04	2
Mill Brook West					1														1	0.02	1
Black Gum Swamp Pond	260	58	39	4	12				1	1	15								390	8.43	7
Cook's Pond	461	270	178	130	6		L				25			2					1,072	23.16	8
Cranberry Bog	501	60	48								1			3		1			614	13.26	6
Folly Pond	384	226	93	2	3			2					2	4					716	15.47	8
Irrigation Pond A	5		7	2	7				2						1		1		25	0.54	6
Mill Brook Wayside	313		40																353	7.63	2
Nelson Pond	78	2	78		41		3	1						1	4				208	4.49	8
Palumbo Ditches	6		10		1	1	1							2	1				22	0.48	7
Palumbo Pond	2		25		L									6	10				43	0.92	4
Pond 4-121	325		3				1												329	7.11	3
Pond O	214		25		11				3		1								254	5.49	4
VC Permanent Pond	10		9	1	2			1						2					25	0.54	6
Elm Brook North												1							1	0.02	1
Elm Brook South									3			24							27	0.58	1
Mill Brook Mouth				1		8	1	2	2					1					15	0.32	5
Mill Brook South			4																4	0.09	1
VC Vernal Pond	3																		3	0.06	1
Virginia Road Pond	200		2	106			4			1	8								321	6.93	6

Table 4. Number of adults recorded and species richness (S) at each of 32 standardized survey sites and 5 incidental encounter locations at Minute Man National Historical Park. Frequency of occurrence (FO) is the number of locations where a species was detected, divided by the total number of locations surveyed (37). L=larvae (continued).

Site	Northern Spring Peeper	Gray Treefrog	Northern Green Frog	Wood Frog	American Bullfrog	Northern Leopard Frog	Eastern American Toad	Pickereel Frog	Unknown <i>Lithobates</i> species	Eastern Red-backed Salamander	Spotted Salamander	Northern Two-lined Salamander	Red-spotted Newt	Eastern Snapping Turtle	Painted Turtle	Spotted Turtle	Common Garter Snake	Eastern Milk Snake	Total # of Adults	% of Total	S
Whittemore Pond		2	18				1				10								31	0.67	4
Woodland #2				1			1			2									4	0.09	3
Woodland #3						1			2	5							2		10	0.22	3
Woodland #4				2						3							1		6	0.13	3
Woodland #6			1	8			1			30							3		43	0.93	5
Woodland #8										23							1		24	0.52	2
Woodland #11		1								11									12	0.26	2
Woodland #12							2			2									4	0.09	2
Fiske Hill Field																	6	2	8	0.17	2
Historic Fields		2		1		8	5										20		36	0.78	5
North Bridge Field						7													7	0.15	1
Palumbo Field				1		2									1		2		6	0.13	4
Incidental Encounter Sites																					
Burke House (field)							1												1	0.02	1
Meriam Field						1								1					2	0.04	2
Nelson House (field)																	7		7	0.15	1
Concord River														1	1				2	0.04	2
Folly Pond Woodland																	1		1	0.02	1
Total # of Adults	2,762	621	581	259	84	28	21	6	13	78	60	25	2	23	19	1	44	2	4,629	100	17
Total # of Localities	14	8	17	12	10	7	12	4	6	9	6	2	1	10	7	1	9	1			
FO (%)	38	22	46	32	27	19	32	11	16	24	16	5	3	27	19	3	24	3			

Minute Man National Historical Park Herpetological Survey

Location of salamander detections

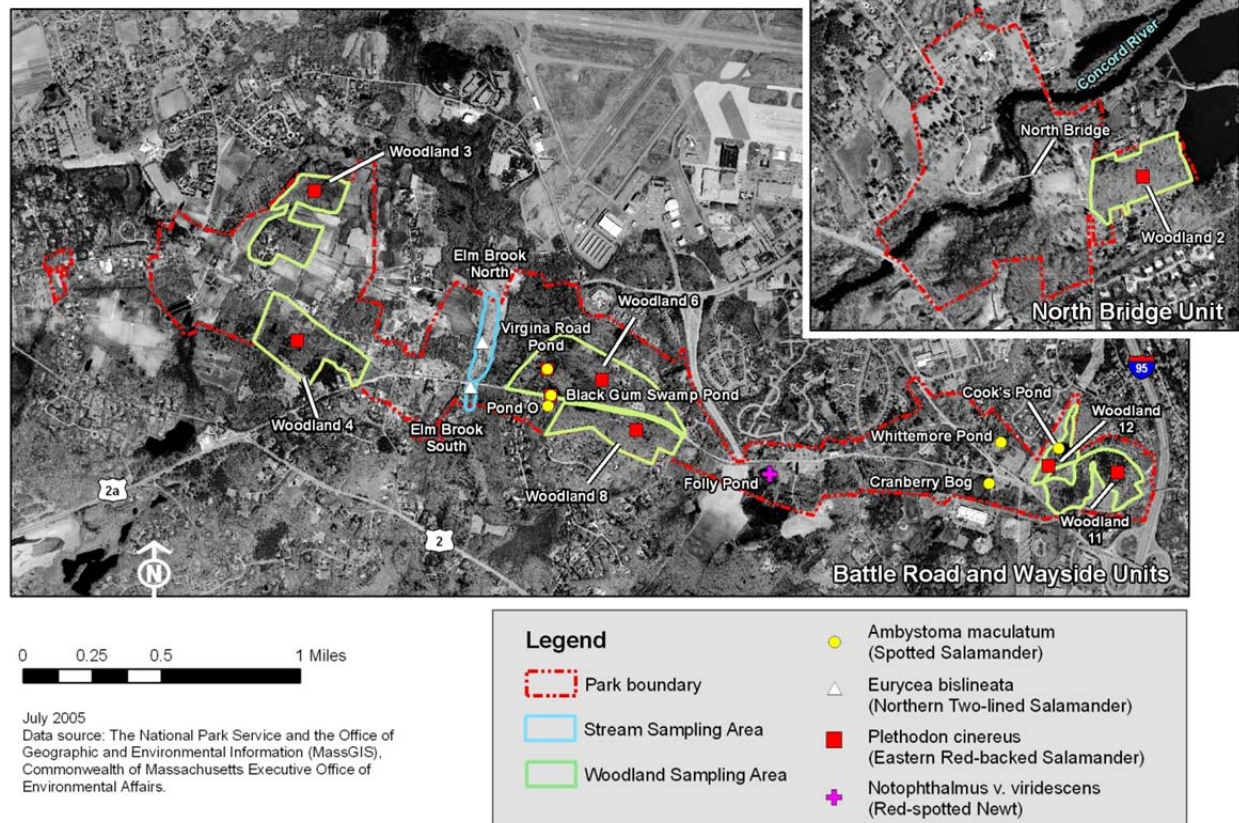


Figure 2. Location of salamander detections at Minute Man National Historical Park. Points represent central location of survey sites where a given species was recorded, not actual location of each individual. Open symbol represents incidental encounter site.

Minute Man National Historical Park Herpetological Survey

Location of anuran detections

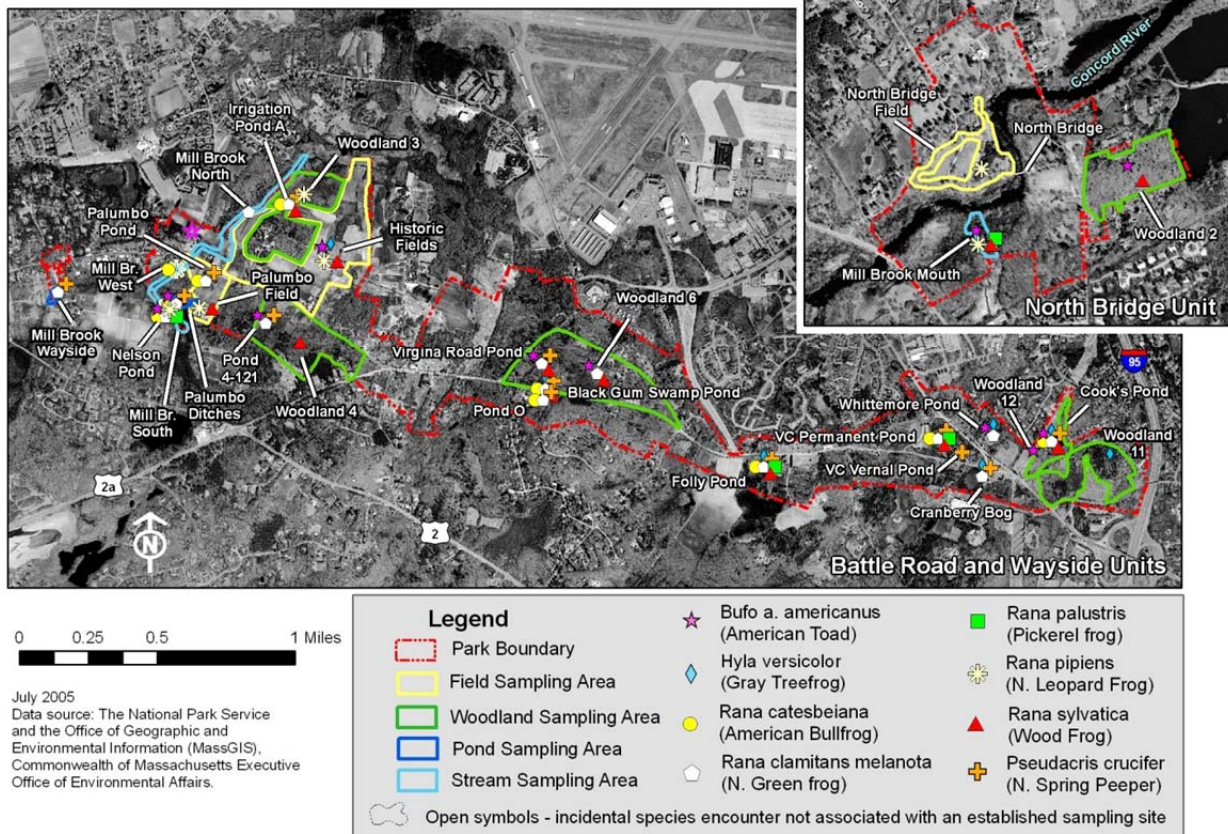


Figure 3. Location of frog and toad detections at Minute Man National Historical Park. Points represent central location of survey sites where a given species was recorded, not actual location of each individual. Open symbol represents incidental encounter site.

Minute Man National Historical Park Herpetological Survey

Location of reptile detections

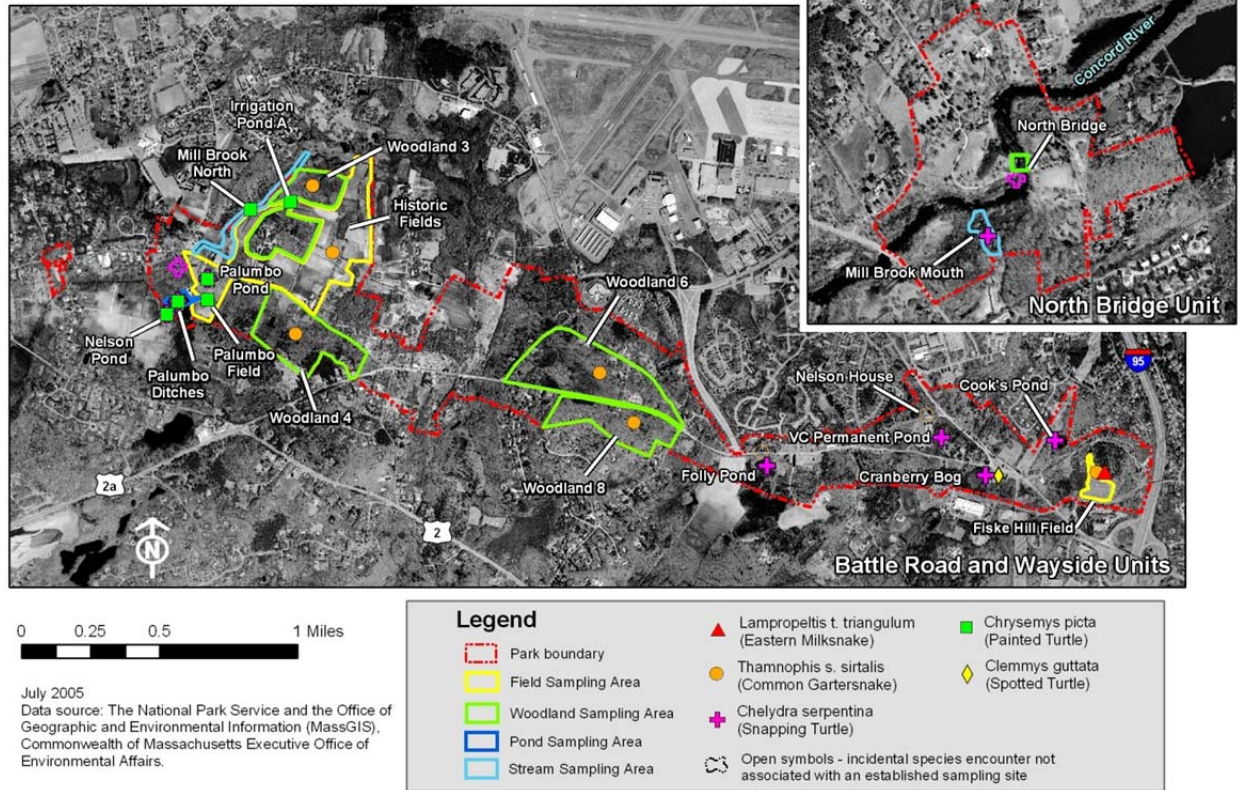


Figure 4. Location of reptile detections at Minute Man National Historical Park. Points represent central location of survey sites where a given species was recorded, not actual location of each individual. Open symbol represents incidental encounter site.

Minute Man National Historical Park Herpetological Survey

Species richness

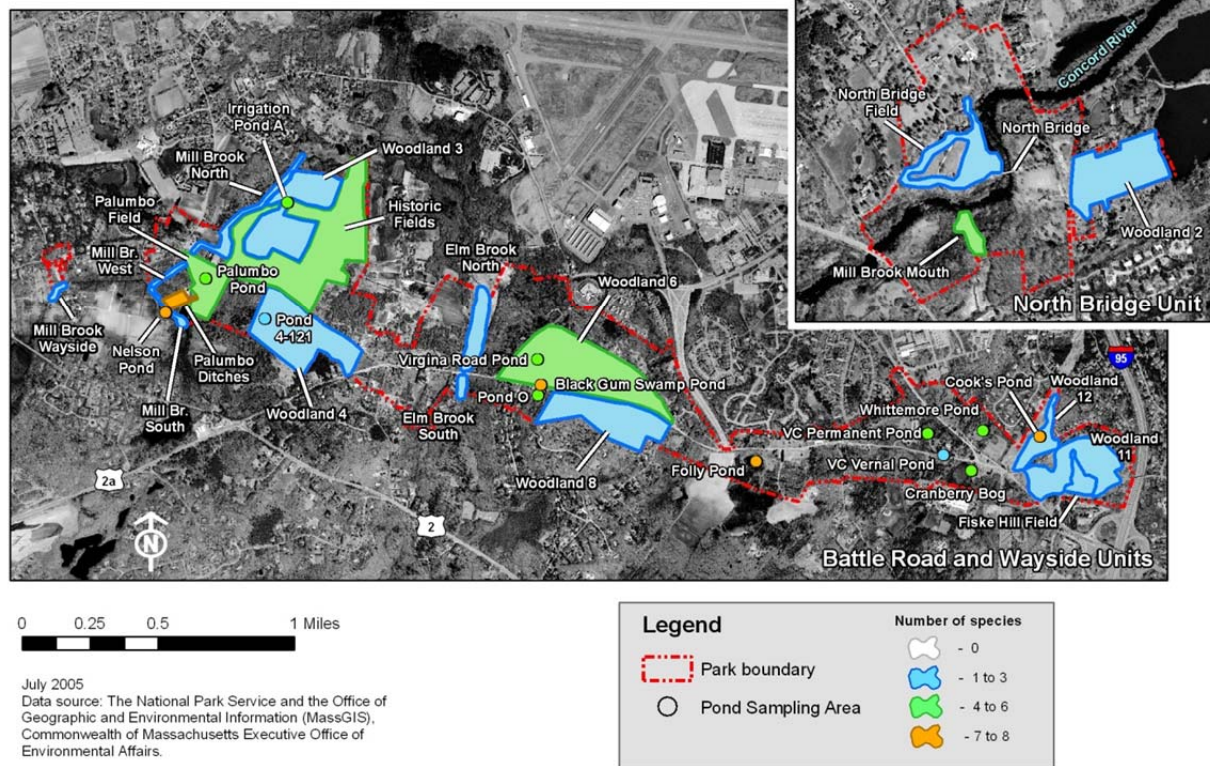


Figure 5. Species richness of areas sampled for amphibians and reptiles at Minute Man National Historical Park.

Survey Method Summaries

For the purposes of calculating species richness at survey sites and by different survey methods, the presence of any age class of a given species constituted a “present” for the status of that species for a given site and/or survey method. Of the standardized surveys, pond TCS and minnow trap surveys detected the greatest number of species (eight species each). Pond TCS was the most productive method of capture for gray treefrog, northern green frog and American bullfrog, and minnow trap surveys was the most productive method for red-spotted newt. Anuran calling surveys detected six species, produced 55.3% of all individuals recorded, and were the most productive method for northern spring peeper. Stream TCS detected seven species and was the most productive method for northern two-lined salamander, woodland TCS detected seven species and was the most productive method for eastern red-backed salamander, and field TCS detected four species and was the most productive method for northern leopard frog. Turtle trap surveys produced four species (one frog and three turtle species), and were the most productive method for all three turtles species encountered in this study. Coverboard surveys also produced four species (one frog, one salamander, and two snake species) and were the most productive method for common garter snake and were the only method that detected eastern milk snakes. Egg mass counts detected two species, wood frog and spotted salamander, and were the most productive method for those species. Incidental encounters recorded nine species and were the most productive method of capture for eastern American toad (Tables 5-7).

Anuran Calling Surveys

Six anuran species were heard during calling surveys at 14 sites. Northern spring peeper and northern green frog were the most widespread species, heard at 12 (86%) sites. American bullfrog and gray treefrog were each heard at 6 (43%) sites, followed by wood frog and eastern American toad which were each heard at 3 (21%) sites (Table 8). Northern spring peeper was also the most abundant species (1,980 adults) based on counts or estimates of numbers calling, followed by gray treefrog (301 adults), northern green frog (239 adults), American bullfrog (23 adults), wood frog (15 adults) and eastern American toad (four adults) (Table 8). Ideally, an equal number of surveys at each site are desired to make equal comparisons between sites. All sites were surveyed three or four times each from 24 March to 19 June. Anuran calling surveys at Black Gum Swamp Pond, Cook’s Pond, and Nelson Pond produced the most species (five each), and Cranberry Bog produced the most northern spring peepers with 451 adults recorded in the course of three surveys. Cook’s Pond (four surveys) and Folly Pond (three surveys) produced the most gray treefrogs, each site with 120 adults recorded (Table 8).

Egg Mass Counts

Spotted salamander and/or wood frog egg masses were counted from six of 13 sites surveyed. Cook’s Pond had the greatest number of spotted salamander egg masses (31 egg masses = est. 20 females), and the mean number of egg masses per pond for the six ponds where egg masses were present was 13.83 (SD $\pm$ 11.55). Wood frog egg masses were only found in Cook’s Pond and Virginia Road Pond, and represented 20 and 96 females respectively (Table 9).

Table 5. Number and species richness (S) of amphibians recorded by survey method at Minute Man National Historical Park. A species was determined as being present for a given survey method if at least one individual of any age-class was detected by that method.

Survey Method ¹	Northern Spring Peeper		Gray Treefrog		Northern Green Frog		Wood Frog		American Bullfrog		Northern Leopard Frog		Eastern American Toad		Pickerel Frog		Unknown <i>Lithobates</i> Species		Eastern Red-backed Salamander		Spotted Salamander		Northern Two-lined Salamander		Red-spotted Newt		Total # of Adults	
	adl ²	adl	lrv ²	adl	lrv	adl	lrv	adl	lrv	adl	adl	lrv	adl	adl	lrv	adl	adl	lrv	adl	adl	lrv	adl	lrv	egg ²	adl			
ACS	1,980	301		239			15			23				4													2,562	6
EMC							116													52							168	2
TCS Stream				5			1			1		8			1	5						25	19	205			46	6
TCS Woodland		1		1			9				1	3				2		70									87	6
TCS Field		2					1				14																17	3
TCS Pond	782	317		327	12	106	200	54	3		5				3	63	2	2									1,598	8
CB							1										6										7	2
TTS				1																							1	1
MTS			2	6	1,904	3	997	5	20			1	1	3	363		6	2							2		26	8
IE				2			7			1		5	9		4												28	6
Total	2,762	621	2	581	1,916	259	1,197	84	23	28	21	1	6	13	426	78	60	2	25	19	205	2					4,540	12

¹ACS = Anuran Calling Survey, EMC = Egg Mass Count, TCS = Time-Constrained Search, CB = Coverboard, TTS = Turtle Trap Survey, MTS = Minnow Trap Survey, IE = Incidental Encounter

²adl = Adult, lrv = Larvae, egg = Egg

Table 6. Number and species richness (S) of adult-form reptiles recorded by survey method at Minute Man National Historical Park.

Survey Method ¹	Common Snapping Turtle	Painted Turtle	Spotted Turtle	Common Garter Snake	Eastern Milk Snake	Total # of Adults	S
TCS Stream		1				1	1
TCS Woodland				4		4	1
TCS Field		1				1	1
CB				31	2	33	2
TTS	18 ²	13 ³	1			32	3
IE	5	4		9		18	3
Total	23	19	1	44	2	89	5

¹TCS = Time-Constrained Search, CB = Coverboard, TTS = Turtle Trap Survey, IE = Incidental Encounter

²17 unique individuals plus one recapture

³11 unique individuals plus two recaptures

Table 7. Percentage of adult-form individuals of each species detected by each survey method at Minute Man National Historical Park. Derived from Tables 5 and 6.

Survey Method ¹	Northern Spring Peeper	Gray Treefrog	Northern Green Frog	Wood Frog	American Bullfrog	Northern Leopard Frog	Eastern American Toad	Pickering Frog	Unknown <i>Lithobates</i> Species	Eastern Red-backed Salamander	Spotted Salamander	Northern Two-lined Salamander	Red-spotted Newt	Snapping Turtle	Painted Turtle	Spotted Turtle	Common Garter Snake	Eastern Milk Snake	Total # Adults	% Total Adults	S ²
ACS	71.7	48.5	41.1	5.8	27.4	0.0	19.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2,562	55.3	6
EMC	0.0	0.0	0.0	44.8	0.0	0.0	0.0	0.0	0.0	0.0	86.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	168	3.6	2
TCS Stream	0.0	0.0	0.9	0.4	1.2	28.6	0.0	16.7	38.5	0.0	0.0	100.0	0.0	0.0	5.3	0.0	0.0	0.0	47	1.0	7
TCS Woodland	0.0	0.2	0.2	3.5	0.0	3.6	14.3	0.0	15.4	89.7	0.0	0.0	0.0	0.0	0.0	0.0	9.1	0.0	91	2.0	7
TCS Field	0.0	0.3	0.0	0.4	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3	0.0	0.0	0.0	18	0.4	4
TCS Pond	28.3	51.0	56.3	40.9	64.3	0.0	23.8	0.0	23.1	2.6	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,598	34.5	8
CB	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	7.7	0.0	0.0	0.0	0.0	0.0	0.0	70.5	100.0	40	0.9	4
TTS	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	78.3	68.4	100.0	0.0	0.0	33	0.7	4
MTS	0.0	0.0	1.0	1.2	6.0	0.0	0.0	16.7	23.1	0.0	10.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	26	0.6	6
IE	0.0	0.0	0.3	2.7	1.2	17.9	42.9	66.7	0.0	0.0	0.0	0.0	0.0	21.7	21.1	0.0	20.5	0.0	46	1.0	9
Total # of Adults	2,762	621	581	259	84	28	21	6	13	78	60	25	2	23	19	1	44	2	4,629		17

¹ACS = Anuran Calling Survey, EMC = Egg Mass Count, TCS = Time-Constrained Search, CB = Coverboard, TTS = Turtle Trap Survey, MTS = Minnow Trap Survey, IE = Incidental Encounter

²S = Species richness

Table 8. Results of anuran calling surveys at Minute Man National Historical Park.

Site	First Date	Last Date	# of Surveys	Northern Spring Peeper		Gray Treefrog		Northern Green Frog		Wood Frog		American Bullfrog		Eastern American Toad		S ³
				CI ¹	# ²	CI	#	CI	#	CI	#	CI	#	CI	#	
Black Gum Swamp Pond	3/25	6/18	4	3	85	2	18	1	5	1	3	1	2			5
Cook's Pond	4/16	6/18	4	3	280	3	120	3	35	2	10	1	3			5
Cranberry Bog	4/16	6/18	3	3	451	3	40	2	15							3
Folly Pond	4/16	6/18	3	3	205	3	120	3	51			1	2			4
Irrigation Pond A	4/17	6/19	3					2	4			1	1			2
Mill Brook Wayside	4/16	6/18	3	3	313			3	40							2
Nelson Pond	4/16	6/18	3	3	78	1	2	3	65			2	14	1	2	5
Palumbo Pond	4/17	6/19	3	1	1			1	6							2
Pond 4-121	3/24	6/18	4	3	325			1	3					1	1	3
Pond O	4/16	6/18	3	3	203			1	5							2
VC Permanent Pond	4/16	6/18	3	2	10			1	6			1	1			3
VC Vernal Pond	3/24	6/18	4	1	3											1
Virginia Road Pond	4/17	6/18	3	2	26					1	2					2
Whittemore Pond	3/24	6/18	4			1	1	1	4					1	1	3
Total # of Sites					12		6		12		3		6		3	
Total # of Adults					1,980		301		239		15		23		4	

¹Highest call index recorded

²Number of adult individuals detected summed across all surveys

³S = Species richness

Table 9. Number of egg masses recorded during egg mass counts at Minute Man National Historical Park.

Site	Date	Spotted Salamander		Wood Frog	
		# of Egg Masses	Est. # of Females	# of Egg Masses	Est. # of Females
Black Gum Swamp Pond	4/19	22	14		
Cook's Pond	4/19	31	20	20	20
Cranberry Bog	4/19	1	1		
Folly Pond	4/18				
Irrigation Pond A	4/18				
Nelson Pond	4/18				
Palumbo Ditches	4/18				
Palumbo Pond	4/18				
Pond O	4/19	2	1		
VC Permanent Pond	4/18				
VC Vernal Pond	4/18				
Virginia Road Pond	4/19	13	8	96	96
Whittemore Pond	4/19	14	9		
Total		83	52 ¹	116	116

¹Due to rounding error when converting from the number of egg masses, the total is one individual less than the sum of the site estimates.

Time-constrained Search

Stream TCS: Seven species were detected during TCS in six stream sections. Mill Brook Mouth had the most species detected (three species) by this method, and Elm Brook South had the most adult individuals detected (24 adults, all of which were northern two-lined salamanders) at any one site. The northern leopard frog (CR = 0.31 individuals per search hour) was the most abundant anuran, followed by the northern green frog (CR = 0.20), American bullfrog (CR = 0.04), pickerel frog (CR = 0.04), and wood frog (CR = 0.04). The northern two-lined salamander (CR = 0.98) was the only salamander and the painted turtle (CR = 0.04) was the only reptile detected by this method (Table 10, Table 11).

Woodland/Field TCS: Seven species were detected during woodland TCS in seven areas. The eastern red-backed salamander was the most widespread species, recorded in all seven woodland areas surveyed. This was followed by the eastern American toad and the common garter snake (each in three areas), wood frog (two areas), and northern leopard frog and northern green frog (each in one area). The eastern red-backed salamander was by far the most abundant species (CR = 2.39 individuals per search hour), while the northern leopard frog, gray treefrog, and northern green frog were the least abundant (each with a CR = 0.03). Woodland #6 had the greatest species richness (five species recorded) and also the greatest number of adults recorded (47.2% of individuals; Table 10, Table 12).

Four species were detected during field TCS in four areas. The northern leopard frog was the most widespread (found at two sites) and the most abundant species (CR = 0.81) for field TCS. The remaining three species were found at only one field area each and had comparatively lower abundances than northern leopard frogs (i.e., gray treefrog CR = 0.12, wood frog CR = 0.06, and painted turtle CR = 0.06). Historic Fields had the greatest species diversity (three species) and also the greatest number of adults recorded (61.1% of individuals). Overall abundance was considerably greater in woodlands (CR = 3.04) compared to fields (CR = 1.04, Table 10, Table 12).

Pond TCS: Eight species were detected during pond TCS at 12 sites. We recorded all eight species in permanent ponds and seven (all except American bullfrog) in temporary ponds. Northern green frog was the most widespread species, recorded at all 12 sites, followed by northern spring peeper (nine sites), American bullfrog (eight sites), gray treefrog (five sites), wood frog (three sites), and eastern American toad, spotted salamander, and eastern red-backed salamander (each at two sites). Northern spring peeper was also the most abundant species (adults) recorded in both permanent pond TCS (CR = 24.32) and temporary pond TCS (CR = 23.84, Table 13). Abundance (CR) of northern spring peepers was calculated from the estimated number of adult males heard (Table 12, Table 13). Estimates of the number of northern spring peepers present during incidents of full chorus during pond TCS surveys are based on the average number of calling males (173) estimated by multiple observers during full chorus episodes of anuran calling surveys (n = 11).

Table 10. Time constrained search effort and dates by habitat at Minute Man National Historical Park.

	Site	First Date	Last Date	# of Surveys	Effort (search hours)
INT. STREAM	Mill Brook North	17-Apr	13-Sep	4	5.7
	Mill Brook West	16-Apr	25-Aug	4	4.2
	Total			8	9.9
PERM. STREAM	Elm Brook North	16-Apr	25-Aug	4	4.0
	Elm Brook South	16-Apr	15-Sep	5	3.7
	Mill Brook Mouth	17-Apr	13-Sep	5	4.2
	Mill Brook South	20-Apr	15-Sep	5	3.8
	Total			19	15.7
TEMP. POND	Virginia Road Pond	19-Apr	14-Sep	5	3.5
	Whittemore Pond	24-Mar	14-Sep	6	3.8
	Total			11	7.3
PERM. POND	Black Gum Swamp Pond	25-Mar	26-Aug	5	2.7
	Cook's Pond	24-Mar	14-Sep	6	3.2
	Cranberry Bog	18-Apr	23-Aug	4	2.5
	Folly Pond	17-Apr	14-Sep	5	3.2
	Irrigation Pond A	18-Apr	23-Aug	4	2.3
	Nelson Pond	17-Apr	23-Aug	4	2.0
	Palumbo Ditches	18-Apr	23-Aug	4	2.6
	Palumbo Pond	18-Apr	23-Aug	4	2.2
	Pond O	18-Apr	26-Aug	4	2.3
	VC Permanent Pond	17-Apr	26-Aug	4	2.0
	Total			44	25.0
WOODLAND	Woodland #2	17-Apr	13-Sep	5	3.3
	Woodland #3	16-Apr	15-Sep	6	8.3
	Woodland #4	17-Apr	13-Sep	5	4.2
	Woodland #6	14-Apr	15-Sep	6	5.0
	Woodland #8	14-Apr	16-Sep	5	2.9
	Woodland #11	17-Apr	13-Sep	5	3.3
	Woodland #12	16-Apr	15-Sep	5	2.3
	Total			37	29.3
FIELD	Fiske Hill Field	17-Apr	24-Aug	4	2.9
	Historic Fields	14-Apr	27-Aug	6	10.2
	North Bridge Field	17-Apr	24-Aug	4	2.4
	Palumbo Field	16-Apr	20-Jun	3	1.8
	Total			17	17.3

Table 11. Number of amphibians and reptiles recorded during stream time-constrained search at Minute Man National Historical Park. The capture rate (CR) is the number of individuals divided by total search hours.

					# Individuals (CR)										
					Northern Two-lined Salamander			Northern Leopard Frog	Northern Green Frog	American Bullfrog	Pickereel Frog	Wood Frog	Painted Turtle		
Site	First Date	Last Date	# of Surveys	Search Hours	adl	lrv	egg	adl	adl	adl	adl	adl	adl	Total Adults	S ¹
Elm Brook North	4/16	8/25	4	4	1 (0.25)		180 (45.00)							1 (0.25)	1
Elm Brook South	4/16	9/15	5	3.7	24 (6.49)	19 (5.14)	25 (6.76)							24 (6.49)	1
Mill Brook Mouth	4/17	9/13	5	4.2				8 (1.9)			1 (0.24)	1 (0.24)		10 (2.38)	3
Mill Brook South	4/20	9/15	5	3.8					4 (1.05)					4 (1.05)	1
Mill Brook North	4/16	8/25	4	5.7					1 (0.18)				1 (0.18)	2 (0.35)	2
Mill Brook West	4/16	8/25	4	4.2						1 (0.24)				1 (0.24)	1
Total			27	25.6	25 (0.98)	19 (0.74)	205 (8.01)	8 (0.31)	5 (0.20)	1 (0.04)	1 (0.04)	1 (0.04)	1 (0.04)	42 (1.64)	7

¹S = Species richness

Table 12. Number of amphibians and reptiles recorded during woodland and field time-constrained search at Minute Man National Historical Park. The capture rate (CR) is the number of individuals divided by search hours.

Site	First Date	Last Date	# of Surveys	Search Hours	# Individuals (CR)								Total	S ¹
					Eastern red-backed Salamander	Northern Leopard Frog	Wood Frog	Eastern American Toad	Gray Treefrog	Northern Green Frog	Painted Turtle	Common Garter Snake		
Woodland #2	4/17	9/13	5	3.3	2 (0.61)			1 (0.30)					3 (0.91)	2
Woodland #3	4/16	9/15	6	8.3	5 (0.60)	1 (0.12)						1 (0.12)	7 (0.84)	3
Woodland #4	4/17	9/13	5	4.2	3 (0.71)		1 (0.24)					1 (0.24)	5 (1.19)	3
Woodland #6	4/14	9/15	6	5	30 (6.00)		8 (1.60)	1 (0.20)		1 (0.20)		2 (0.4)	42 (8.40)	5
Woodland #8	4/14	9/16	5	2.9	20 (6.90)								20 (6.90)	1
Woodland #11	4/17	9/13	5	3.3	9 (2.73)				1 (0.30)				10 (3.03)	2
Woodland #12	4/16	9/15	5	2.3	1 (0.43)			1 (0.43)					2 (0.87)	2
		Total	37	29.3	70 (2.39)	1 (0.03)	9 (0.31)	3 (0.10)	1 (0.03)	1 (0.03)	0	4 (0.14)	89 (3.04)	7
Fiske Hill Field	4/17	8/24	4	2.9									0	0
Historic Fields	4/14	8/27	6	10.2		8 (0.78)	1 (0.10)		2 (0.20)				11 (1.08)	3
North Bridge Field	4/17	8/24	4	2.4		6 (2.50)							6 (2.5)	1
Palumbo Field	4/16	6/20	3	1.8							1 (0.56)		1 (0.56)	1
		Total	17	17.3	0	14 (0.81)	1 (0.06)	0	2 (0.12)	0	1 (0.06)	0	18 (1.04)	4

¹S = Species richness

Table 13. Number of amphibians and reptiles recorded during pond time-constrained search at Minute Man National Historical Park. The capture rate (CR) is the number of individuals divided by search hours.

Site	First Date	Last Date	# of Surveys	Search Hours	# Individuals (CR)											Total # of Adults
					Adults					Vocalization						
					Northern Green Frog	Wood Frog	American Bullfrog	Eastern American Toad	Spotted Salamander	Eastern Red-backed Salamander	Northern Spring Peeper	Northern Green Frog	Gray Treefrog	Wood Frog	American Bullfrog	
Permanent Ponds																
Black Gum Swamp Pond	3/25	8/26	5	2.7	4 (1.48)		7 (2.59)		1 (0.37)	1 (0.37)	175 (64.81)	30 (11.11)	40 (14.81)	1 (0.37)	1 (0.37)	260 (96.29)
Cook's Pond	3/24	9/14	6	3.2	42 (13.13)	100 (31.25)	2 (0.63)				181 (56.56)	100 (31.25)	150 (46.88)		1 (0.31)	576 (180.00)
Cranberry Bog	4/18	8/23	4	2.5	7 (2.80)						50 (20.00)	22 (8.80)	20 (8.00)			99 (39.60)
Folly Pond	4/17	9/14	5	3.2	4 (1.25)						179 (55.94)	37 (11.56)	106 (33.13)		1 (0.31)	327 (102.19)
Irrigation Pond A	4/18	8/23	4	2.3	2 (0.87)		5 (2.17)				5 (2.17)	1 (0.43)			1 (0.43)	14 (6.09)
Nelson Pond	4/17	8/23	4	2	1 (0.50)		15 (7.50)	1 (0.50)				10 (5.00)			12 (6.00)	39 (19.50)
Palumbo Ditches	4/18	8/23	4	2.6	2 (0.77)		1 (0.38)				6 (2.31)	8 (3.08)				17 (6.54)
Palumbo Pond	4/18	8/23	4	2.2	2 (0.91)						1 (0.45)	17 (7.73)				20 (9.09)
Pond O	4/18	8/26	4	2.3			7 (3.04)				11 (4.78)	20 (8.70)			1 (0.43)	39 (16.96)
VC Perm. Pond	4/17	8/26	4	2								3 (1.50)				3 (1.50)
	Total		44	25	64 (2.56)	100 (4.00)	37 (1.48)	1 (0.04)	1 (0.04)	1 (0.04)	608 (24.32)	248 (9.92)	316 (12.64)	1 (0.04)	17 (0.68)	1,394 (55.76)
Temporary Ponds																
Virginia Road Pond	4/19	9/14	5	3.5	2 (0.57)	2 (0.57)	4 (1.14)		1 (0.29)		174 (49.71)			3 (0.86)		186 (53.14)
Whittemore Pond	3/24	9/14	6	3.8	9 (2.37)				1 (0.26)			4 (1.05)	1 (0.26)			15 (3.95)
	Total		11	7.3	11 (1.51)	2 (0.27)	0	4 (0.55)	1 (0.14)	1 (0.14)	174 (23.84)	4 (0.55)	1 (0.14)	3 (0.41)	0	201 (27.53)

Table 13. Number of amphibians and reptiles recorded during pond time-constrained search at Minute Man National Historical Park. The capture rate (CR) is the number of individuals divided by search hours (continued).

Site	First Date	Last Date	# of Surveys	Search Hours	# Individuals (CR)			S ¹
					Larvae			
					Northern Green Frog	Wood Frog	American Bullfrog	
Permanent Ponds								
Black Gum Swamp Pond	3/25	8/26	5	2.7	5 (1.85)			7
Cook's Pond	3/24	9/14	6	3.2	5 (1.56)			5
Cranberry Bog	4/18	8/23	4	2.5				3
Folly Pond	4/17	9/14	5	3.2				4
Irrigation Pond A	4/18	8/23	4	2.3	1 (0.43)		2 (0.87)	3
Nelson Pond	4/17	8/23	4	2				3
Palumbo Ditches	4/18	8/23	4	2.6				3
Palumbo Pond	4/18	8/23	4	2.2			1 (0.45)	3
Pond O	4/18	8/26	4	2.3	1 (0.43)			3
VC Perm. Pond	4/17	8/26	4	2				1
Total			44	25	12 (0.48)	0	3 (0.12)	8
Temporary Ponds								
Virginia Road Pond	4/19	9/14	5	3.5		200 (57.14)		5
Whittemore Pond	3/24	9/14	6	3.8				3
Total			11	7.3	0	200 (27.40)	0	7

¹S = Species richness

Coverboards

A total of 384 board checks in seven woodland sites produced six eastern red-backed salamanders, three common garter snakes, and one wood frog. Woodland #8 was the only site where multiple species were detected (two species) and was also the site with the greatest number of individuals detected (four individuals, Table 14). A total of 358 board checks in eight field sites produced 28 common garter snakes and two eastern milk snakes. Fiske Hill Field array #1 was the only site where multiple species were detected and was the only site where eastern milk snakes were detected, while Historic Field array #1 had the greatest number of individuals detected (11 common garter snakes, Table 14). Although the number of boards checked during the late survey period (August – September) was greater, 64% of all snake captures occurred during the early survey period (April – June; Table 15). However, due in part to the low number of captures, these seasonal differences were not significant ($\chi^2 = 1.975$, $df = 1$, $p = 0.160$, `chisq.test` in R version 2.12.2). Sampling effort with metal versus plywood coverboards were almost equal (377 vs. 365 board checks, respectively) and although a few more snakes (and both eastern milk snakes) were captured under metal coverboards, these differences were not significant ($\chi^2 = 0.537$, $df = 1$, $p = 0.537$, `chisq.test` in R version 2.12.2, Table 16, Appendix E).

Turtle Trap Surveys

Most turtle detections at MIMA were through trapping. Seventeen individual common snapping turtles (one of which was recaptured once), 11 individual painted turtles (two of which were each recaptured once), and one individual spotted turtle were captured using turtle traps (Table 17, Appendix F). Common snapping turtles were captured at eight of 13 sites (62%), painted turtles were captured at three of 13 sites (23%), and the single spotted turtle was captured at one of 13 sites (8%). All turtles were captured in permanent ponds. Both common snapping turtles and painted turtles were most abundant in Palumbo Pond, with five captures (five individuals unique to the pond) and a capture rate of 16.1 captures per 100 trap nights for common snapping turtles and 10 captures (nine individuals unique to the pond) and a capture rate of 32.3 captures per 100 trap nights for painted turtles. A single spotted turtle was captured at Cranberry Bog (Table 17). Although there were too few turtle recaptures during this survey to calculate a population size estimate, movement of painted turtles between Palumbo Pond and Palumbo Ditches and movement of common snapping turtles between Folly Pond and Palumbo Pond was documented.

Minnow Trap Surveys

Eight species were detected using minnow traps. With four species captured, Cook's Pond had the greatest species richness (Table 18). Overall captures of adults from minnow trapping were low (total of 23 adults captured) compared to other survey methods, with the most abundant and most widespread species in permanent ponds being the northern green frog (total of six adults captured at three sites, CR = 1.38 captures/100 trap nights). Only four adult amphibians were captured in temporary ponds, three of which were wood frogs captured at Virginia Road Pond (CR = 2.80 captures per 100 trap nights). Captures of larval amphibians from minnow trapping were high (total of 3,290 larvae captured), with the most abundant and widespread species in permanent ponds and temporary ponds being the northern green frog (total of 799 individuals captured at eight of ten permanent pond sites, CR = 184.10 captures per 100 trap nights, and 1,108 individuals captured at two of two temporary pond sites, CR = 545.81 captures per 100 trap nights). Of the 1,108 larval green frogs captured at temporary ponds, 1,101 of these were captured at Whittemore Pond (CR = 2001.82 captures per 100 trap nights). Also of note, 969

larval wood frogs (CR = 1,863.46 captures per 100 trap nights) were captured during minnow trapping at Virginia Road Pond, one of the two temporary ponds trapped by this survey method (Table 18).

Incidental Encounters

Nine species from 18 sites were recorded incidental to survey efforts conducted at standardized survey sites. Nelson House had the greatest number of individuals captured (seven captures, all being common garter snakes), and Folly Pond, Irrigation Pond A, and Nelson Pond had the greatest species diversity (three species captured at each site). Eastern American toad and common garter snake were the most abundant species captured (nine individuals captured of each species), and eastern American toad, wood frog, and common snapping turtle were the most widespread species, with each species being captured at five sites (Table 19).

Table 14. Number of reptiles and amphibians recorded during woodland and field coverboard surveys at Minute Man National Historical Park. Capture rate (CR) is the total number of captures (including recaptures) per 100 board checks. Board checks are number of boards per site, multiplied by number of site visits.

Site	Common Garter Snake	Eastern Milk Snake	Eastern Red-backed Salamander	Wood Frog	# of Snakes	# of Amphibians	S_1	Snake CR	# Boards/ Site	# of Site Visits	# of Board Checks	# of Boards with Snakes
Woodland #2							0	0.00	8	6	48	
Woodland #3	1 (1.04)				1	1	1	1.04	8	6	96	1
Woodland #4				1 (2.08)		1	1	0.00	8	6	48	
WOODLAND Woodland #6	1 (2.08)				1	1		2.08	8	6	48	1
WOODLAND Woodland #8	1 (2.08)		3 (6.25)		1	3	2	2.08	8	6	48	1
WOODLAND Woodland #11			2 (4.17)			2	1	0.00	8	6	48	
WOODLAND Woodland #12			1 (2.08)			1	1	0.00	8	6	48	
WOODLAND Woodland Total	3 (0.78)	0	6 (1.56)	1 (0.26)	3	6	3	0.78	56	6	384	3
Fiske Hill Field array #1	4 (8.33)	2 (4.17)			6	2		12.50	8	6	48	2
Fiske Hill Field array #2	2 (4.17)				2	1		4.17	8	6	48	2
Historic Field array #1	11 (19.64)				11	1		19.64	8	7	56	5
FIELD Historic Field array #2	7 (17.50)				7	1		12.50	8	6	36 ²	3
FIELD Historic Field array #3							0	0.00	8	6	46 ²	
FIELD Historic Field array #4	2 (4.17)				2	1		4.17	8	6	48	1
North Bridge Field							0	0.00	8	4	28 ²	
Palumbo Field	2 (4.17)				2	1		4.17	8	6	48	2
FIELD Field Total	28 (7.82)	2 (0.56)	0	0	30	2		8.38	64	4-7	358	15
Overall Total	31 (4.18)	2 (0.27)	6 (0.81)	1 (0.001)	33	6	3	4.45	120		742	18

¹S = Species richness

²Some boards disappeared or were temporarily flooded

Table 15. Seasonal variation in snake captures during coverboard surveys at Minute Man National Historical Park, April to June versus August to September 2001. Capture totals include recaptures. Board checks are the number of boards per site, multiplied by the number of site visits.

Dates	Number (%) of Board Checks	Number of Board Checks Producing Snakes	Percent of Board Checks Producing Snakes	Number (%) of Snakes
April – June	256 (34%)	12	4.69%	21 (64%)
August – September	486 (66%)	12	2.47%	12 (36%)
Total	742	24	3.23%	33

Table 16. Number of snake captures under metal versus plywood during coverboard surveys at Minute Man National Historical Park.

Species	Number of New Snakes	Number of Recap Snakes	Coverboard Type			
			Metal ¹		Plywood ¹	
			# of Snakes	% of Snakes	# of Snakes	% of Snakes
Common Garter Snake	28	3	17	55%	14	45%
Eastern Milk Snake	2	0	2	100%	0	0%
Total Snakes	30	3	19	58%	14	42%

¹64 metal and 64 plywood boards deployed for 377 and 365 coverboard checks respectively

Table 17. Number of unique individuals (Inds) and turtle captures (Caps) during turtle trapping at Minute Man National Historical Park. Capture rate (CR) is the number of captures per 100 trap nights.

	Site	First Date	Last Date	# Traps	# of Trap Nights	Common									S ²
						Painted Turtle			Snapping Turtle			Spotted Turtle			
						Inds	Caps	CR	Inds	Caps	CR	Inds	Caps	CR	
PERMANENT	Black Gum Swamp Pond	5/15	6/23	3	30										0
	Cook's Pond	5/15	6/23	3	30				2	2	6.7				1
	Cranberry Bog	5/15	6/23	3	30				2	2	6.7	1	1	3.3	2
	Folly Pond	5/15	6/23	3	30				3	3	10.0				1
	Irrigation Pond A	5/15	6/23	3	40										0
	Mill Brook Mouth	8/23	8/27	2	8				1	1	12.5				1
	Nelson Pond	5/15	6/23	3	29	2	2	6.9	1	1	3.4				2
	Palumbo Ditches	5/15	6/23	8	80	1	1	1.3	2	2	2.5				2
	Palumbo Pond	4/16	6/23	3	31	8	10	32.3	4	5	16.1				2
	Pond O	5/15	6/23	3	30										0
	VC Perm Pond	5/15	6/23	3	30				2	2	6.7				1
	Permanent Pond Total				368	11 ¹	13	3.5	17 ¹	18	4.9	1	1	0.3	3
TEMP	Virginia Road Pond	5/15	6/23	3	30										0
	Whittemore Pond	5/15	6/23	3	30										0
	Temporary Pond Total				60	0	0	0	0	0	0	0	0	0	0
	Overall Pond Total				428	11 ¹	13	3.0	17 ¹	18	4.2	1	1	0.2	3

¹Total number of unique individuals is less than sum because one individual was captured at two sites

²S = Species richness

Table 18. Number of amphibians captured in minnow traps at Minute Man National Historical Park. Capture rate (CR) is the number of captures per 100 trap nights.

					# Captures (CR)							
					Adults							
Site	First Date	Last Date	# of Traps	Trap Nights	Spotted Salamander	Northern Green Frog	American Bullfrog	Wood Frog	Red-spotted Newt	Pickereel Frog	Total # of Adults	
PERMANENT	Black Gum Swamp Pond	3/24	9/17	2 to 3	56			2 (3.57)			2 (3.57)	
	Cook's Pond	3/24	9/17	2	50	5 (10.00)	1 (2.00)				6 (12.00)	
	Cranberry Bog	4/15	8/28	2	40		4 (10.00)				4 (10.00)	
	Folly Pond	4/15	9/17	2	46		1 (2.17)		2 (4.35)		3 (6.52)	
	Irrigation Pond A	4/15	8/28	2	40						0	
	Nelson Pond	4/15	8/28	2	40						0	
	Palumbo Pond	4/15	8/28	2	40						0	
	Palumbo Ditches	4/15	8/28	2	40						0	
	Pond O	4/15	8/28	2	42			3 (7.14)			3 (7.14)	
	VC Perm. Pond	4/15	8/28	2	40						1 (2.50)	
Permanent Pond Total				434	5 (1.15)	6 (1.38)	5 (1.15)	0	2 (0.46)	1 (0.23)	19 (4.38)	
TEMP	Virginia Road Pond	4/15	8/28	2 to 3	52			3 (5.77)			3 (5.77)	
	Whittemore Pond	3/24	9/17	2 to 3	55	1 (1.82)					1 (1.82)	
	Temporary Pond Total				107	1 (0.93)	0	0	3 (2.80)	0	0	4 (3.74)
Overall Pond Total					541	6 (1.11)	6 (1.11)	5 (0.92)	3 (0.55)	2 (0.37)	1 (0.18)	23 (4.25)

Table 18. Number of amphibians captured in minnow traps at Minute Man National Historical Park. Capture rate (CR) is the number of captures per 100 trap nights (continued).

Site	First Date	Last Date	# of Traps	Trap Nights	# Captures (CR)						S ¹	
					Larvae							
					Northern Green Frog	American Bullfrog	Wood Frog	Eastern American Toad	Gray Treefrog	Unknown Lithobates species		
PERMANENT	Black Gum Swamp Pond	3/24	9/17	2 to 3	56	121 (216.07)				1 (1.79)	135 (241.07)	3
	Cook's Pond	3/24	9/17	2	50	120 (240.00)		28 (56.00)	1 (2.00)			4
	Cranberry Bog	4/15	8/28	2	40	100 (250.00)					201 (502.50)	1
	Folly Pond	4/15	9/17	2	46	237 (515.22)				1 (2.17)	1 (2.17)	3
	Irrigation Pond A	4/15	8/28	2	40	4 (10.00)						1
	Nelson Pond	4/15	8/28	2	40		11 (27.50)					1
	Palumbo Pond	4/15	8/28	2	40	20 (50.00)						1
	Palumbo Ditches	4/15	8/28	2	40	3 (7.50)	1 (2.50)				8 (20.00)	2
	Pond O	4/15	8/28	2	42	194 (461.90)	8 (19.05)				12 (28.57)	2
	VC Perm. Pond	4/15	8/28	2	40						1 (2.50)	1
Permanent Pond Total					434	799 (184.10)	20 (4.61)	28 (6.45)	1 (0.23)	2 (0.46)	358 (82.49)	8
TEMP	Virginia Road Pond	4/15	8/28	2 to 3	52	7 (13.46)		969 (1863.46)			4 (7.69)	2
	Whittemore Pond	3/24	9/17	2 to 3	55	1,101 (2001.82)					1 (1.82)	2
	Temporary Pond Total					203	1,108 (545.81)	0	969 (477.34)	0	0	5 (2.46)
Overall Pond Total					636	1907 (299.84)	20 (3.14)	997 (156.76)	1 (0.16)	2 (0.32)	363 (57.08)	5

¹S = Herptofaunal species richness

Table 19. Number of adult-form amphibians and reptiles recorded as incidental encounters at 18 localities at Minute Man National Historical Park.

Site	Northern Green Frog	Eastern American Toad	Wood Frog	Northern Leopard Frog	Pickereel Frog	American Bullfrog	Common Garter Snake	Painted Turtle	Common Snapping Turtle	S ¹
Mill Brook Mouth		1			1					2
Cranberry Bog									1	1
Folly Pond			2		2				1	3
Irrigation Pond A			2				1	1		3
Nelson Pond	2				1			2		3
Palumbo Ditches		1		1						2
Palumbo Pond									1	1
VC Permanent Pond			1			1				2
Woodland #2			1							1
Woodland #12		1								1
Historic Fields		5								1
North Bridge Field				1						1
Palumbo Field			1	2						2
Burke House ²		1								1
Meriam Field ²				1					1	2
Nelson House ²							7			1
Concord River ²								1	1	2
Folly Pond Woodland ²							1			1
Total # of Adults	2	9	7	5	4	1	9	4	5	
Total # of Sites	1	5	5	4	3	1	3	3	5	

¹S = Species richness

²Non-standard sites; all other incidental encounters were encounters at standard survey sites

Discussion

Community Analysis, Factors Affecting Species Presence, and Important Habitats

Of the 44 species of native, non-marine amphibians and reptiles that occur in Massachusetts, the numbers of species are fairly evenly divided among the four orders present: 10 salamander, 10 anuran, 10 turtle, and 14 snake (Cardoza and Mirick 2009). This relatively even community composition also existed among the 32 species that occurred historically (early 20th century) in the vicinity of MIMA (Concord area), with seven salamander, nine anuran, seven turtle, and nine snake species recorded (Ricketson 1911, Carnegie 1914, Greer et al. 1973). As discussed in the introduction, it is likely that most of these 32 species occurred on the lands that now comprise MIMA. Of these 32 species, 17 were recorded at MIMA during the surveys in 2001, plus two additional species (northern water snake and Blanding's turtle) have been recorded since. Thus the 19 species of amphibians and reptiles currently known to occur at MIMA represent 59% of the 32 species historically present locally, and 83% of the 23 species documented at or near MIMA in the mid-1990's (Martinez 1992, Thomas 1992, Windmiller and Walton 1992, Jackson et al. 2010).

Of the 23 species recorded at or near MIMA in the 1990's, stinkpot, northern black racer, northern ring-necked snake, and eastern ribbon snake have not been recorded recently. However, all but ribbon snake occur at Great Meadows NWR (pers. comm., E. McGourty, Wildlife Biologist, Eastern Massachusetts NWR complex, 1 October 2010) and may still occur at MIMA in very low numbers. Of these 23 species, there were four salamander, eight anuran, five turtle, and six snake species. Based on recent data (this survey plus more recent observations), there are four salamander, eight anuran, four turtle, and three snake species currently present at MIMA. Thus, although there is some uncertainty due to the unknown current status of some species, salamanders, turtles, and snakes appear to have declined over the course of the 20th century. (Appendix A). These declines may be in the form of local extirpation, or a reduction in density to the point where detection probability becomes very low.

The herpetofauna of Massachusetts is relatively low in species richness, ranking 38th among the 50 states (Moriarty 2004). This reflects Massachusetts' northerly latitude and the negative relationship between herpetofaunal species richness and latitude in North America (Porter 1972). In addition to total species richness being lower in northern locales, northern herpetofaunal communities tend to be dominated by amphibians, particularly in numbers of individuals. Although amphibians and reptiles historically had equal numbers of species in the Concord area (16 species each), amphibians now dominate the herpetofauna of MIMA in terms of species richness (63%, 12/19 of current species). Amphibians also dominate the current herpetofauna of MIMA in terms of numbers, 98% of all individuals recorded in 2001, but this is not likely a dramatic change from historic conditions. However, if one considers that some of the five additional species of reptiles present at Great Meadows (stinkpot, black racer, ringneck snake, northern brown snake, red-bellied snake) may still occur at MIMA in low numbers, then the two classes may be more equal in terms of species richness.

The 13 species historically present in Concord, but not currently recorded, are either species that were historically never common or widespread in this area to begin with, or were once common species that declined in the 20th century, or both (Appendix A). In addition, for many of these

species, detectability and adequacy of sampling may be a factor. Thus, for many of these potentially-occurring species that have not been documented at MIMA, there is no way to know for certain if the lack of records from MIMA is due to historic absence, more recent declines, inadequate sampling, or a combination of these factors. For example, six of the 13 species are snakes, which were considered in decline due to human activities as far back as the mid-19th century (Allen 1868). Some are also “secretive” and hard to find.

Blue-spotted salamander complex, northern dusky salamander, four-toed salamander, Fowler’s toad, Blanding’s turtle, eastern box turtle, northern ring-necked snake, northern red-bellied snake, and eastern ribbon snake were considered rare to uncommon in the early 20th century (Ricketson 1911, Carnegie 1914, Greer et al. 1973). The blue-spotted salamander complex was historically uncommon and is now a “Special Concern” species in Massachusetts. Many populations in Eastern Massachusetts have been reduced or lost due to habitat loss and fragmentation (Klemens 1993), including one in Lincoln, MA (Lazell 1968). Similarly, northern dusky salamanders have also declined due to urban impacts to stream and seep habitats (Klemens 1993) and they are rare in this part of Massachusetts, occurring on steep hillside seeps, a habitat not present at MIMA (pers.comm., Bryan Windmiller, independent consultant, 1 March 2011). Four-toed salamanders are habitat specialists, nesting in sphagnum mats overhanging open water, and Greer et al. (1973) suggested their rarity may be a sampling artifact. This species was listed as a “Special Concern” species for many years, but was de-listed in 2008, after sampling became more precise and it was found to be more common than originally thought. In Massachusetts, Fowler’s toad is primarily a species of the coast and Connecticut River Valley, whose range expanded inland in response to forest clearing (Lazell 1976, Klemens 1993). Blanding’s turtle, a “Threatened” species in Massachusetts, is restricted to the eastern portion of the state. Populations have declined in Southern New England due road-kill and habitat loss and fragmentation (Grgurovic and Sievert 2005). Eastern box turtles are near their northern limits in Massachusetts and most abundant along the coast and in the Connecticut River valley (Klemens 1993, Mirick 2009). In addition, they have declined in Southern New England due to habitat loss and fragmentation (Klemens 1993) and are a “Special Concern” species in Massachusetts. Eastern ribbon snakes were considered uncommon by Carnegie (1914) but somewhat more common by Greer et al. (1973). Many populations of eastern ribbon snakes have declined or become extirpated in Southern New England (Klemens 1993). Northern ring-necked and northern red-bellied snakes are both forest dwelling species and were uncommon in early 20th century Concord (Carnegie 1914). Windmiller and Walton (1992) suggested these two species were limited at MIMA by a lack of woodland habitat.

The five species not currently recorded that were generally common to abundant historically are stinkpot, wood turtle, northern black racer, smooth green snake, and northern brown snake. The stinkpot remains a relatively common species in this part of Massachusetts and its current absence at MIMA may be the result of insufficient sampling of the Concord River and the mouth of Mill Brook. The northern brown snake is still considered common to abundant in Massachusetts (Mirick 2009), and is known to be urban tolerant. However, recent MA Herp Atlas records suggest it may no longer be common in the region surrounding MIMA (Jackson et al. 2010). Wood turtle, listed as a “Threatened Species” in Massachusetts, is a wide ranging riverine species that makes long distance overland forays in summer. Northern black racers also have large home ranges and are typically found in open and edge habitats. Both species have

declined in the Northeast due to development, habitat fragmentation, road kill and, in the case of the northern black racer, loss of early successional habitats (Klemens 1993, Kjos and Litvaitis 2001, Mirick 2009). Although they have much smaller home ranges, smooth green snakes have also declined in the Northeast, for many of the same reasons, plus possible impacts of pesticides on their invertebrate prey (Klemens 1993).

The importance of wetland habitats to MIMA's current herpetofauna is evident. With the exception of the terrestrial eastern red-backed salamander, all of the amphibians at MIMA depend on some type of wetland or stream habitat for reproduction. In addition, five of the seven species of reptiles present (common snapping turtle, painted turtle, spotted turtle, Blanding's turtle and northern water snake) are primarily aquatic. In the 2001 surveys, wetlands had the greatest species richness with 15 species, followed by uplands with 10, and streams with nine. Similarly, wetlands accounted for 95.2% of all adults recorded (4,406 of 4,629), with uplands accounting for 3.4% (171 of 4,629) and streams 1.1% (52 of 4,629, Table 2). Some of this disparity is due to sampling bias, because more sampling took place in wetlands, and much of the sampling occurred in spring, when otherwise terrestrial or fossorial amphibians were concentrated in breeding ponds and more readily detected than when in the uplands. In contrast, terrestrial reptiles such as small snakes tend to be more difficult to detect, particularly when in low densities.

The number and variety of wetlands at MIMA are integral to the abundance and diversity of the site's herpetofauna, particularly amphibians. Semlitsch (2003) describes an ideal landscape for amphibians in which a diversity of ponds with varying hydroperiods are in close proximity, available to support all the locally-occurring species. MIMA has an abundance and diversity of wetlands in close proximity, with over 20 ponds and marsh sites identified at the start of this project, plus stream, river and riparian habitat. However, due to the linear nature of most of the park, and its' bisection by Route 2A, many of these wetlands are close to, or within a couple of hundred meters of this high volume road. Windmiller and Walton (1992) felt that the roads through and adjacent to MIMA played a major role in shaping the structure of MIMA's herpetofaunal community, skewing it towards generalist species tolerant of habitat fragmentation and limiting the abundance and presence of those that were not. There is now an abundance of literature in support of this view (e.g. Johnson and Klemens 2005, Gagne and Fahrig 2007, Andrews et al. 2008, Egan and Paton 2008), as well as the current inventory's results. In all orders, the most numerous species are generally sedentary, generalist species capable of surviving in fragmented, urban landscapes, whereas the rarest species, as well as most of those that went unrecorded, are species with large home ranges and complex patterns of habitat use.

Species richness was greatest at Cook's Pond, Folly Pond, and Nelson Pond, with eight species found at each, and the total number of amphibians encountered was greatest at Cook's Pond, accounting for 23.2% of all amphibians (Tables 2 and 4). Palumbo Ditches and Black Gum Swamp Pond were nearly as species rich, with seven species each, and Palumbo Pond was particularly important to both common snapping turtles and painted turtles. Virginia Road Pond and Cook's Pond were important breeding sites for wood frogs and spotted salamanders, and Black Gum Swamp and Whittemore Pond were also important breeding sites for spotted salamanders (Table 4). In spite of its close proximity to Rt. 2A, Cranberry Bog was also an important site, with six species recorded in 2001, including the only spotted turtle, plus the only

recent record of northern water snake, observed in 2004. Although lower in species richness, temporary ponds serve as important breeding habitat for wood frogs and spotted salamanders, with 41% of all wood frogs being recorded in Virginia Road Pond and 30% of all spotted salamanders recorded in Whittemore Pond and Virginia Road Pond combined (Tables 2 and 4).

Permanent and temporary wetlands at MIMA were considerably different in their species richness ($S = 15$ and seven, respectively). Although some of this difference may be due to sampling more permanent ponds (12) than temporary (three), some studies have found that amphibian species richness increases with length of hydroperiod (Pechmann et al. 1989) and is greatest in permanent ponds (Babbitt et al. 2003). There is also overlap in species composition of permanent and temporary ponds, and at MIMA all the amphibian species recorded in temporary ponds were also recorded in permanent ponds. Many of the species unrecorded at temporary ponds at MIMA are known from other sites to use both types of ponds, sometimes breeding in both and sometimes using them for different purposes or at different life stages or ages. For example, species with larvae that overwinter, such as the northern green frog, may only breed successfully in permanent or semi-permanent ponds, but utilize temporary ponds and stream corridors as juveniles to forage and grow until mature enough to acquire a territory in a breeding pond. Similarly, all three species of turtles recorded at MIMA in 2001, common snapping turtle, painted turtle, and spotted turtle, occur in both temporary and permanent ponds on Cape Cod and use of temporary ponds by common snapping turtles was primarily by young individuals (Cook et al. 2007).

It is also important to recognize that these wetland “types” are an oversimplification. Pond duration or hydroperiod is better viewed as a continuous rather than a categorical attribute. “Temporary” ponds can vary dramatically in their hydroperiods, both among themselves and from year-to-year, and some “permanent” ponds may actually be “semi-permanent”, holding water year round in some but not all years. In addition to differences in species richness as a function of hydroperiod, between-pond differences in hydroperiod may also result in differences in the relative abundance and dominance of different species (Babbitt et al. 2003, Egan and Paton 2004, Karraker and Gibbs 2009). Thus community composition may vary over time due to variation in hydroperiod, as well as changes in other factors, such as canopy closure (Skelly et al. 1999).

At MIMA, in addition to supporting greater species richness, greater numbers of individuals were recorded at permanent ponds relative to temporary ponds. After accounting for sampling effort by converting to mean numbers per pond, the total number of individuals for permanent ponds was 270 per pond (4,050 individuals in 15 ponds) and 119 per pond for temporary ponds (356 individuals in 3 ponds). In a Southern New Hampshire amphibian community very similar in species composition to that of MIMA, larval amphibian density was greatest in long hydroperiod ponds (Babbitt et al. 2003). Thus, the difference between temporary and permanent ponds in mean number of total individuals may be related to hydroperiod. However, because permanent ponds are generally much larger than temporary ponds, the greater mean total number of individuals recorded at permanent ponds could also be related to pond size.

By species, the mean number of individuals per pond in temporary versus permanent ponds were: northern spring peeper, 68 versus 171; grey treefrog, one versus 41; northern green frog,

seven versus 37; wood frog, 35 versus nine; American bullfrog, zero versus six; eastern American toad, two versus zero; and spotted salamander, six versus three. In terms of relative abundance, northern spring peepers dominated the amphibian community of both types, accounting for 57% of all individuals in temporary ponds and 63% in permanent ponds. Among the remaining species, grey treefrogs and northern green frogs were the next most dominant species in permanent ponds, with a relative abundance of 15% and 14% respectively, versus 1% and 6% in temporary ponds. In temporary ponds, the sub-dominant species were wood frog, northern green frog and spotted salamander. Wood frog and spotted salamander had a relative abundance of 30% and 5% respectively, versus 3% and 1%, in permanent ponds. Permanent ponds also accounted for 86% of all turtle captures in 2001, and none were captured or observed in temporary ponds. This is consistent with surveys on Cape Cod, where the occurrence and abundance of common snapping turtles and painted turtles, which accounted for 98% of all turtles recorded at MIMA in 2001, was greatest in permanent water bodies (Cook et al. 2007).

Streams had the lowest species richness of the three habitat categories, nine species total, with permanent streams accounting for eight species recorded and intermittent streams three. Species diversity was greater in Mill Brook than Elm Brook, nine and two species respectively. However, the species recorded in Mill Brook were generally widespread at MIMA, whereas Elm Brook is very important as the only site at MIMA where the stream dwelling northern two-lined salamander occurs. The 25 individuals recorded suggest the presence of an important local population. Elm Brook is also important as part of a larger patch of habitat bounded by Rt 2A on the south and Virginia Road to the north consisting of both NPS and private conservation lands and farms. This patch, which includes the Historic Fields, the headwaters of Mill Brook, and several irrigation ponds, was utilized by one Blanding's turtle during the winter of 2010-11 and a second one in late spring 2011 (pers. comm., Bryan Windmiller, independent consultant, 4 July 2011), and also had 10 species recorded in it in 2001, including significant numbers of northern leopard frog, eastern American toad, and common garter snake. Indeed, throughout MIMA, the complex of streams and fields in close proximity are important for northern leopard frog. Streams are also important travel corridors for many amphibians and reptiles. In an urbanized landscape such as the one MIMA occurs in, streams may provide the only safe way to cross barriers such as roads.

Although freshwater wetlands and streams are critical to supporting the diversity of amphibian species found at MIMA, the adjacent upland habitats are also important. Eastern red-backed salamanders, the most common salamander at MIMA, are wholly terrestrial and do not breed in wetlands. Many of the amphibians found in pond habitats at MIMA only use them for breeding, and spend the rest of the year in uplands, where they forage and hibernate. Thus, spotted salamander, wood frog, eastern American toad, northern spring peeper, and grey treefrog are dependent on the woodland habitats of MIMA, as are red-spotted newts, which utilize this habitat for their juvenile stage (red eft). Similarly, northern leopard frogs spend much of the active season foraging in fields and meadows, usually near watercourses. In addition, the relatively few species of reptiles here depend either almost entirely on uplands for foraging and hibernation (e.g., common garter snake and eastern milk snake) or, in the case of aquatic turtles, they require open, well drained, uplands for nesting. Thus, although amphibians and reptiles commonly utilize specific habitats for part of the year, their complex life cycles require the use and occupancy of a number of different habitats for breeding, foraging, dispersal, nesting, and

hibernation and it is important to ensure the integrity and connectivity of all available habitats at MIMA.

Species at Risk

Most of the species previously or currently known to occur at MIMA are still relatively common and widespread in North America (Conant and Collins 1998). MIMA does not support any species that are exceptionally rare at the national level nor can it be considered by itself to be a critical site for a regionally rare or declining species. However, several of the species known from or adjacent to MIMA have experienced declines in the Northeast region and/or in Eastern Massachusetts (Klemens 1993, Windmiller 1996) and MIMA provides important habitat for them. In most instances, the habitat provided by MIMA is part of a larger local complex of adjacent or linked protected areas that, in their sum total, help support local populations and maintain species richness at the town or county level. Individually these sites would not be large enough. Blanding's turtle is a good illustration of this. It is a rare declining species in the Northeast, listed as "Threatened" in New York and Massachusetts and "Endangered" in New Hampshire and Maine. Blanding's turtle was recorded historically in the Concord River by Thoreau (Howe 1911), occurs at Great Meadows NWR, and is known to use the marshes of Elm Brook and Mill Brook adjacent to the Historic Fields. The Blanding's turtle uses a wide variety of wetland and upland habitat types, which vary according to the individual and the amount of precipitation, with more upland utilization during dry years (Joyal et al. 2001). This complex use of habitats and the movements associated with them make Blanding's turtle populations especially vulnerable to decline from road kill. Decline of this species throughout much of its range is attributed to development, habitat fragmentation, and road kill (Beaudry et al. 2010).

Several other species at MIMA are also of conservation concern. Northern leopard frog, grey treefrog, spotted turtle, northern black racer, eastern milk snake, and eastern ribbon snake have all declined in Southern New England (Klemens 1993, Kjos and Litvaitis 2001). Spotted salamander and wood frog populations have declined in and around Concord due to urbanization (Windmiller 1996) and their relatively small populations at MIMA are likely due to the impacts of road kill (Windmiller and Walton 1992). Red-spotted newts do not persist in fragmented urbanizing environments (Gibbs 1998). In this survey, northern leopard frog, grey treefrog, and wood frogs were uncommon to common, suggesting these species are currently able to persist within the protected habitats that MIMA is a part of. However, the long term outlook for the other species noted above is uncertain. The only species that currently are common to abundant at MIMA are those that survive in urban-suburban landscapes due to small home ranges, generalized habitat and food preferences, simplified life history, or dependence on permanent ponds (Schlauch 1976, Rubbo and Kiesecker 2005).

Population Trends

Determining population trends in and around the vicinity of MIMA can be difficult, given the general nature of the historic literature from the early 20th century and the sometimes limited understanding of some species' life history at that point in time. Data from the mid-1990's are more specific and quantitative, and although assessment of species status at that point in time (Windmiller and Walton 1992) was subjective, it was informed by extensive experience conducting herpetological field work in the MIMA region, as well as an understanding of the factors influencing occurrence and abundance (e.g. Windmiller 1996). Thus, we consider the

analysis of MIMA's herpetofauna in the 1990's (Windmiller and Walton 1992) to be particularly insightful and valuable to our understanding of the current status of MIMA herpetofauna.

Although the current surveys are also specific and quantitative, our determination of a species' status and trends are still subjective. However, in spite of these limitations, given what is known about species trends in the region and the factors affecting them, it is apparent that many species have declined. Of the 23 species that have been recorded in or around MIMA, four of eight anurans, two of four salamanders, two of five turtles, and six of six snakes appear to have declined over the course of the 20th century (Table 20). Although Windmiller and Walton (1992) recorded five species of snakes, they considered this group "remarkably rare", recording only one individual for three of the five species. Of the two snake species we recorded, plus the northern water snake recorded in 2004, only the common garter snake could be considered still common. Similarly, the three species of turtles they recorded were the common ones that had not declined during the 20th century. Although we now have current records of spotted and Blanding's turtle, each is for a single individual.

Among the species historically common, only four anurans (grey treefrog, spring peeper, American bullfrog, northern green frog), two salamanders (northern two-lined salamander, eastern red-backed salamander), two turtles (common snapping turtle, painted turtle) and one snake (common garter snake) can be considered as having emerged from the 20th century still reasonably common. These species are, as noted above, urban tolerant generalists. Although we lack the kind of data that allows for statistically precise determinations, it appears that the herpetofauna of MIMA has undergone the declines due to urbanization that typify most of Eastern Massachusetts. For some groups, such as snakes, the decline may be continuing, but most of the decline occurred prior to the surveys conducted in the 1990's (Table 20). All aspects of MIMA's natural resources have undergone a decline in quality and integrity due to a host of factors relating to agricultural practices and urbanization (James-Pirri 2009), and the long term decline in most of MIMA's herpetofauna is undoubtedly a reflection of that process.

Stressors

Given its location in an urbanized landscape long affected by human activities, MIMA is subjected to numerous stressors, both local and global. Global stressors tend to affect large geographic areas and are often far removed from their ultimate cause or source. Global stressors include ultraviolet-B radiation and atmospherically transported pollutants such as mercury and acid rain. Stressors such as other heavy metals, chemicals found in fertilizers, herbicides, pesticides, habitat degradation, disease, road mortality, and introduced species (Dunson et al. 1992, Blaustein 1994, Blaustein et al. 1994, Pechmann and Wilbur 1994, Daszak et al. 2000, Knapp and Matthews 2000) may also be widespread in their scope, but tend to be more variable across the landscape in their extent. Thus their impacts may be at either a regional or local level.

Mercury is transported atmospherically and often deposited far from the source. Upon entering aquatic ecosystems, particularly acidified ones, mercury is biologically and chemically converted to methylmercury, a biologically active and highly toxic form (Bank et al. 2005) that can be accumulated by aquatic organisms to the point of causing lethal or sub-lethal effects.

Table 20. Status of amphibians and reptiles of Concord area in early 20th century, mid-1990's, and current survey. Long term trend is from early 20th century to the end of the 20th century. Species in bold have been recorded in or very close to Minute Man National Historical Park (MIMA) since 1990. Other species historically occurred in Concord, and most likely occurred on lands now MIMA.

Species	Historic Status	Mid-1990's Status	Current Status	Long Term Trend
Blue-spotted salamander	uncommon	rare	not recorded	decline
Spotted Salamander	common	uncommon	uncommon	decline
Red-spotted newt	common	common	uncommon	decline
Northern Dusky Salamander	uncommon	rare	not recorded	decline
Two-lined Salamander	uncommon	uncommon	uncommon	stable
Eastern Red-backed salamander	common	common	common	stable
Four-toed Salamander	rare	rare	not recorded	stable
Eastern American toad	common	uncommon	uncommon	decline
Fowlers Toad	common	rare	not recorded	decline
Gray Treefrog	common	common	common	stable
Northern Spring peeper	abundant	abundant	abundant	stable
American Bullfrog	common	common	common	stable
Northern Green Frog	abundant	abundant	abundant	stable
Pickerel Frog	common	uncommon	rare	decline
Northern Leopard Frog	common	rare	uncommon	decline
Wood Frog	common	uncommon	uncommon	decline
Common Snapping Turtle	common	common	common	stable
Stinkpot	common	rare	not recorded	decline
Painted Turtle	common	common	common	stable
Spotted Turtle	abundant	rare	rare	decline
Wood Turtle	common	rare	not recorded	decline
Blandings Turtle	rare	rare	rare	stable
Eastern Box Turtle	rare	rare	not recorded	stable
Northern Black Racer	common	rare	not recorded	decline
Northern Ringneck snake	uncommon	rare	not recorded	decline
Eastern Milk Snake	common	rare	rare	decline
Eastern Smooth Green Snake	common	rare	not recorded	decline
Northern Water Snake	common	rare	rare	decline
Northern Brown Snake	common	rare	not recorded	decline
Northern Red-bellied Snake	uncommon	rare	not recorded	decline
Common Garter Snake	abundant	common	common	decline
Eastern Ribbon Snake	uncommon	rare	not recorded	decline

Anthropogenically produced mercury deposition is occurring throughout the Northeast, and even aquatic systems of relatively undeveloped areas such as Acadia National Park (Bank et al. 2006) and Cape Cod National Seashore contain high levels of mercury. Because methylation of mercury increases at low pH, either naturally acidic waters or acid rain can lead to elevated concentrations of methylmercury. This process has been linked to the decline of northern dusky salamanders at Acadia NP, and both northern green frogs and northern two-lined salamanders there also show elevated mercury levels (Bank et al. 2006, Bank et al. 2007). Given that both acid precipitation and mercury deposition occur in the vicinity of MIMA (Likens et al. 1996, Chalmers et al. 2005), it is reasonable to conclude that MIMA is subjected to inputs from both of these stressors. However, existing water quality data suggest that streams and ponds at MIMA have pH values in the pH 5-7 range (Farris and Chapman undated) and excessive mercury levels are not considered a problem at MIMA (James-Pirri 2009).

Diseases are also a global issue, with one in particular, Chytridiomycosis being linked to the decline and disappearance of amphibians. The fungus that causes it, *Batrachochytridium dendrobatis*, is believed to be native to Africa and spread globally through international trade in the mid-20th century (Weldon et al. 2004). Recent surveys suggest that chytrid fungus is widespread in the Northeast, but there is little evidence it has caused die-offs in this region. Surveys of anurans at Great Meadows NWR found chytrid fungus in two of 23 northern green frogs (Longcore et al. 2007) and rates of occurrence approaching 50% were found in northern green frogs and American bullfrogs on Cape Cod, with no apparent die-offs (Tupper et al. 2011). Thus, this particular stressor does not appear to be affecting amphibians at MIMA.

Although MIMA is subjected to global stressors, considering the urbanized landscape it is embedded in, localized stressors have likely had a greater impact on its amphibians and reptiles than global stressors. The local stressors affecting MIMA and the condition of all aspects of its natural resources have been extensively detailed by James-Pirri (2009) and the following are the key findings of this work:

- Urbanization continues both adjacent to and within the boundaries of MIMA, and 17% of land in MIMA is urban or residential.
- The terrestrial habitats of MIMA have been dramatically altered from their original condition by over 350 years of intense manipulation, which has facilitated the invasion of many non-native plants. Invasive plant species occupy a large percent of the park (84%) and are a significant concern. The condition of native plant communities is rated as “caution”.
- The Concord River and its watershed are classified as “stressed” due to a decline in water quantity. The Concord has also been assessed as “impaired” due to metals (copper) contamination, excessive nutrient levels, pathogens (fecal coliform), and non-native plants. Mill Brook suffers from habitat alterations and Elm Brook has problems with fecal coliform, turbidity, and habitat alterations. Water quality in these waterways is rated as declining.
- Riparian wetlands of MIMA are impacted by poor stream water quality.
- Integrity of other (i.e., non-riparian) freshwater wetlands at MIMA is declining due to invasive species.

- Most of the vernal ponds at MIMA are within 200 m of roads and the water quality of these ponds is most likely polluted by road salts and other road run-off.
- Faunal communities are in decline and most taxonomic groups can be characterized as lacking in “sensitive” species and being dominated by “urban tolerant” ones.
- As a result of these stressors, “Most of natural resources at MIMA appear to be in less than desirable condition” (James-Pirri 2009).

Thus, the herpetofauna of MIMA has been subjected to a broad array of localized stressors related to agricultural practices such as land clearing, use of fertilizers and pesticides and urbanization. Urbanization results in loss, alteration, and fragmentation of habitats, water pollution, and indirect and direct mortality, particularly road kill. This reduces herpetofaunal diversity by extirpating some species, primarily those with complex life histories, specialized habitat requirements and/or large home ranges, and reducing the distribution of surviving species, mostly widespread generalists, to suitable habitat remnants (Schlauch 1976, Klemens 1985, Gibbs 1998, Germaine and Wakeling 2001, Rubbo and Kiesecker 2005). Studies conducted not far from MIMA have shown that the occurrence and abundance of wood frog, spotted salamander, and blue-spotted salamander are negatively related to measures of urbanization such as amount of impervious surface, road length, amount of dense residential development (Clark et al. 2008) and populations of these species decline dramatically when forest adjacent to vernal ponds are replaced by urban development (Windmiller et al. 2008). Similar negative relationships to measures of urbanization or positive relationships to amount of intact forest have been documented in Rhode Island (Skidde et al. 2007, Egan and Paton 2008).

MIMA is essentially a highly altered habitat remnant, albeit a moderately-sized one with some connectivity to a network of other protected areas. The largest of these, the Concord Division of Great Meadows NWR (1,542 acres, 624 ha) adjoins the North Bridge Unit, whereas the Battle Road unit of MIMA abuts a number of farm field, wetlands, and woodlands. It is however, bisected by Route 2A, and surrounded and traversed by several other heavily traveled roads. In the Northeastern United States, populations of common snapping turtle and eastern box turtle are particularly vulnerable to extirpation from road kill (Gibbs and Shriver 2002) and road kill appears to be a significant source of direct mortality to both amphibians and reptiles at MIMA (Windmiller and Walton 1992). Roads also act indirectly to reinforce fragmentation by limiting the ability of animals to move successfully between habitat patches, thereby limiting gene flow. Populations in fragmented landscapes such as MIMA may be affected by decreased reproductive success, increased mortality, decreased genetic diversity, and are more vulnerable to extirpation (Byers and Mitchell 2005). In addition, because of isolation, dispersal barriers, and lack of source populations, the odds of natural re-colonization following a localized extinction are low (Scott et al. 2001).

Because amphibians and reptiles utilize both aquatic and terrestrial habitats, they are important indicators of overall environmental quality. The semi-permeable skin of amphibians makes them more susceptible to changes in their environment than other vertebrates, and they are often among the first species to respond to changes in environmental conditions (Pough et al. 2004). The loss of keystone species and important habitats can alter herpetofaunal communities and the ecosystem as a whole. From what we have been able to determine, the herpetofaunal community of MIMA has been impacted by a number of severe stressors over the course of the 20th century

and has been changed by them. There are many stressors potentially responsible for the decline and extirpation of species at MIMA, and it is likely that for many species, more than one has been responsible. Although historic data are sparse, given that most of the species that have declined are relatively mobile ones with large home ranges or ones that make extensive or long distance terrestrial movements, it appears that road kill and habitat fragmentation may be more significant stressors than vegetative or chemical changes to wetland communities. Permanent pond amphibians (e.g., northern spring peeper, grey treefrog, and northern green frog), as well as the eastern red-backed salamander and northern two-lined salamander, do not make extensive overland movements as adults. They appear to be maintaining themselves better than the more mobile species.

Recommendations for Management and Future Inventory and Monitoring

Both its herpetofauna and MIMA's natural resources in general have been severely impacted by numerous agricultural and urban-related stressors (James-Pirri 2009). Many of these are irreversible (e.g., human population density and general urbanization) and the potential to mitigate them is limited. However, there are still many ways in which the NPS (staff of MIMA, the Northeast Region, and the Northeast Temperate Network) can work to bring about changes that can improve the condition of MIMA's natural resources in general and herpetofauna in particular.

1. **Monitor/Prevent/Mitigate External Threats and Stressors** – Considering that the herpetofauna of MIMA is largely affected by activities on the adjacent landscape, to the extent possible, the park may want to ensure that activities in the “neighborhood” are consistent with protection of native wildlife, including herpetofauna. Potential activities that could negatively affect amphibians and reptiles include applications of pesticides, anything that increases vehicular traffic, anything that pollutes or diminishes ground or surface waters, and anything that increases the abundance of “subsidized predators” such as raccoons and feral cats. Considering the continued development in the region, the park should consider promoting protection of the adjoining landscape and watershed, and become involved in ensuring that any future developments will not contribute to further degradation of the park and vicinity. To do this, MIMA may want to be involved in and comment on local and regional planning efforts to ensure that stream and river water quality is improved. Similarly, MIMA should consider supporting the protection of nearby open space and natural areas by towns, private conservation groups, state and federal agencies. Whenever road or culvert replacement work is being planned in or around MIMA, the park should advocate for increasing the size and capacity of culverts and bridges, and installing wildlife tunnels to increase landscape connectivity and reduce road kill (Singler and Graber 2005, Massachusetts Highways 2006).
2. **Monitor/Prevent/Mitigate Internal Threats and Stressors** – The park should take steps to ensure that the activities listed above do not take place on NPS property or are kept to a minimum. In particular, ensure that runoff from park roads and parking lots is not contributing to pollution of groundwater, streams and wetlands and bridges and culverts in the park are designed to facilitate unimpeded movement of fish and wildlife. MIMA should also make sure that use of pesticides in the park conforms to NPS pesticide use policy.

3. **Maintain Habitat Diversity** – The amphibians and reptiles currently utilizing MIMA require a combination of woodland, field, and wetland habitat to provide for all aspects of their life cycles. Ensuring woodland health is important but concern for such health should recognize that natural woodlands contain dead and dying trees and an abundance of downed, rotting logs. Such dead snags and coarse woody debris on the ground are important habitat for many species of amphibians and reptiles, as well as cavity nesting birds and small mammals. In open habitats associated with the cultural core of the park, as well as the historic fields, to the extent that it is possible, maintain the open habitats as native grasses and forbs mowed infrequently, rather than “lawn”. Mowing as a maintenance and habitat management tool should be used carefully to minimize direct mortality.
4. **Minimize Direct Mortality from Mowing Operations** – Most species of snakes use field and field edge habitats to bask and hunt, and turtles, both aquatic and terrestrial, use fields for nesting, which generally occurs in late May through early July. At MIMA, American toad and leopard frog also use fields, especially ones near aquatic habitats. Mowing should be conducted in a way that minimizes the potential for direct mortality to these and other animals. There are a number of ways to do this, depending on how a particular area is being managed. For areas being maintained as lawn or roadside verge, it is best to mow frequently, so that the grass is close-cropped. This may make the habitat less attractive, and turtles and snakes are readily observed by staff operating mowers and can be avoided. If grass has gotten taller, having a person walk ahead of the mower to check for turtles and chase away snakes and frogs is the safest approach.

Fields and pastures (as opposed to lawns) at MIMA are maintained as part of the cultural landscape and their long term maintenance benefits many species of wildlife dependant on edge or early successional stage habitat. This includes snakes and turtles, which use fields and field edges for basking and nesting, and American toad and leopard frog, which forage in fields. Maintaining fields at MIMA should be done in a way that minimizes the risk of killing amphibians and reptiles with mower blades and/or tractor wheels. First, because some fields may not need to be mowed annually to maintain them, the park should consider only mowing a portion of the field habitats in any given year. Ideally, fields should be mowed during the cold months, when animals are not active. Thus, mowing fields from November until mid-April poses minimal risks to turtles, snakes and anurans. However, in fields that are actively farmed or hayed this may not be possible. The worst times of year to mow are late May to early July, which is generally when turtles nest, and in mid to late spring and late summer-early fall, when snakes often bask at field edges. If mowing must occur in summer, it should be done during the hottest months (July and August). Snakes, turtles, and anurans tend to avoid open areas during times of drought and high heat intensity, making the heat of day on hot and dry days the best time to mow, if necessary, during the active season. Mowers with rotary blades or sickle bars are preferable to reel or flail mowers. Rotary blades and sickle bars are oriented horizontally. If these blades are set to cut at least 7 inches above ground, they will safely pass over many small animals and the blades will wear more slowly. Field

mowing should start in the center and spiral outward, so animals in the field are pushed out of the way of the mower slowly (MA NHESP 2009).

5. **Minimize Direct Mortality from Vehicles** – As noted throughout this report, road kill is linked to the decline and disappearance of amphibians and reptiles in urban areas and is a significant factor affecting the abundance and species composition of MIMA's amphibians and reptiles. Amphibians cross roads in large numbers on rainy nights, especially in spring as they migrate to breeding ponds. Snakes often bask on roads in spring and autumn and turtles cross roads and move to open fields in late spring and early summer to nest. Although much of the problem related to road impacts is beyond the park's ability to mitigate, improvements to existing bridges and culverts, and installation of additional wildlife tunnels could help improve landscape connectivity and reduce road kill (Singler and Graber 2005, Massachusetts Highways 2006). In addition to the heavy mortality on Route 2A, Old Massachusetts Avenue south of Cook's Pond is a significant source of road kill (Windmiller and Walton 1992). The closure of this road to thru traffic on selected rainy nights in late March to protect wood frogs and spotted salamanders and in late May to early June to protect grey treefrogs, as recommended by Windmiller and Walton (1992), should be considered. MIMA should also consider erecting "frog crossing" or "salamander crossing" signs on the roads nears Cook's Pond, Folly Pond, Cranberry Bog, and Black Gum Swamp Pond or working with town or state officials if these locations are outside NPS jurisdiction.
6. **Additional Inventory and Monitoring** – The current survey still leaves uncertainties regarding the presence/absence and status of several species. For example, the current status of most species of snakes is still uncertain, and more intense surveys for them are needed to better resolve questions regarding their status. Sampling effort for turtles in the Concord River and Mill Brook's confluence with it was eight trap nights, a relatively small amount of effort that yielded only one snapping turtle. Considering that this area of the park produced three species of turtles and supported MIMA's largest population of painted turtles in the 1990's (Windmiller and Walton 1992), a greater sampling effort should have been made there. A follow-up survey to better determine turtle presence and abundance in the North Bridge Unit would be valuable. Similarly, in light of recent records, trapping for Blanding's turtles in the sections of Mill Brook and Elm Brook north of Route 2A should be conducted to better determine this species' use of these habitats.

Although a detailed reptile and amphibian monitoring protocol is beyond the scope of this inventory, MIMA is part of the National Park Service's Northeast Temperate Network and a broad based approach to monitoring the site's natural resources is underway (Mitchell et al. 2006). In our view, anuran calling surveys, stream salamander surveys, and vernal pond egg mass surveys for spotted salamander and wood frogs would be the most useful methods for monitoring MIMA's amphibians. Recommendations for long term monitoring of reptiles should be held off until the additional snake and aquatic turtle surveys discussed above are conducted.

Species Accounts: Species currently or historically recorded at or near Minute Man NHP

Spotted Salamander (*Ambystoma maculatum*)

The spotted salamander is widely distributed throughout the Eastern United States and Southeastern Canada (Petranka 1998) and in New England it occurs both inland and along the coastal plain, down to sea level (Klemens 1993). They occur primarily in forested landscapes and breed in vernal and semi-permanent ponds (Petranka 1998). Adults are most easily detected in early spring, when they migrate on rainy nights from underground burrows to breeding ponds. Mating occurs in the ponds and females attach gelatinous egg masses to twigs and vegetation in the pond (Petranka 1998). Spotted salamanders are difficult to find once they leave the breeding ponds. Outside of the breeding season, spotted salamanders are terrestrial, primarily subterranean, and many disperse as far as 200 to 400 meters from their breeding ponds (McDonough and Paton 2007).

This species is common to abundant and widespread in Southern New England (Klemens 1993) and is distributed statewide in Massachusetts except for Nantucket Island (Cardoza and Mirick 2009). It was historically considered widespread and relatively abundant in Concord (Greer et al. 1973), and they continue to be widespread in the Concord area. They occurred in 56 of 78 (~71.7%) vernal pools sampled by Burne (2000). In the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²), spotted salamander was the third most recorded species (tied with eastern red-backed salamander), accounting for 21 of 270 (7.8%) of all records, including two records from MIMA (Jackson et al. 2010). However, although widespread in the suburbs west of Boston, they are not necessarily abundant. Spotted salamander egg masses were present in 94 of 193 ponds sampled in Concord, MA, but most ponds had relatively few egg masses in them and only 12 ponds had egg mass counts indicative of a viable population (i.e. > 104 egg masses) (Windmiller 1996). Surveys in 1992 indicated that spotted salamanders at MIMA were similarly widespread not but abundant (Windmiller and Walton 1992). Thomas (1992) recorded spotted salamanders at five wetlands, including four of the wetlands surveyed in our current study. Numbers observed were relatively low: Black Gum Swamp Pond (1+ egg mass); Cook's Pond (18 egg masses, two juveniles, and three adults); Virginia Road Pond (20 egg masses); Whittemore Pond (70 juveniles, and 17 adults).

In the current survey, the spotted salamander was the second most abundant salamander at MIMA, with a relative abundance of 36.36% among salamanders. A total of 83 egg masses representing an estimated 53 females, plus eight adults were recorded. Spotted salamanders were found in six of 15 ponds (40%) surveyed, with an overall frequency of occurrence of 16.22% (Tables 2 and 3). Spotted salamanders were most abundant in Cook's Pond (25 individuals, 41.7% of the total), and were recorded in two of the three temporary wetlands surveyed in this study (Table 4). The majority of individuals (86.7% of the total) were recorded via egg mass counts (Table 7). In general, egg mass counts in 2001 (Table 9) were higher than in 1992 (83 versus 35 respectively) but greater numbers of adults and juveniles were observed in 1992 (eight adults versus 21 adults and 75 juveniles) (Thomas 1992). These modest differences could be accounted for by differences in methodology between the two studies and annual variation in breeding effort (Husting 1965). Thus the population of spotted salamanders at MIMA appears unchanged from the 1990's, moderately widespread, but not very large.

Studies conducted not far from MIMA have shown that the occurrence and abundance of spotted salamanders are negatively related to measures of urbanization such as amount of impervious surface, road length, amount of dense residential development (Clark et al. 2008) and populations decline dramatically when forest adjacent to vernal ponds are replaced by urban development (Windmiller et al. 2008). Similar negative relationships to measures of urbanization or positive relationships to amount of intact forest have been documented in Rhode Island (Skidds et al. 2007, Egan and Paton 2008). Compared to many other areas where they occur, e. g. Cape Cod National Seashore (Cook et al. 2006b), spotted salamanders are not very abundant at MIMA. Landscape analysis in Southern New England has shown that the ideal landscape for spotted salamanders is a non-urbanized, non-fragmented, roadless, forested landscape with well drained soils and moderately hilly topography, containing relatively large (> 1,000 square meter), deep (> 1 m), fishless, permanent or semi-permanent ponds (Windmiller 1996, Egan and Paton 2004). They are not well adapted to fragmented, urbanized landscapes (Rubbo and Kiesecker 2005), although they can persist in suburban and agricultural landscapes where forest cover exceeds ca. 30-50% (Gibbs 1998, Homan et al. 2004). Juveniles did not survive to maturity in fields, and ponds surrounded by non-forested habitats may be population sinks (Rothermel and Semlitsch 2006). In addition, the use of road de-icing salts may have negative effects on spotted salamander populations near roads via reduced embryonic and larval survival (Karraker et al. 2008). Thus, spotted salamander breeding wetlands located near roadsides at MIMA are subjected to this additional stressor.

This survey, as well as prior ones (Windmiller and Walton 1992) suggest that although there is a widespread diversity of potential breeding ponds at MIMA, the density of roads through and adjacent to MIMA, as well as the lack of large tracts of unfragmented forest severely limit the numbers of spotted salamanders present. Therefore, although still widespread at MIMA, the long-term persistence of spotted salamanders at MIMA cannot be taken for granted, and the size of breeding populations should be monitored via early spring egg mass counts.

Red-spotted Newt (*Notophthalmus v. viridescens*)

Eastern newts (*Notophthalmus viridescens*) occur throughout most of the Eastern United States and Southeast Canada, with the sub-species *viridescens* ranging from Canada south through the Northeastern United States, down through Virginia and inland through Appalachia (Petranka 1998). Red-spotted newts are generally common to abundant in Southern New England (Klemens 1993) and are distributed statewide in Massachusetts with the exception of Nantucket County (Cardoza and Mirick 2009).

The red-spotted newt has one of the most complex and variable life cycles of all North American salamanders (Roe and Grayson 2008). Adults typically occur in permanent ponds and lakes and are aquatic year round in these habitats. They can also occur in and breed successfully in long hydroperiod vernal ponds, although they achieve higher densities in permanent ponds (Herrmann et al. 2005). Following a typical aquatic embryonic and larval stage, larvae transform in their first year into a terrestrial juvenile stage known as red eft. The eft, bright orange with red spots, may be found under logs and brush or seen moving in woodlands and grassy areas, particularly during rainy conditions (Petranka 1998). The efts may spend 2-7 years on land before returning to water and transforming into an aquatic adult, taking on the adult's green coloration and keeled tail (Healy 1974). Thus, unlike nearly all other amphibians, the red-spotted newt generally

metamorphoses twice. However, in some populations such as coastal populations of Massachusetts, the red eft stage is absent or very rare (Healy 1974).

In addition to the terrestrial efts, which are the primary stage for dispersal, post-breeding adults may also leave the pond and become terrestrial (Roe and Grayson 2008). In a semi-permanent pond in Sudbury MA, not far from MIMA, adult red-spotted newts left the pond and moved into and hibernated in adjacent forests. Most but not all hibernated within 100 m of the pond (Regosin et al. 2005). Although red efts may be handled safely by humans, they have skin toxins that deter potential predators (Hurlbert 1970). This enables their conspicuous activities in both aquatic and terrestrial habitats. The red-spotted newt is considered to be a keystone predator in temporary pond communities where the species controls insect populations and anuran species composition (Kurzava and Morin 1994).

Historically, red-spotted newts were fairly common in Concord ponds and pools (Carnegie 1914). Greer et al. (1973) also considered them common in certain lakes and ponds, but noted that red efts were very rare in the Concord area and suggested that this stage may be absent. More recently, in the 1990's Massachusetts Herp Atlas project, there were four records of red-spotted newts in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²), including two records from Cook's Pond in MIMA (Jackson et al. 2010). Of the 28 native species recorded in these quads, red-spotted newt was 17 of 28, accounting for four of 270 (1.5%) records. Similarly, Burne (2000) recorded red-spotted newts in five of the 78 (6%) vernal pools he sampled in the Concord area. These data suggest that by the late 20th century, red-spotted newts were no longer very widespread or common in this area.

Surveys at MIMA in the 1990's recorded red-spotted newt at three of 21 ponds sampled (Martinez 1992, Windmiller and Walton 1992, Thomas 1992). Thomas (1992) considered this species rare at MIMA and recorded low numbers at Cook's Pond (seven adults), Folly Pond (one juvenile), and Whittemore Pond (one larvae and one juvenile). However, Windmiller and Walton (1992), who sampled more extensively, noted that both Cook's and Folly pond supported "sizeable populations". In the current survey, only two red-spotted newts (RA = 1.21% among salamanders; Table 2) were observed (in minnow traps) at Folly Pond (FO = 2.7%) making it the least common and least widespread salamander species at MIMA (Tables 3 and 4). These results suggest the red-spotted newt is now uncommon in MIMA and appears to have declined in recent years.

There is a growing body of literature linking absence or decline of red-spotted newts on landscapes subjected to forest clearing, habitat fragmentation, and urbanization (Guerry and Hunter 2002, Rubbo and Kiesecker 2005, Steen and Gibbs 2005). They have been found to disappear from habitat patches when forest cover decreases below approximately 50% (Gibbs 1998) and achieve much greater densities when forest cover within 500 m of breeding ponds exceeds 81% (Herrmann et al. 2005). In addition, clear-cut timbering may significantly affect red-spotted newt populations (Petranka et al. 1993) and repopulation may take 30-60 years (Pough et al. 1987). The high sensitivity of red-spotted newts to habitat loss and forest fragmentation may also be due to the vulnerability of red efts to road kill during their many years of long distance terrestrial movements (Gibbs 1998, Cushman 2006). Plus, adults may become terrestrial when breeding in semi-permanent or vernal ponds (Regosin et al. 2005) and also become vulnerable to road kill. Thus, the decline of red-spotted newts in and around MIMA appears to be another example of a species with a complex life cycle and large area requirements being unable to sustain itself on the fragmented landscape of MIMA.

Eastern Red-backed Salamander (*Plethodon cinereus*)

The eastern red-backed salamander is a lungless terrestrial salamander that is widespread and common throughout the Northeast, including New York State (Gibbs et al. 2007) and New England (Klemens 1993). It occurs as a number of different color morphs, with the red striped and unstriped (or lead-backed) the two most common and widespread (Petranka 1998). Although they reach their greatest density in well-drained deciduous and mixed forests with well developed leaf litter (Gibbs et al. 2007) and in some forest ecosystems dominate the vertebrate biomass (Burton and Likens 1975), eastern red-backed salamanders are not necessarily restricted to mature forest habitats (Klemens 1993). At Cape Cod National Seashore, they can also be found in open habitat such as beneath power lines and under woody debris deposited by storm surge at the upper limits of salt marshes (R. Cook, pers. obs.). Because all embryonic and larval development takes place in the “aquatic” environment within the egg membrane, eastern red-backed salamanders are completely terrestrial and do not require wetlands for reproduction. This attribute, in conjunction with their small home range and limited movements, has facilitated their widespread distribution and made them one of the most urban tolerant amphibians, capable of persisting in small woodland patches in highly fragmented urban landscapes (Schlauch 1976, Gibbs 1998).

The eastern red-backed salamander is widespread and abundant in Massachusetts (Lazell 1974, Cardoza and Mirick 2009) and throughout Southern New England (Klemens 1993). It has long been considered common in Massachusetts (Storer 1840, Allen 1868), including the vicinity of MIMA (Carnegie 1914). Greer et al. (1973) considered it the most abundant and easily observed salamander in the Concord area. In the 1990’s Massachusetts Herp Atlas, eastern red-backed salamander was the 3rd most recorded native species (tied with spotted salamander) in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²), accounting for 21 of 270 (7.8%) of records, including one record within MIMA (Jackson et al. 2010).

In prior surveys at MIMA, the eastern red-backed salamander was widespread, found near the edges of ponds and streams, and in forested areas, primarily inside rotten logs and under boards, bricks, and debris (Martinez 1992, Thomas 1992, Windmiller and Walton 1992). It was considered the most abundant salamander species at MIMA, recorded from nine of 12 sites sampled by Thomas (1992), including five surveyed in our current study: Black Gum Swamp Pond had greater than five adults, Cook’s Pond had two adults, Elm Brook had two adults, Folly Pond had more than five adults, and Virginia Road Pond had more than 10 adults and juveniles.

In the current survey, the eastern red-backed salamander was the most abundant and widespread salamander at MIMA with 78 individuals recorded (RA=47.27% among salamanders, and FO = 24.3%). It was found at all seven of the deciduous forest survey sites in addition to a single permanent pond and a single temporary pond (Tables 2, 3, and 4). This latter point reflects its terrestrial nature as nearly all individuals (97% of individuals) were recorded in deciduous forest (Table 2). Of the 78 individuals recorded, 21 (27%) were lead-backed morphs. Thomas (1992) also recorded both red and lead-backed morphs, but provided no data on numbers.

The encounter rate of red-backed salamanders during Woodland TCS at MIMA (2.39 individuals/search hour), is within the range of values for other NPS sites in the Northeast Temperate Network that are predominantly forested, e.g. Saratoga NHP (1.56 inds/hr), Weir Farm NHS (1.75 inds/hr), Acadia NP (2.8 inds/hr), Saint-Gaudens NHS (2.91 inds/hr), and Morristown NHS (4.14 inds/hr) (Cook et al. 2011a, Brotherton et al. 2005a, Brotherton et al.

2005b, Cook et al. 2008, Brotherton et al. 2005c). Windmiller and Walton (1992) considered the eastern red-backed salamander “not especially abundant” at MIMA, which suggests it was not as abundant at MIMA as other sites they were familiar with. Based on this inventory, and the above comparison with other sites we surveyed, we would concur with this assessment and consider the eastern red-backed salamander to still be fairly common in forested habitats at MIMA.

Northern Two-lined Salamander (*Eurycea bislineata*)

The northern two-lined salamander (*Eurycea bislineata*) is distributed throughout the Eastern United States from the Gulf of Mexico north into Quebec, Canada (Petranka 1998). This stream salamander is typically more aquatic in nature than the northern dusky salamander, often found in the stream and splash zones of cool, swift moving streams. Females deposit eggs singly on the underside of flat rocks in streams (Petranka 1998). The northern two-lined salamander is the most widespread and abundant stream salamander in New England, as well as the most urban tolerant (Klemens 1993). It even occurs in a small length of remnant stream at the heavily urbanized Saugus Iron Works NHS in Saugus, MA, approximately 25 km east of MIMA (Cook et al. 2010b).

This species is widespread and generally common in Massachusetts except on Cape Cod and Islands (Klemens 1993, Cardoza and Mirick 2009). However, Greer et al. (1973) considered it “locally distributed” and “not commonly encountered” in the Concord area. In the 1990’s Massachusetts Herp Atlas project, northern two-lined salamander was the 14th most recorded native species, accounting for eight of 270 records (3.0%) in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²), including one record within MIMA at Elm Brook (Jackson et al. 2010). Thus, in our view, the absence of early 20th century records for Concord (Carnegie 1914) reflects a failure of early naturalists to detect a species that was not widespread locally, rather than actual absence.

In the current survey, the northern two-lined salamander was recorded from two adjacent sites on Elm Brook (FO = 5.4%) where 25 total individuals (RA = 15.15%) were observed (Tables 2 and 3). The vast majority of captures (24/25) were in a small section of stream just south of Route 2A, whereas surveys in the 1990’s recorded 20 two-lined salamanders in a small section of Elm Brook just north of Route 2A (Thomas 1992, Windmiller and Walton 1992). Although a lack of standardization between the current study and these previous two studies make comparisons difficult, it appears that in recent decades this population of northern two-lined salamanders at MIMA has remained fairly stable, both numerically and geographically, and very localized. This restricted distribution is due to a lack of well-oxygenated stream habitat throughout most of MIMA (Windmiller and Walton 1992). Mill Brook has been impaired by habitat alterations, and the section of Elm Brook that runs through MIMA is “impaired or threatened” by turbidity, pathogens (coliform bacteria), and habitat alterations. Apparently the impairment due to habitat alterations occurred after this survey, prompting concerns that Elm Brook is deteriorating even further (James-Pirri 2009). These stream impairments limit the amount of suitable habitat for northern two-lined salamanders at MIMA and likely serve to isolate it, making extinction more likely in the event of further degradation.

At MIMA, the capture rate for adults is 6.49 individuals/hr for Elm Brook South and 3.25 inds/hr for both Elm Brook North and South combined. This is comparable to capture rates at another nearby urban site, Saugus Iron Works (6.3 inds/hr) (Cook et al. 2010b) and with capture rates at Saint-Gaudens NHS (SAGA) in rural New Hampshire and Acadia National Park in Maine. At

SAGA's Blow-Me-Up Brook, the capture rate in 2001 (by the same field crew that surveyed MIMA) was 7.74 adults/search hour (Cook et al. 2008). At Acadia, the capture rate for adults was 2.8 adults/search hour (Brotherton et al. 2005b). However, at Saratoga National Historic Park, where two-lined salamanders were present in five of seven streams sampled, the capture rate of adults in those five streams was 15.58 inds/hr (Cook et al. 2011a). Thus, we consider two-lined salamanders to still be fairly common in the small section of Elm Brook where they occur. However, their continued persistence at MIMA is uncertain and efforts to improve water quality in Elm Brook should be pursued.

Eastern American Toad (*Anaxyrus americanus*)

The eastern American toad occurs throughout most of the Eastern United States and Canada, ranging from Northern Louisiana and Southern Appalachia northward into Northern Ontario and Quebec (Conant and Collins 1998). It is widespread and common throughout the Northeast (Klemens 1993, Gibbs et al. 2007), although in Southern New England and along the Atlantic coast, it occurs primarily inland, away from the more open and xeric coastal habitats, where the closely related Fowler's toad predominates (Klemens 1993). The eastern American toad is a terrestrial species that breeds in early spring in a variety of shallow aquatic habitats including temporary ditches, flooded meadows, marshes and ponds (Klemens 1993). It is easily identified in spring by its prolonged, high pitched, trilling call. Eastern American toads occur in moist upland woods and meadows and appear to be less sensitive to habitat fragmentation than many other amphibian species (Hager 1998, Kolozsvary and Swihart 1999). They are most abundant on landscapes with more pasture, deciduous and mixed forest and less evergreen forest and less urbanization, but are also found in various human-altered habitats on suburban landscapes (Gibbs et al. 2007).

The eastern American toad is found statewide in Massachusetts with the exception of outer Cape Cod and Nantucket (Lazell 1974). Eastern American toads were considered common to abundant in Massachusetts in the mid-19th century (Storer 1840, Allen 1868), although these accounts must be read carefully because these authors did not distinguish between American and Fowler's toad. The distinctness of these two species was recognized by the late 19th century and in the early 20th century both species were considered common in Concord (Carnegie 1914). American toads continued to be common in the Concord area during the mid-20th century (Greer et al. 1973). In the 1990's Massachusetts Herp Atlas project, the eastern American toad was the eighth most recorded native species in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²), accounting for 16 of 270 (5.9%) of records (Jackson et al. 2010). In addition, Burne (2000) documented eastern American toads in seven of the 78 (9%) vernal pools he sampled in the Concord area. These records from the 1990's suggest that by the late 20th century, eastern American toads had become uncommon in the Concord region and surveys at MIMA concurred. Windmiller and Walton (1992) recorded small numbers of eastern American toads at six sites, including five surveyed in our current study: several males were calling along the north bank of the Concord River; males were heard calling from Mill Brook Wayside; Cook's Pond had some larvae; a few males were calling from Palumbo Ditches; and Whittemore Pond had adults trapped moving to and from the pond, though no calling was observed.

In the current survey, the eastern American toad was one of the least abundant anurans at MIMA, (RA = 0.48% among anurans) but it was widespread (FO = 32.43%) especially given this species' low overall abundance (Tables 2 and 3). In addition, 20 of the 21 individuals

encountered were equally distributed among temporary ponds, permanent ponds, fields, and deciduous forests, highlighting this species' diverse habitat utilization (Table 2). In 2001, eastern American toads were recorded from 12 sites, including seven wetlands (Table 4). Four of these wetlands were sites where toads were recorded in 1992 (Windmiller and Walton (1992)). We found one adult along the Concord River at Mill Brook Mouth, larvae in Cook's Pond, one adult in Palumbo Ditches, and one adult in Whittemore Pond. Although lack of standardization make comparisons difficult, in all instances at the sites we had in common, we recorded fewer individuals than Windmiller and Walton (1992).

Eastern American toads in Southern New England sustain high road mortality and have experienced localized extinctions (Klemens 1993). Their long term persistence was less at ponds surrounded by residential or commercial land uses and developed lands (Gibbs et al. 2005) suggesting that there are limits to urban tolerance in American toads. On an agricultural-forested landscape, they were negatively associated with forest area (Guerry and Hunter 2002) and research near Ottawa, Canada found that abundance of eastern American toads was significantly negatively associated with traffic density but had only a weak negative association with forest cover (Eigenbrod et al. 2008). These findings suggest that urban development and associated road kill on the highly developed landscape that surrounds MIMA has been the primary cause of the long term decline of eastern American toads at and near MIMA. Pesticide applications in agricultural fields may also be a factor. In contrast to MIMA, on the larger and less intensely developed local landscape at Great Meadows NWR, eastern American toads were documented during standardized anuran calling surveys conducted from 2005-2010 from all four monitoring sites as follows; two sites-all six years, one site-five years, one site-four years (USFWS unpubl. data). Our results indicate that eastern American toads remain widespread but uncommon at MIMA, and their persistence here may be uncertain.

Gray Treefrog (*Hyla versicolor*)

Gray treefrogs occur throughout most of the Eastern United States as a pair of sibling species distinguishable from each other in the field only by voice (Conant and Collins 1998). The species which occurs in Massachusetts, *Hyla versicolor*, is found throughout the Northeast and Canada (Klemens 1993). The gray treefrog has large toe pads, orange/yellow coloration on the underside of the hind limbs, and their dorsal color ranges from gray to brown, green, light gray, to almost white depending on activity and environmental conditions (Conant and Collins 1998). Grey treefrogs live high in trees and shrubs, descending to wetlands to breed (Behler and King 1979). Because gray treefrogs breed moderately late in the season (Cook et al. 2011b), yet have larvae that metamorphose later that same year, they tend to breed in long hydro-period vernal or semi-permanent ponds. After metamorphosis, the majority of juveniles remain in close proximity (i.e., within 35 meters) to natal wetlands, but adults are more mobile and frequently make migrations of 200 meters or more between foraging grounds, overwintering sites, and breeding ponds (Johnson et al. 2007).

Gray treefrogs are widespread in Southern New England (Klemens 1993) and occur statewide in Massachusetts except for Martha's Vineyard and Nantucket (Cardoza and Mirick 2009). Grey treefrogs were historically considered common in Massachusetts (Storer 1840, Allen 1868), including the Concord area in the early 20th century (Carnegie 1914). Greer et al (1973) suggested they were widespread but not as abundant as northern spring peepers in the Concord area. In the 1990's Massachusetts Herp Atlas project, gray treefrog was the 13th most recorded

species, with nine of 270 (3.3%) records in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²), including one at MIMA in the Cranberry Bog (Jackson et al. 2010). However, intensive, multiple method surveys during the late 1990's documented gray treefrogs in 26 of 78 (33%) vernal pools sampled in Concord area (Burne 2000), suggesting it is moderately widespread and common. Surveys at MIMA during this period are consistent with this. Windmiller and Walton (1992) recorded gray treefrogs in relatively moderate numbers at five sites, including four of the wetlands surveyed in our current study. In that study, Cook's Pond was a very productive site, with many killed crossing old Massachusetts Avenue; Cranberry Bog had a small chorus and adults killed crossing Route 2A; and Folly Pond had a moderate breeding chorus and many larvae.

In the current survey, we recorded a total of 621 gray treefrogs from eight sites, six of which were ponds. It was the second most abundant anuran at MIMA (RA=14.19%) and it was moderately distributed (FO = 21.6%; Tables 2 and 3). Nearly all individuals were recorded at permanent ponds (Table 4) as calling adults during anuran call counts and pond TCS (99.5%) (Table 7). Gray treefrogs were most abundant at Cook's Pond (270 individuals, 43.5% of the total) and Folly Pond (226 individuals, 36.4% of the total), with lesser numbers at Cranberry Bog and Black Gum Swamp Pond (Table 4).

These results are similar to the qualitative results of Windmiller and Walton (1992) and suggest that gray treefrog was and continues to be a common species at MIMA, although less widely distributed than most other anurans. Gray treefrogs also appear to be moderately widespread and common in the Concord Division of Great Meadows National Wildlife Refuge, where it was documented calling most years from 2005-2010 at four of four monitoring sites (USFWS unpubl. data). However, gray treefrogs have declined in Connecticut due to urbanization and pollution (Klemens 1993) and in the National Capital region of Canada, their abundance was greatest at ponds in forested landscapes and significantly less in ponds set in urban landscapes and areas of high road density (Gagne and Fahrig 2007, Eigenbrod et al. 2008). Thus, although the present results are encouraging, MIMA staff should continue to work to protect and improve water quality and reduce urban impacts. In particular, given the importance of Cook's and Folly Pond to gray treefrogs at MIMA, the conditions in and around these two ponds should be closely monitored.

Northern Spring Peeper (*Pseudacris c. crucifer*)

The northern spring peeper is widespread and abundant throughout the eastern United States and Canada and breeds in a wide range of freshwater wetlands. Its unique, high-pitched breeding call is often a deafening chorus of hundreds of individuals. These loud and distinct calls, in combination with a prolonged calling season that stretches from mid-March to late-May make it the most readily detected of local anurans (Crouch and Paton 2002). Northern spring peepers are terrestrial outside of the breeding season, and utilize a broad range of terrestrial habitats (Gibbs et al. 2007). They are tolerant of human disturbance and manage to persist in many urban and suburban areas (Gibbs 1998, Zampella and Bunnell 2000), making them one of the most common frogs in Southern New England (Klemens 1993).

Northern spring peepers are abundant throughout Massachusetts (Lazell 1974) and have been considered so historically (Allen 1868). They were common in Concord in the early 20th century (Carnegie 1914). In the 1990's Massachusetts Herp Atlas project, northern spring peeper was the ninth most reported native species, accounting for 13 of 270 (4.8%) records in the nine Herp

Atlas quads centered on MIMA (an area of approximately 1,350 km²), including one record within MIMA (Jackson et al. 2010). Surveys at MIMA in 1992 noted that this species was found in a large number and diversity of wetlands throughout MIMA, including ephemeral ponds, permanent ponds, and ditches (Windmiller and Walton 1992) and surveys in Concord in the late 1990's documented northern spring peepers in 50 of 78 (64%) vernal pools sampled (Burne 2000).

In the current survey, we recorded 2762 northern spring peepers. It was the most abundant anuran at MIMA with a relative abundance of 63.13% among anurans and was the second most widely distributed anuran, being found in 12 permanent and two temporary ponds (FO = 37.8%; Tables 2 and 3). Northern spring peepers were most abundant in Cranberry Bog (501 individuals, 18.1% of the total) and Cook's Pond (461 individuals, 16.7% of the total), and the majority of individuals (71.7% of the total) were recorded via anuran calling surveys (Tables 4 and 7).

Our results indicate that this species continues to be abundant and widespread at MIMA, which is consistent with prior surveys here (Windmiller and Walton 1992). Northern spring peepers are also widespread and common in the Concord Division of Great Meadows National Wildlife Refuge, where it was documented in calling surveys every year from 2005-2010 at all four monitoring sites (USFWS unpubl. data). Given the urban tolerance of spring peepers, this species should remain common and widespread in and around MIMA.

American Bullfrog (*Lithobates catesbeianus*)

The American bullfrog is a widespread and common species throughout much of its native range, which is "the eastern two-thirds of the United States and adjacent portions of Southern Canada and Northeastern Mexico" (Klemens 1993). It has also been introduced into many other areas of the Western U.S., where it has negatively impacted and displaced native species (Adams 1999, Stumpel 1992) and dramatically altered aquatic community structure (Kupferberg 1994).

American bullfrogs require two or more years for their tadpoles to metamorphose, so they breed in open bodies of water such as lakes and permanent ponds (Conant and Collins 1998). Their primary habitat requirement is a permanent water body with abundant emergent and shoreline vegetation (Albright 1999). However, because American bullfrogs may require a few years beyond metamorphosis to reach adulthood and, in the case of males, attain a size capable of defending a breeding territory, juveniles may inhabit temporary ponds and streams and travel overland between these sites. This species is an aggressive predator and includes other frogs, young turtles, small snakes, and many invertebrates in its diet. It is adept at colonizing new habitats, especially those constructed or modified by humans (Lacki et al. 1992). American bullfrogs may increase on forested landscapes as it is altered by agriculture, urbanization, and stream impoundments (Zampella et al. 2010) and are considered relatively urban tolerant (Klemens 1993).

American bullfrogs are widespread and common in New York and Southern New England (Klemens 1993, Gibbs et al. 2007) and are native to all of Massachusetts except the Islands (Lazell 1974). The historic status of American bullfrogs is somewhat vague. Storer (1840) stated they were "not common in this part of the state", although it is not clear what part he was referring to. They were however, abundant in central Massachusetts (Allen 1868). American bullfrogs were present in lakes, ponds, and rivers of early 20th century Concord, but no comments on abundance were provided (Carnegie 1914). In mid-20th century Concord,

American bullfrogs were locally abundant around large bodies of water and common in Great Meadows (Greer et al. 1973). In the 1990's Massachusetts Herp Atlas project, American bullfrog was the sixth most recorded native species, accounting for 19 of 270 (7.0%) records in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²). At this same point in time at MIMA, American bullfrogs were recorded at five of 23 wetland sites sampled, primarily permanent ponds, and were considered fairly common (Martinez 1992, Windmiller and Walton (1992).

In the current survey, we also found the American bullfrog was common but not abundant at MIMA and moderately distributed. We recorded 84 individuals (RA=1.92% among anurans) at 10 sites, nine of which were permanent ponds (FO = 27.03%; Tables 2, 3, 4). American bullfrogs were most abundant at Nelson Pond (41 individuals, 48.8% of the total), and the majority of individuals (64.3%) were recorded during pond TCS (Tables 4 and 7). Windmiller and Walton (1992) described Pond O as the best breeding site at MIMA, with many larvae and adults present, but they did not sample Nelson Pond. Although we found adults, larvae and calling males at Pond O, our results suggest that Nelson Pond supports a larger population of the American bullfrog. American bullfrogs are also widespread and common in the Concord Division of Great Meadows National Wildlife Refuge, where, from 2005 to 2010, it was documented at all four monitoring sites during every late-spring or early summer calling survey (USFWS unpubl. data). Given their ability to persist on agrarian and suburban landscapes (Rubbo and Kiesecker 2005, Zampella et al. 2010) American bullfrogs should remain moderately common and widespread in and around MIMA.

Northern Green Frog (*Lithobates clamitans melanota*)

The northern green frog is common and widespread throughout the Eastern United States and Canada, using a wide range of wetland habitats (Klemens 1993). However, in northern populations, northern green frog tadpoles must overwinter in the breeding pond (Wright and Wright 1949), limiting successful reproduction to ponds that are permanent and semi-permanent. Although adult northern green frogs breed and forage in permanent ponds, non-breeding juveniles and dispersing adults may also be found in and along vernal ponds, streams, rivers, marshes, and on roads on rainy nights. Some adults are also known to hibernate in streams (Gibbs et al. 2007). Dorsolateral ridges extending down the back help distinguish the northern green frog from the American bullfrog in which the ridges are absent.

The northern green frog is ubiquitous in Southern New England (Klemens 1993) including Massachusetts, (Cardoza and Mirick 2009). Northern green frogs were historically widespread and abundant in Massachusetts (Storer 1840, Allen 1868) and common in the streams and ponds of early 20th century Concord (Carnegie 1914). In the 1990's Massachusetts Herp Atlas project, northern green frog was the 5th most recorded native species, accounting for 20 of 270 (7.4%) records in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²) (Jackson et al. 2010). Although it breeds in more permanent ponds, northern green frogs occurred in 32 of 78 (41%) Concord area vernal pools sampled in the mid-1990's (Burne 2000). At this same point in time, northern green frogs were also widespread and common at MIMA. They were recorded from 12 of 23 wetland sites sampled, including permanent and vernal ponds and Mill Brook (Martinez 1992, Windmiller and Walton 1992). These included eight sites surveyed in our current study: Black Gum Swamp Pond had a moderate population, Cook's Pond had a large population, Cranberry Bog had numerous larvae, Folly Pond had a large population,

Mill Brook had non-breeding habitat, Palumbo Ditches had adults and a small number of larvae, Virginia Road Pond had a moderate population, and Whittemore Pond was an important non-breeding site and also had several larvae observed (Windmiller and Walton 1992). Martinez (1992) observed calling at Black Gum Swamp Pond, Cook's Pond, and Pond 4-121.

In the current survey, we also found northern green frog to be abundant and widespread. It was the third most abundant anuran at MIMA, with 581 individuals recorded (RA=13.28% among anurans). It was the most widely distributed of any species, recorded from 17 sites (FO = 45.95%; Tables 2 and 3). Northern green frogs were recorded from all habitat types except for "fields", but the great majority of individuals (96%) were recorded at permanent ponds. Northern green frogs were most abundant at Cook's Pond (178 individuals, 30.6% of the total), Nelson Pond, and Folly pond, and the majority of individuals (56.3%) were identified during pond TCS (Tables 4 and 7). Of the 11 wetland sites surveyed in 1992 (Windmiller and Walton 1992), we surveyed 10 and recorded northern green frogs in nine (Table 4). Thus, there appears to be no change in their status at MIMA. Northern green frogs are also widespread and common in the Concord Division of Great Meadows National Wildlife Refuge, where, from 2005 to 2010, it was documented at all four monitoring sites during every late-spring or early summer calling survey (USFWS unpubl. data).

Because permanent ponds are more likely to survive urbanization than shallow, temporary ones, and have increased in some instances through the damming of streams (Schlauch 1976), permanent pond species such as northern green frogs have remained one of the most widespread and abundant amphibians of urban and suburban landscapes (Rubbo and Kiesecker 2005). Thus, as previously pointed out, species tolerant of urbanization and habitat fragmentation, such as the northern green frog, tend to dominate at MIMA (Windmiller and Walton 1992). It is and will likely continue to be abundant at MIMA, with the majority of individuals occurring in permanent pond habitat. However, temporary ponds and streams are also important habitat for dispersal and foraging, especially by non-breeding juveniles that occupy these habitats until they are able to occupy and defend a territory in the breeding ponds.

Pickerel Frog (*Lithobates palustris*)

The pickerel frog ranges from Southeastern Canada south through most of the Eastern United States, except for Florida and the Gulf States, westward to Eastern Texas (Conant and Collins 1998). It breeds in shallow permanent wetlands and outside of breeding season, can be found in permanent and ephemeral wetlands, streams, springs, sphagnum bogs, fields, and woodlands (Klemens 1993, Gibbs et al. 2007). This species is distinguished from the northern leopard frog by a dorsal pattern of brown squares arranged symmetrically, and the inner surfaces of the hind legs are orange or yellow (Klemens 1993).

The pickerel frog is common and widespread in Southern New England (Klemens 1993) and is distributed statewide in Massachusetts (Cardoza and Mirick 2009). It was historically widespread and common in Massachusetts (Storer 1840, Allen 1868) and occurred in cold streams, ponds, and grassy meadows in early 20th century Concord (Carnegie 1914). In the mid-20th century pickerel frogs were locally distributed in the Concord area, usually found along the margins of swampy areas (Greer et al. 1973). In the 1990's Massachusetts Herp Atlas project, pickerel frog was the 11th most recorded native species, accounting for 10 of 270 (4.4%) records in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²) (Jackson et al. 2010).

Surveys at this same point in time at MIMA recorded pickerel frogs at four of 23 sites surveyed (Martinez 1992, Windmiller and Walton 1992).

In the current survey, the pickerel frog was the least abundant and least widely distributed anuran at MIMA. Six individuals (RA = 0.14%) were recorded from four sites (FO = 10.81%) (Tables 2 and 3). Of the six individuals recorded, four were incidental encounters. In prior surveys at MIMA, pickerel frog was uncommon, yet Cook's pond had many juveniles and larvae, Whittemore Pond was an important non-breeding site for juveniles, and Folly Pond had a small number of larvae and juveniles (Windmiller and Walton 1992). In 2001, of these three site, we only recorded pickerel frogs at one, Folly Pond (two individuals).

These comparisons suggest the pickerel frog has become rare at MIMA and may be in decline. However, on the larger and less intensely developed landscape at Great Meadows NWR, during standardized anuran calling surveys conducted from 2005-2010, pickerel frogs were documented calling at all four monitoring sites as follows; three sites-all six years, one site-five years (USFWS unpubl. data).

Pickerel frogs appear less tolerant of urbanization than either American bullfrogs or northern green frogs, likely due to a preference for thick herbaceous shoreline vegetation that frequently is lacking in urban wetlands (Klemens 1993). Moreover, pickerel frogs have a complex pattern of seasonal movements that includes extensive use of upland habitats after breeding. This likely makes them vulnerable to road kill, and the differences in apparent abundance between MIMA and Great Meadows may be due to Great Meadows providing a larger, less fragmented habitat patch, with a continuous wetland corridor, fewer roads, and less traffic.

Northern Leopard Frog (*Lithobates pipiens*)

The northern leopard frog is found throughout most of the Northeast and Northern Midwest regions of the United States, extending southwest into Northern New Mexico and Arizona. It also ranges across the southern half of Canada, from the Maritimes west to Alberta (Conant and Collins 1998). Northern leopard frogs are frequently confused with the pickerel frog (and vice versa). Both species have distinct spots down the back, but the spots of the northern leopard frog are oval and less uniform than the two parallel rows of square spots that appear on the pickerel frog. Also, northern leopard frogs are typically greener in color and lack the bright yellow-orange coloration present on the undersurface of the hind legs of pickerel frogs.

Although widespread across Northern New England (Hinshaw 1999), in Southern New England the northern leopard frog is localized in the Housatonic and Connecticut river drainage basins and from Rhode Island north along the coast into the Merrimack River basin (Klemens 1993). Within these basins, it typically occurs in floodplain forest and meadows, riparian wetlands, and around large lakes (Klemens 1993). Due to the widespread release of this species outside its original range, confusion with pickerel frog and complex taxonomy involving a species complex, determining the distribution and historic and taxonomic status of northern Leopard frog in Massachusetts can be challenging (Klemens 1993, Cardoza and Mirick 2009). Early accounts suggest the northern leopard frog was widespread and common in Massachusetts, although much less abundant than northern green frog and pickerel frog (Storer 1840, Allen 1868). It was common in ponds and streams in early 20th century Concord (Carnegie 1914) and it remained locally common throughout the area in open meadows, near water (Greer et al. 1973).

Although they may be the dominant frog in a narrow habitat strip, near the end of the 20th century, the northern leopard frog was regionally rare in Southern New England (Klemens 1993). In the 1990's Massachusetts Herp Atlas project, there were four records of northern leopard frogs in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²), though none of these occurred within MIMA (Jackson et al. 2010). Of the 28 native species recorded in these quads, northern leopard frog ranked 17th, accounting for four of 270 (1.5%) records. Although Burne (2000) found northern leopard frogs in nine of the 78 (12%) vernal pools he sampled in the Concord area in the mid 1990's neither Windmiller and Walton (1992) nor Martinez (1992) recorded northern leopard frogs at MIMA.

In the current survey, the northern leopard frog was one of the least abundant (RA = 0.64%) and least widely distributed (FO = 18.92%) anurans at MIMA (Tables 2 and 3). A total of 28 individuals were recorded, 23 of which were recorded at three sites (eight individuals each at Mill Brook Mouth and Historic Fields, and seven individuals at North Bridge Field; Table 4). Half of the individuals (14) were recorded during field TCS (Table 7). These observations are the first records of this species at MIMA and suggest the northern leopard frog is an uncommon resident in MIMA. Its occurrence at MIMA in riparian fields and floodplain is consistent with its known habitat affinities (Klemens 1993).

The northern leopard frog has apparently declined throughout much of New England due to farm abandonment, forest regeneration, and decreases in grassland (Klemens 1993, Hinshaw 1999). In addition, northern leopard frogs have a complex pattern of post-breeding movement that makes them vulnerable to road kill (Carr and Fahrig 2000). A number of studies comparing among urban, agricultural, and forested landscapes point to urban development and traffic density as the most important factors negatively affecting northern leopard frog abundance (Guerry and Hunter 2002, Gagne and Fahrig 2007, Eigenbrod et al. 2008). These findings suggest that urban development and associated road kill on the highly developed landscape that surrounds MIMA has been the primary cause of the long term decline of northern leopard frogs at and near MIMA. In contrast to MIMA, at the Concord Division of Great Meadows NWR, northern leopard frogs were documented during all early spring anuran calling surveys conducted from 2005-2010 (USFWS unpubl. data). These differences in apparent abundance between MIMA and Great Meadows may be due to Great Meadows providing a larger, less fragmented habitat patch, with a continuous wetland corridor, fewer roads, and less traffic. Our results suggest that northern leopard frogs will remain uncommon at MIMA and their persistence here may be uncertain.

Wood Frog (*Lithobates sylvaticus*)

The wood frog has an extensive range that includes Appalachia, the Northeast, most of Canada, and Alaska (Conant and Collins 1998). It is widespread in New York and New England, occurring both inland and on the coastal plain (Klemens 1993, Gibbs et al. 2007). Wood frogs are terrestrial, typically associated with forested landscapes, except during the breeding season when they breed in fishless vernal pools (Conant and Collins 1998). Breeding in early spring, the wood frog is an explosive breeder. Often a large percentage of a population migrates to ponds synchronously, laying eggs together in large floating masses. They breed in greatest abundance at vernal ponds with short to intermediate hydro-periods (Egan and Paton 2004) and equally use both closed and open canopy ponds (Skelly et al. 2002). Outside of the breeding season, wood frogs disperse from breeding ponds, spending late spring and summer primarily in forested wetlands (Baldwin et al. 2006). Both occurrence and abundance of wood frogs at breeding ponds

has been positively linked to amount of forested wetlands nearby (Egan and Paton 2008). In autumn, wood frogs move to upland forest in close proximity to their breeding ponds to hibernate in leaf litter (Regosin et al. 2003). In the course of these seasonal movements, adults may travel up to 200-300 meters from the breeding pond (Regosin et al. 2005, Baldwin et al. 2006). Wood frogs are philopatric (behavior of remaining in, or returning to, an individual's birthplace), with around 80% breeding in their pond of origin. The other 20% disperse as juveniles, travelling on average, roughly 1.2 km from their natal pond to breed as an adult the following year in a different pond (Berven and Grudzein 1990).

Wood frogs are generally common and widespread in Southern New England (Klemens 1993) and occur statewide in Massachusetts with the exception of Dukes and Nantucket Counties (Cardoza and Mirick 2009). Early accounts also suggest that wood frogs were historically widespread and common in Massachusetts (Storer 1840, Allen 1868). In the Concord area, Carnegie (1914) noted their presence in the woods, but did not comment on their abundance whereas Greer et al. (1973) noted they were encountered in large numbers during the early spring breeding season. In the 1990's Massachusetts Herp Atlas project, wood frog was the second most recorded native species, accounting for 23 of 270 (8.5%) records in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²). In the mid-1990's, wood frog was documented in 59 of 78 (76%) vernal pools sampled in the Concord area (Burne (2000). Surveys at MIMA in 1992 recorded breeding wood frogs from nine of 22 wetlands; four of eight vernal/temporary ponds and five of 14 permanent ponds (Martinez 1992, Windmiller and Walton 1992). Virginia Road Pond had the largest population, with approximately 350 egg masses, and several others had counts of adults or egg masses ranging from 11 to 37.

In the current survey, wood frog was the fourth most abundant anuran at MIMA, with 259 individuals recorded (RA = 5.92%). It was moderately distributed, recorded from 12 sites (FO = 32.43%), including five upland, one stream, and six ponds (Tables 2, 3, 4). Wood frogs were most abundant at Cook's Pond (130 individuals, 50.2%) and Virginia Road Pond (106 individuals, 40.9%), and these two ponds accounted for ca. 91% of all individuals recorded. Most individuals were identified during egg mass counts (44.8%) and pond TCS (40.9%; Table 7). Similar to earlier surveys, the majority of wood frog egg masses in 2001 (83%) were found at Virginia Road Pond (Table 9). However, the 96 egg masses found in 2001 were less than the 350 found at this pond in 1992 (Windmiller and Walton 1992). Given how late in the spring this count was conducted (April 19th) and the fact that most eggs were in late development stages, this count may have missed the peak number of egg masses and is an underestimate. However, the relatively small numbers recorded in 2001 in ponds such as Cook's, Folly, and Black Gum Swamp are comparable to 1992 and other sites where wood frogs were recorded in 1992, i.e. Palumbo Ditches and Pond (14 egg masses) and Whittemore Pond (37 adults trapped), had none recorded in 2001.

Although it appears there were fewer wood frogs recorded in 2001 than in 1992, a lack of standardization makes it hard to compare these two points in time. In addition, breeding population size of wood frogs can vary dramatically from one year to the next as a function of the effect of hydro-period length on larval survival in preceding years (Berven 1990). Given these limitations, our results suggest that the wood frog has been and remains an uncommon species at MIMA since the 1990's and its population appears relatively stable. It also appears to be limited in abundance at the adjacent Concord Division of Great Meadows National Wildlife

Refuge. There, wood frogs have been recorded on only two of twelve sampling occasions from two of four sites during anuran calling surveys from 2005-2010 (USFWS unpubl. data).

Windmiller and Walton (1992) felt that in spite of the presence of many potential breeding ponds, wood frogs were uncommon at MIMA because of woodland fragmentation and proximity of major roads to breeding ponds. Since those 1992 surveys were conducted, there has been a large body of research demonstrating that the occurrence and abundance of wood frogs is positively related to amount of forest adjacent to breeding ponds (Guerry and Hunter 2002, Porej et al. 2004, Rubbo and Kiesecker 2005, Skidds et al. 2007, Egan and Paton 2008, Eigenbrod et al. 2008) and that their abundance is greatest in forested landscapes and declines as the amount of agriculture and/or urbanization adjacent to breeding ponds increases (Herrmann et al. 2005, Gagne and Fahrig 2007). Moreover, in studies conducted in the MIMA area, wood frog abundance was negatively related to measures of urbanization such as amount of impervious surface, road length, amount of dense residential development (Clark et al. 2008) and populations declined dramatically when forest adjacent to vernal ponds are replaced by urban development (Windmiller et al. 2008).

Although the most important landscape elements and the scale at which they operate on wood frog occurrence and abundance may vary geographically, in Rhode Island the landscape within 1000 meters of the breeding pond was most important (Egan and Paton 2008) and in Eastern Massachusetts the best models explaining wood frog occurrence were based on landscape features within 1-2 km of the breeding pond (Clark et al. 2008). These results indicate that wood frog populations are significantly affected by features of the landscape seemingly far from the breeding ponds, presumably because of the extensive movements made by wood frogs as they disperse from ponds or make seasonal habitat shifts. Given these findings and the proximity of MIMA ponds to roads, the heavy volume of traffic on these roads, and the extensive urban development and agriculture adjoining MIMA, we would concur with Windmiller and Walton (1992) that woodland fragmentation and road impacts limit wood frogs here. Therefore, although still widespread, wood frogs remain uncommon at MIMA. Considering the declining trends in natural resource conditions here (James-Pirri 2009), their long-term persistence should not be taken for granted and their breeding populations should be monitored yearly via early spring egg mass counts.

Common snapping Turtle (*Chelydra s. serpentina*)

The common snapping turtle occurs from Southern Canada, south through the mid-west and east coast, down to Florida and the Gulf of Mexico (Ernst et al. 1994). It is abundant and widespread in New York State (Gibbs et al. 2007) and New England (Klemens 1993), and is the largest freshwater turtle in the Northeastern United States. It has a high tolerance for water pollution and tends to be among our most urban tolerant turtles (Klemens 1993). Although common snapping turtles occur in nearly all freshwater habitats and also in brackish marshes, adults tend to occur more frequently in permanent water bodies and are most abundant in shallow, muddy ones (Klemens 1993, Cook et al. 2007). Although these highly aquatic turtles are common, because they are bottom walkers more than swimmers and they bask in shallow waters along the shore of a pond or wetland rather than haul out like a painted turtle does, they are not as readily observable. Typical of all turtles, their eggs are laid on land. Female common snapping turtles must emerge from wetlands and travel overland in search of nesting areas, generally open, sandy, sparsely vegetated patches (Gibbs et al. 2007). They are often seen crossing roads in late spring to early summer. Females dig nests and deposit eggs in loose sand or soil, and the hatchlings emerge in the late summer or early fall (Ernst et al. 1994).

Snapping turtles have long been considered widespread and abundant in New England (Storer 1840, Allen 1868, Babcock 1919, Cardoza and Mirick 2009). They were common in brooks, ponds, and streams of early 20th century Concord (Ricketson 1911). Because permanent water bodies are more likely to survive urbanization and have increased in some instances through the damming of streams, snapping turtles tend to remain relatively common in urban and suburban areas (Schlauch 1976). Consequently, snapping turtles remained widespread and “probably rather abundant” in the Concord region well into the 20th century, occurring in a greater diversity of habitats than other turtles (Greer et al. 1973). In the 1990’s Massachusetts Herp Atlas project, snapping turtle was the 10th most recorded native species in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²), accounting for 12 of 270 (4.4%) records (Jackson et al. 2010). Surveys of MIMA at this time found snapping turtle populations to be widespread but relatively small, due to a lack of large ponds. A total of seven snapping turtles were recorded from five sites: Concord River-one adult, Cranberry Bog-one adult, Palumbo Pond-one adult, Virginia Road Pond-two sub-adults, and Whittemore Pond-one sub-adult and one adult (Windmiller and Walton 1992).

In the current survey, the common snapping turtle was the most abundant (RA = 53.49%) and widespread turtle at MIMA (FO = 27.03%; Tables 2 and 3). A total of 23 captures involving 22 unique individuals were recorded from 10 sites, seven of which were permanent ponds. The majority of captures (18 or 78.3%) were during turtle trapping surveys, and the remaining five were incidental encounters (Tables 4, 7, 19). The greatest number of captures was at Palumbo Pond (six individuals, 26.1% of the total). Although we recorded more snapping turtles than prior surveys, this is because of greater trapping effort in 2001. In 2001, 428 trapnights at 13 sites produced 18 captures (4.20 captures/100 trapnight). In 1992, 120 trapnights at seven sites produced six captures (5.0 captures/100 trapnights; Windmiller and Walton 1992). In 2001, we trapped six of these seven sites and, for these six sites, 158 trapnights produced eight captures (5.0 captures/100 trapnights). The similarity of trapping capture rates between 1992 and 2001 suggest there has been little change in snapping turtle abundance at MIMA. Moreover, these capture rates are greater than overall capture rates for snapping turtles on Cape Cod (2.4 inds/100 trapnights), although population sizes are much larger on Cape Cod, especially in large wetlands of suitable habitat (Cook et al. 2007).

Two of the 23 snapping turtles recorded in this survey were encountered on roads during nesting season. One was killed on Rt 2A adjacent to Cranberry Bog on 6/18/2001 and the second was encountered alive on Rt2A, adjacent to Meriam Field on 6/20/2001. Because even small increases in adult mortality can lead to population declines (Congdon et al. 1994), road kill may also limit populations of snapping turtles in the Northeast (Gibbs and Shriver 2002). In a comparison between ponds set in low versus high road density landscapes, snapping turtle populations in high road density landscapes had a higher proportion of males, likely because of higher rates of road kill in females on nesting migrations (Steen and Gibbs 2003). At MIMA however, the sex ratio of snapping turtles was slightly female biased (Appendix F), so in spite of the fact that road kill is occurring, there is no evidence it has altered the sex ratios here. Thus, our results suggest that snapping turtles remain a widespread and somewhat common species here, but they are limited to relatively small scattered populations by a lack of large permanent ponds and by road kill.

Painted Turtle (*Chrysemys picta*)

The painted turtle is the only North American turtle whose range extends across the continent, from Southern Canada down through the Pacific northwest, midwest, and the northeast coast to Louisiana, Georgia, and the Carolinas (Ernst et al. 1994). There are four subspecies, with standard English names that describe each subspecies' distribution. The eastern painted turtle has an unmarked yellow plastron and the seams of the central and lateral carapace scutes are aligned, while the midland painted turtle has a variable dark marking on the plastron and alternating seams on the carapacial scutes (Ernst et al. 1994). Hybrid painted turtles are intermediate in these characters and are highly variable both within and among populations. In the Northeast and New England, the eastern painted turtle (*C. p. picta*) and the midland painted turtle (*C. p. marginata*) intergrade, forming a hybrid swarm (Pough and Pough 1968) and it is best referred to simply as "painted turtle".

In addition to a wide geographic distribution, painted turtles are widespread ecologically, occurring in a broad range of freshwater habitats, including vernal ponds. However, they prefer permanent, shallow, standing or slow-moving water bodies with soft bottoms and an abundance of aquatic vegetation (Ernst et al. 1994, Cook et al. 2007, Gibbs et al. 2007). Painted turtles are highly aquatic, feeding and hibernating in ponds. However, they lay their eggs on land and, as with all aquatic turtles, adult females must leave the relative safety of the wetland and travel overland to patches of open habitat with well drained soils to nest.

Painted turtles have long been considered a widespread and abundant turtle in New England (Storer 1840, Allen 1868, Babcock 1919, Cardoza and Mirick 2009) and because of their abundance and habit of basking on rocks, logs, and clumps of vegetation, they are also the region's most familiar and conspicuous turtle (Klemens 1993). They were common in brooks and ponds of early 20th century Concord (Ricketson 1911). Because permanent water bodies are more likely to survive urbanization, and have increased in some instances through the damming of streams, painted turtles tend to remain relatively common in urban and suburban areas (Schlauch 1976). Thus, painted turtles remained common and frequently seen in Concord in the mid-20th century (Greer et al. 1973) and, in the 1990's Massachusetts Herp Atlas project, the painted turtle was the most recorded native species in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²), accounting for 25 of 270 (9.3%) of all records (Jackson et al. 2010). Surveys of MIMA at this time recorded painted turtles in four of 18 wetlands sampled: Concord River – the only large population at MIMA, Palumbo Pond – one adult observed, VC Permanent Pond – one adult observed, and Whittemore Pond – shell of an adult found (Windmiller and Walton 1992). The lack of records from most sites and small numbers recorded were attributed to lack of large ponds (Windmiller and Walton 1992).

In the current survey, the painted turtle was the second most abundant (RA = 44.19%) and second most widespread (FO = 18.92%) turtle at MIMA (Tables 2 and 3). A total of 19 captures involving 17 unique individuals were recorded from seven sites, six of which were pond or stream. The majority of captures (68.4%) were during turtle trapping surveys (Table 7) and the capture rate of painted turtles was slightly less than that of snapping turtles (4.0 captures/100 trap nights versus 4.9; Table 17). The greatest number of captures were at Palumbo Pond (9 individuals, 10 captures, 52.6% of total captures). Although painted turtles appear moderately widespread at MIMA, with the exception of a single painted turtle observed swimming in the Concord River, all records of painted turtles in this survey were from the western end of the Battle Road Unit (Nelson Pond, Palumbo Pond, Ditches, and Field, Mill Brook North, and Irrigation Pond A). One individual was captured initially in Palumbo Ditches and recaptured in Palumbo Pond, suggesting that the painted turtles here use these wetlands in close proximity as a

complex rather than as distinct sites. Movement between nearby ponds is well documented in painted turtles (Zweifel 1989).

Trapping effort in 2001 was greater than in 1992, 428 trap nights versus 120 respectively, yet painted turtles were not recorded in 2001 from Whittemore Pond and VC Permanent Pond, two ponds they were recorded from in 1992 (Windmiller and Walton 1992). Unfortunately, our trapping effort in and around the Concord River, which had the only large population in 1992 (Windmiller and Walton 1992), was minimal in 2001, so comparisons are not possible. In addition, the site where we trapped the greatest numbers of painted turtles in 2001, Palumbo Pond, was not trapped in 1992 (although a painted turtle was recorded). Thus, although we are unable to make direct comparisons of abundance between 1992 and 2001, our results suggest that painted turtles remain locally common, but not as widespread as previously.

Windmiller and Walton (1992) felt that the lack of large permanent ponds at MIMA limited the abundance of painted turtles at MIMA. However, this is not consistent with results from Cape Cod, where density of painted turtles in vernal ponds and shallow permanent kettle ponds was comparable (Cook et al. 2007). Painted turtle populations are negatively affected by some aspects of urbanization, such as road density and increased numbers of subsidized predators such as raccoons, but other factors such as pond substrate, pond vegetation, and proximity of pond to other ponds and nesting areas also influence abundance (Baldwin et al. 2004, Marchand and Litvaitis 2004). The positive relationship between painted turtle abundance and proximity to neighboring ponds and amount of nesting area nearby (Marchand and Litvaitis 2004) may explain the relatively larger numbers of painted turtles in the complex of ponds and ditches at Palumbo farm. With nearby ponds and nesting areas, painted turtles would travel smaller distances overland and be less vulnerable to road kill (Baldwin et al. 2004). Thus, the isolation of most of ponds in the Battle Road Unit may be a factor in the absence of painted turtles from those sites. This might also explain the relatively even sex ratio of painted turtles captured at sites on Palumbo farm (Appendix F), which is contrary to what might be expected, given that sex ratios of turtle populations that reside close to roads are becoming male biased due to differential road kill of females (Steen and Gibbs 2003, Marchand and Litvaitis 2004).

Stinkpot (*Sternotherus odoratus*)

Stinkpots occur throughout most of the Eastern United States, including Southern New England, excluding higher elevations (Ernst et al. 1994, Klemens 1993). They are a highly aquatic species commonly found in slow-moving, muddy-bottomed streams and rivers, and also are abundant in weed-choked, shallow portions of small reservoirs; they are usually absent from temporary ponds and ponds and lakes not directly connected to or near riparian systems (Klemens 1993). Stinkpots are largely nocturnal in their activity patterns, but occasionally bask during daytime hours. Because of their secretive, nocturnal, and aquatic habits, stinkpots go unnoticed in many areas, even where dense populations occur (Klemens 1993, Johnson 2009).

Stinkpots are distributed statewide in Massachusetts with the exception of Dukes and Nantucket Counties (Cardoza and Mirick 2009). They were historically considered widespread and abundant in spite being infrequently seen due to their aquatic habits (Babcock 1919). In the early 20th century, stinkpots were considered common in the Concord River (Ricketson 1911) and they remained so into the mid 20th century, at sites such as Great Meadows (Greer et al. 1973). In the 1990's Massachusetts Herp Atlas project, the stinkpot was tied for the 19th most recorded native species in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²),

accounting for three of 270 (1.1%) of all records (Jackson et al. 2010). During trapping surveys at MIMA during this same time period, roughly 20 trap days of effort at Mill Brook Mouth and in the Concord River caught one stinkpot Mill Brook Mouth (Windmiller and Walton (1992).

No stinkpots were recorded in the current survey. This may be due, in part, to insufficient sampling in appropriate sites/habitats. Considering the stinkpot's affinity for slow moving streams and associated wetlands and the historic occurrence of stinkpots in the Concord river, the absence of stinkpots in the isolated ponds of the Battle Road Unit is not surprising. Moreover, sampling at MIMA sites most likely to be occupied by stinkpots, i.e., Concord River and Mill Brook Mouth, were limited to only eight trap nights and 4.2 search hours at the latter. In retrospect, it was a mistake not to sample this part of the park more extensively.

Stinkpots currently occur at Great Meadows NWR (pers. comm., E. McGourty, Wildlife Biologist, Eastern Massachusetts NWR complex, 1 October 2010) and extensive amounts of impoundment and riparian wetland habitats exist along the Concord-Sudbury-Assabet River in this area. The Concord-Sudbury River, with much of it protected within Great Meadows NWR, may still support a large stinkpot population, but current data on its status in this system do not exist. Because the North Bridge Unit is a relatively small length of the Concord River located between much more extensive lengths of river in the Concord Division of Great Meadows to the north and Sudbury Division to the south, it is likely that the occurrence of stinkpots at MIMA is more a reflection of the status of the regional population of this species than a reflection of conditions at MIMA. With the limited information we have, i.e. a single record of this species at MIMA from 1992, and no records in this study, the stinkpot appears to have become rare by the 1990's and remains so today. However, recent data from a site in Palmer Massachusetts, on an agrarian-residential landscape less developed than the Concord area, show that stinkpots can be quite numerous in Massachusetts (Johnson 2009). Given the elusive nature of this species, further trapping-intensive investigation in the North Bridge Unit is needed to better understand the stinkpot's status in MIMA and in the Concord-Sudbury River in general.

Spotted Turtle (*Clemmys guttata*)

A small semi-aquatic turtle with distinct yellow spots on a black carapace, the spotted turtle occurs along the Atlantic coastal plain, from Maine to Florida, including lower elevation areas of Southern New England (Klemens 1993), and westward into Ohio, Indiana, Illinois, Michigan, and Southeastern Canada (Ernst et al. 1994). Spotted turtles are widespread and occur in a broad range of shallow habitats, both freshwater and slightly saline, including marshes, bogs, red maple swamps, ditches, vernal pools, and small streams (Klemens 1993, Graham 1995). They are considered semi-aquatic, because they may spend a lot of time on land when temporary wetlands dry (Ernst et al. 1994). In the Northeast, spotted turtles typically shift habitats seasonally. They overwinter in bogs and swamps, then shift to vernal pools to take advantage of a seasonal abundance of food. When vernal pools dry up, they may move to uplands and aestivate or return to the wetlands they hibernated in (Gibbs et al. 2007)

Spotted turtles are currently widespread but uncommon in Massachusetts, having been delisted as a "Species of Special Concern" by the Massachusetts Division of Fisheries and Wildlife in 2006 (Cardoza and Mirick 2009). However, historic accounts describe spotted turtles as common to abundant in New England, with authors varying as to whether the spotted turtle was as common as or more common than painted turtles (Storer 1840, Allen 1868, Babcock 1919). Spotted turtles were abundant in brooks in early 20th century Concord (Ricketson 1911) and

appear to have remained so into the mid-20th century (Greer et al. 1973). Yet by this point in time, spotted turtles were declining in some areas of Massachusetts (Lazell 1974). In the 1990's Massachusetts Herp Atlas project, spotted turtles were tied for the 15th most recorded native species, accounting for seven of 270 (2.6%) records in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²) (Jackson et al. 2010). Surveys at this same time at MIMA did not find any spotted turtles, in spite of intense effort to find them (Windmiller and Walton 1992). However, an incidental encounter at Palumbo Pond in 1994 (pers. comm., Bryan Windmiller, independent consultant, 3 March 2011), indicates it was present but apparently rare at this time. Its rarity at MIMA was attributed to a paucity of shrub swamp habitat and the extreme barrier presented by Route 2A and Old Lexington Road (Windmiller and Walton 1992).

In the current survey, only a single spotted turtle was captured (RA = 2.33%, FO = 2.70%) during turtle trapping surveys at Cranberry Bog (Tables 2, 3, and 4). The few records of this species at MIMA suggest that since the late 20th century this species has been rare at MIMA. It is also present at Great Meadows NWR, but no detailed data on its status and distribution there exist (pers. comm., E. McGourty, Wildlife Biologist, Eastern Massachusetts NWR complex, 1 October 2010).

Spotted turtles are not very urban tolerant (Schlauch 1976) and appear to be declining throughout their range, with a number of causes implicated including: habitat fragmentation, wetland drainage, suburban development, invasive wetland plants, road mortality, collection for the pet trade, and increases in predator populations (Levell 2000, Lewis et al. 2004). In Southern New England, spotted turtles have declined and disappeared from some areas due to urbanization, and habitat loss and fragmentation threaten their long term survival in these areas (Klemens 1993). Spotted turtles in central Massachusetts moved 20 to 550 meters through upland habitats in spring to utilize vernal pools (Milam and Melvin 2001). Extensive movements such as these would place spotted turtles at MIMA at risk for road kill and seem to corroborate the earlier assessment of Windmiller and Walton (1992). Thus, although spotted turtle is present at MIMA, it has been rare here since at least the late 20th century. Further investigation of the size, structure, reproductive success, movements, and habitat utilization of spotted turtles in the Park are recommended to better understand its status and long-term prospects.

Blanding's Turtle (*Emydoidea blandingii*)

Blanding's Turtle ranges widely across the upper Mid-west and Northeast into Southeastern Canada. Its main range extends eastward from Iowa through the Southern Great Lakes states and north into Southern Ontario and Southwestern Quebec (Ernst et al. 1994). It also occurs in scattered relict populations in the Southern Hudson River Valley of New York, Eastern Massachusetts north into Southern Maine, and Nova Scotia, with New England populations apparently tied to the drainage basins of the Nashua, Concord, and Merrimack Rivers (Butler 1992, Klemens et al. 1992). The Blanding's turtle is a moderate sized, semi-aquatic turtle species that uses a variety of upland and wetland habitat types, including seasonal pools, marshes, scrub-shrub wetlands and open uplands in Massachusetts (Sievert et al. 2003). Habitat use varies on an individual basis and with precipitation, with more upland habitat use occurring during dry years (Joyal et al. 2001). Individual Blanding's turtles can have large home ranges (up to 63 ha) and may move considerable distances during the active season, some travelling nearly a kilometer overland to nest and as much as 3 km in 14 days (Butler 1992, Grgurovic and Sievert 2005). In Eastern Massachusetts, Blanding's turtle typically engages in seasonal habitat shifts similar to

those of spotted turtles, with long distance movements in spring from overwintering wetlands to vernal ponds to feed on amphibian eggs (Fowle 2001, Grgurovic and Sievert 2005).

Blanding's turtle is a "Threatened" species in Massachusetts and is limited to Bristol, Essex, Middlesex, Norfolk, Plymouth, and Worcester Counties, with older records from Franklin County (Mirick 2009). It has historically been rare and localized in New England, with records limited to Northeastern Massachusetts and Southern New Hampshire (Storer 1840, Babcock 1919). The earliest record in the Concord area was a specimen found in the Concord River by Henry David Thoreau and the publication of a second record, also from the Concord River, in 1911 (Howe 1911), suggests that Blanding's turtles were not often encountered in early 20th century Concord. They remained rare in the Concord area into the mid-20th century, occurring primarily in Great Meadows and "scattered brook systems elsewhere" (Greer et al. 1973). In the 1990's Massachusetts Herp Atlas project, there were three records of Blanding's turtle in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²), two of which were in the Concord Division of Great Meadows NWR (Jackson et al. 2010). Butler (1992) noted that the largest known New England population of Blanding's Turtle was at Fort Devens, approximately 23 km west of MIMA, and the best place to observe them, was at Great Meadows NWR in Concord. Thus, although late 20th century surveys did not record any Blanding's turtles specifically at MIMA (Martinez 1992, Windmiller and Walton 1992), MIMA was in close proximity to and abutted one of Massachusetts's most important sites for this species, Great Meadows.

We did not record any Blanding's turtles in the current survey, but their presence at MIMA has been recently documented through radio-telemetry of individuals initially caught at Great Meadows. In spring 2010, an adult female Blanding's turtle moved from Great Meadows to the Elm Brook system south of Virginia Road. It spent the winter of 2010-2011 in the marshes of Elm Brook that adjoin the Historic Fields, a couple of hundred meters north of the MIMA boundary, on lands owned by the Concord Land Conservation Trust (pers. comm., Bryan Windmiller, independent consultant, 3 March 2011). In June 2011, a second individual, an immature female, moved from the lower impoundment at Great Meadows to wetlands inside MIMA, along the east side of the Historic Fields, in a section of Mill Creek North and near Irrigation Pond B (pers. comm., Bryan Windmiller, independent consultant, 4 July 2011). These records suggest that Blanding's turtle is, and may have long been a rare presence at MIMA, and the habitats here are utilized as a part of the larger regional landscape used by this species.

The complex use of habitats and the movements associated with them make Blanding's turtle vulnerable to road kill in fragmented and developed landscapes. Because of demographic traits that include delayed sexual maturity, high adult survival, and low survival of nests and young, populations of Blanding's turtles are sensitive to this increased mortality (Grgurovic and Sievert 2005). Thus, habitat fragmentation, and resultant road kill has caused the decline of this species throughout much of its range (Beaudry et al. 2010). Although the most robust populations of Blanding's turtles in New England occur in Middlesex county and the Fort Devens area immediately to the west (Butler 1992), ensuring the long term survival of Blanding's turtle on the largely suburbanized landscape of Eastern Massachusetts will be a challenge (Grgurovic and Sievert 2005). MIMA is clearly a relatively small part of this landscape, but the use of wetland habitats in and adjacent to MIMA by Blanding's turtle highlight the important role MIMA plays in helping to support regional biodiversity. MIMA staff should make sure the quality and integrity of park wetlands, especially those between Rt. 2A and Virginia Road are maintained, if

not improved, and ensure that agricultural activities in the Historic Fields are not a threat to turtles that may use the fields to nest. In particular, mowing should be done in the cold season if at all possible and if not blade heights should be at least 7 inches above the surface (MA NHESP 2009). For more details, see Management Recommendation #4 “Minimize Direct Mortality from Mowing Operations”, above.

Northern Black Racer (*Coluber c. constrictor*)

The northern black racer is subspecies of the eastern racer, which is widespread throughout most of the United States, except for the desert southwest (Ernst and Ernst 2003). The northern black racer occurs from the Southern Appalachian Mountains northward, extending to the coastal plain in the mid-Atlantic states and into Southern New York and New England (Conant and Collins 1998). The northern black racer is widespread in Southern New York and Southern New England occurring primarily at relatively low elevations along the coast and in river valleys (Klemens 1993, Gibbs et al. 2007). Black racers occur primarily in landscapes with open habitats and are a large, conspicuously active species with a large home range. It is found in open, dry woodlands, fields, grasslands, along the borders of wetlands, and on barrier islands ((Ernst and Ernst 2003; Kjos and Litvaitis 2001). Large sheets of corrugated sheet metal and plywood are a favorite cover type of this species, along with other debris at the edge of woodlands (Klemens 1993). Juvenile northern black racers have distinct gray/brown or reddish/brown patterning down their bluish/gray back that will disappear as they mature. Adults are satiny black in color with a white throat patch and can reach 5 to 6 feet in length (Conant and Collins 1998). An opportunistic feeder, the racer diet includes a variety of animals such as shrews, voles, birds, small turtles, lizards, anurans, salamanders, and snakes (Ernst and Ernst 2003).

The northern black racer is distributed statewide in Massachusetts with the exception of Nantucket County (Mirick 2009). Historical accounts indicate that racers have at some times and places been abundant (Allen 1868), whereas others considered it “not uncommon” (Storer 1840). In early 20th century Concord, it was “not uncommon, especially about brooks” (Ricketson 1911) and in the mid 20th century it reportedly was “encountered frequently in some years and rarely in others” (Greer et al. 1973). In the 1990’s, there were no records of northern black racer in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km², Jackson et al. 2010), but Windmiller and Walton (1992) report a reliable northern black racer sighting by a MIMA Ranger at Fiske Hill Field. Thus it appears that by the 1990’s, black racers had become rare in and around MIMA, likely due to road kill (Windmiller and Walton 1992).

In the current survey, no black racers were found at MIMA. It is reportedly present at Great Meadows NWR, but no detailed data on its status and distribution there exist (pers. comm., E. McGourty, Wildlife Biologist, Eastern Massachusetts NWR complex, 1 October 2010). Given that this is a large, conspicuous species and, in spite of herp surveys in 1992 and 2001 and a constant presence by MIMA staff, there is only one record of northern black racer at MIMA since 1992, and none elsewhere from the MIMA region during the 1990’s Herp Atlas, it is clear that by the end of the 20th century this species had declined locally to the point of being either extremely rare, and perhaps extirpated from MIMA.

Northern black racers have declined on heavily urbanized landscapes (Schlauch 1976, Klemens 1993) and appear to be declining throughout much of the Northeast. Part of this broader regional decline is in response to the loss of open, early successional habitat, but road kill, habitat fragmentation and reduction in size of suitable habitat patches are also factors (Kjos and

Litvaitis 2001, Mirick 2009). Because they are so active diurnally, have large home ranges, and have low rates of road avoidance and high immobilization response to approaching vehicles (Andrews and Gibbons 2005), black racers are very susceptible to road kill. Thus, although MIMA and its immediate vicinity have a fair amount of open, early succession habitat, the density of roads and volume of traffic on them appear to have greatly reduced, if not eliminated black racers from the area.

Northern Water Snake (*Nerodia s. sipedon*)

The northern water snake is a sub-species of water snake that occurs from the Northeastern United States and Southeastern Canada westward into the mid-west (Conant and Collins 1998). In New York and New England, the northern water snake is widespread and common, occurring both along the coastal plain and inland, although it does not range into high elevations (Klemens 1993, Gibbs et al. 2007). Northern water snakes are primarily aquatic and occur in a broad range of freshwater wetlands, provided that they contain an abundance of cover and food, primarily fish and secondarily amphibians (Ernst and Ernst 2003). They are frequently observed basking on the shore, on rocks, and on branches overhanging the water and occasionally enter brackish water (Conant and Collins 1998, Ernst and Ernst 2003). Similar to the brown snake and garter snake, water snakes give birth to live young rather than laying eggs.

This species is common in Massachusetts and is distributed statewide with the exception of Dukes County (Cardoza and Mirick 2009). Water snakes were historically common to abundant in wet meadows, ponds, streams, and wetlands (Storer 1840, Allen 1868). In early 20th century Concord, it was common in Bateman's Pond (ca. 3 km from MIMA) and also found in brooks (Ricketson 1911). Water snakes remained common in the Concord region in the mid 20th century, "due to the abundance of ideal habitat, i.e. relatively quiet water with some vegetation" (Greer et al. 1973). In the 1990's Massachusetts Herp Atlas project, northern water snake was tied for 11th most recorded native species, accounting for 10 of 270 records in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²) (Jackson et al. 2010). At this same point in time, an adult northern water snake was observed at Whittemore Pond (Windmiller and Walton 1992) and there was another possible sighting near Virginia Road Pond (Hyla Ecological Services 1993). Windmiller and Walton (1992) considered water snakes rare at MIMA, likely due to road kill.

In the current survey, we did not record any water snakes. However a DOR northern water snake was found on Rt2A, adjacent to Cranberry Bog, on 13 August 2004 (pers. comm., Robert Zaremba, Ecologist, NatureServe, 17 August 2004). This indicates that water snakes still occur at MIMA, but have been rare since at least the late 20th century. Water snakes are also reportedly present at Great Meadows NWR, but no detailed data on its status and distribution there exist (pers. comm., E. McGourty, Wildlife Biologist, Eastern Massachusetts NWR complex, 1 October 2010). The northern water snake appears to have declined at MIMA, and road kill and habitat fragmentation have undoubtedly been causal factors. However, the relatively small, scattered wetlands of MIMA may also pre-dispose water snakes here to be more sensitive to those factors, than at a larger site with more continuous wetland habitat.

Eastern Milk Snake (*Lampropeltis t. triangulum*)

The eastern milk snake is a subspecies of the milk snake, which is one of the most widespread species of snakes, ranging from the East and Mid-western U.S.A. down to Ecuador in South

America (Ernst and Ernst 2003). The eastern milk snake occurs from Northern Georgia and Alabama northward to Wisconsin and through the northeastern states into Southern Canada (Conant and Collins 1998). Identifying characters include a “Y” shaped, cream-colored patch on the nape, and a black and white checkerboard pattern on the belly (Conant and Collins 1998). Eastern milk snakes are widespread in the Northeast U.S. and occur both inland and along the coast in habitats ranging from woods, meadows, bogs, streams, and farmland. It is a secretive species most active at night. They are frequently associated with old farm fields, dilapidated structures, and trash piles, and thrive in such human altered habitats (Klemens 1993, Gibbs et al. 2007).

In Southern New England, the eastern milk snake is second in abundance to the common garter snake, occurring in most state parks, forests, game management areas, and private sanctuaries (Klemens 1993). It is common and widespread in Massachusetts (Cardoza and Mirick 2009). Eastern milk snakes were historically considered “not uncommon” (Storer 1840) and they apparently had declined in some parts of Massachusetts by the mid-19th century (Allen 1868). In early 20th century, eastern milk snakes were “common in dry situations” in the Concord area (Ricketson, Jr. 1911), but appear to have been uncommon in the area by the mid-20th century (Greer et al. 1973). In the 1990’s Massachusetts Herp Atlas project, there was only a single record of eastern milk snake in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²) (Jackson et al. 2010). During this same time period, a single adult eastern milk snake was recorded DOR on Route 2A near the MIMA Visitor’s Center (Windmiller and Walton 1992). Windmiller and Walton (1992) considered eastern milk snakes rare at MIMA, likely due to road kill.

In the current survey, two eastern milk snakes were captured during coverboard surveys at Fiske Hill Field (RA = 4.35%, FO = 2.70%; Tables 2, 3, and 4). Our findings suggest that eastern milk snakes have been rare at MIMA since at least the late 20th century. As a species with a large home range, eastern milk snakes are vulnerable to impacts from habitat fragmentation and road kill, and they have declined in some urban areas (Klemens 1993, Kjos and Litvaitis 2001, Ernst and Ernst 2003). Their nocturnal habits make them relatively inconspicuous, which complicates efforts to determine their status. More intensive sampling with coverboards near field edges and around buildings and stone walls is recommended to better understand the status of eastern milk snakes here.

Common Garter Snake (*Thamnophis sirtalis*)

The common garter snake is a species that ranges throughout the United States (except for Texas and the southwest) and all of Southern Canada (Ernst and Ernst 2003). The subspecies found at MIMA, also known as the common garter snake, occurs primarily east of the Mississippi River from Florida northward into New York and Southern New England and also into Canada (Conant and Collins 1998). In New York and Southern New England, common garter snakes are widespread and common, both inland and along the coast, and are the most conspicuous and well known snake in this area (Klemens 1993, Gibbs et al. 2007). Common garter snakes are ubiquitous in New England found in a variety of habitats including meadows, marshes, woodlands, and cultivated and developed areas (Behler and King 1979).

The common garter snake is abundant and widespread in Massachusetts (Lazell 1974, Mirick 2009) and has historically been considered the commonest snake (Storer 1840, Allen 1868). It was abundant in early 20th century Concord (Ricketson 1911) and in the mid-20th century was

still considered the area's most abundant snake (Greer et al. 1973). In the 1990's Massachusetts Herp Atlas project, common garter snakes were the seventh most recorded native species, accounting for 18 of 270 records in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²), including one record within MIMA (Jackson et al. 2010). At this same point in time, common garter snakes were moderately common at MIMA, with records from Fiske Hill (several occasions), Powerline North of Rt2A (several observations), Whittemore Pond (one adult), and South of Virginia Road (two occasions) (Windmiller and Walton 1992).

In the current survey, the common garter snake was the most abundant (RA = 95.65%) and most widespread (FO = 27.03%) of the two snake species recorded at MIMA (Tables 2, 3, and 4). A total of 44 captures involving 41 individuals were recorded from 10 sites, all in the Battle Road Unit, nine of which were in upland habitats. The majority of captures (71%) were during coverboard surveys (Tables 4 and 7). In those surveys, the capture rate of common garter snake was 7.65 captures/100 board checks in field habitat versus 0.78 in woodland, with the Historic Fields and Fiske Hill Field accounting for most captures and highest encounter rates (Table 14).

The present survey suggests that common garter snakes are common and widespread in the Battle Road Unit of MIMA. In fact, the overall coverboard capture rate of common garter snakes at MIMA (4.31/100 board checks) is higher than the capture rates we recorded at eight other National Park Service sites in the Northeast Region where common garter snakes were present, which ranged from 0.28 to 3.8 captures/100 board checks. Our survey also suggests that common garter snakes are more common and widespread at MIMA than reported by Windmiller and Walton (1992), although this difference is most likely due to our greater focus on snakes and use of coverboards.

Because of their generalized food and habitat needs, and live birth of many young, common garter snakes are relatively urban tolerant and able to persist in relatively small habitat patches (Schlauch 1976). Thus they are able to flourish at MIMA, particularly because the two species of local snakes known to prey on other snakes, northern black racer and milk snake (Ernst and Ernst 2003) are not urban tolerant and have declined here. Although there are no records, past or present, from the North Bridge Unit, given the broad tolerances of common garter snakes, it would not be surprising if they were found there too.

Eastern Ribbon Snake (*Thamnophis sauritis*)

The eastern ribbon snake is a subspecies of the common ribbon snake, which ranges throughout most of the Eastern United States, except for most of Appalachia (Ernst and Ernst 2003). The eastern ribbon snake occurs primarily from Southern New England and Southeastern New York state southward through South Carolina and then west into Mississippi and up the Mississippi River valley into Southern Illinois (Conant and Collins 1998). Ribbon snakes feed primarily on amphibians, especially frogs, and are mostly found in freshwater wetlands, particularly grassy or shrubby ones with an open canopy that allows them to bask (Gibbs et al. 2007). They are closely related to, and look very similar to garter snakes, and specimens must be captured and examined carefully to identify correctly (Klemens 1993). On Cape Cod, ribbonsnakes are often observed in the course of springtime fieldwork in open freshwater wetlands (Cook, pers. obs.).

The eastern ribbon snake occurs throughout Massachusetts and is locally common (Mirick 2009). Historic accounts of ribbon snakes in Massachusetts vary, with Storer (1840) considering

it uncommon but Allen (1868) noting it was nearly as common as garter snakes, but restricted to wetlands. Ricketson (1911) considered ribbon snakes uncommon in early 20th century Concord whereas, by mid-century, Greer et al. (1973) noted they were not as common as garter snakes but frequently encountered in wetlands. In the 1990's Massachusetts Herp Atlas project, there were no records of eastern ribbon snake in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km², Jackson et al. 2010), but two were recorded at MIMA in 1992. One juvenile was observed on a power line south of Route 2A, and an adult was observed eating a radio-tagged wood frog at VC Vernal Pond South (Windmiller and Walton 1992).

In the current survey, no eastern ribbon snakes were found at MIMA and it has not been reported from Great Meadows NWR (pers. comm., E. McGourty, Wildlife Biologist, Eastern Massachusetts NWR complex, 1 October 2010). Populations of eastern ribbon snakes are declining over much of their range due to habitat loss and road kill (Ernst and Ernst 2003). Because they are habitat specialists tied to freshwater swamps and marshes with an abundance of anurans, and these habitats are often the first to disappear during urbanization, eastern ribbon snakes have disappeared in urban areas (Schlauch 1976). An additional factor in their decline in Southern New England, may also be loss of open wetlands to successional "reforestation" (Klemens 1993), but this is not likely the cause of their rarity at MIMA. Thus, it would appear that since the late 20th century, eastern ribbon snakes have been rare in and around MIMA and may no longer occur here. If they are still present locally, they are most likely to occur at Great Meadows NWR, which has far more extensive and connected freshwater wetlands than MIMA.

Northern Ringneck Snake (*Diadophis punctatus edwardsii*)

As a species, the northern ringneck snake ranges throughout the Northeastern United States and Southern Canada southward through the mid-west and south-central states and northward along the Pacific coast (Ernst and Ernst 2003). The northern sub-species occupies the northeastern and Appalachian Mountain portion of that range (Conant and Collins 1998). Northern ringneck snakes occur widely in Southern New England from sea level to mountaintops and are variable in abundance (Klemens 1993). It is a small, inconspicuous, primarily nocturnal species, typically found in moist woodlands with abundant cover where it feeds on small salamanders, especially eastern red-backed salamanders and worms (Conant and Collins 1998; Ernst and Ernst 2003).

Early Massachusetts naturalists considered the northern ringneck snake to be a "not uncommon" and retiring species (Storer 1840, Allen 1868). In the early 20th century they were "rather uncommon" in the Concord area (Ricketson 1911) and by the mid-20th century they were "not commonly encountered" in the Concord area (Greer et al. 1973). In the 1990's Massachusetts Herp Atlas project, northern ringneck snake accounted for one of 270 native species records in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km², Jackson et al. 2010). This record, of adults and juveniles was ca. 5 km south of the Battle Road Unit. None were found in surveys of MIMA in the 1990's, possibly because of a lack of moderately large patches of woodlands (Windmiller and Walton 1992).

Although northern ringneck snakes tend to be inconspicuous and are considered "secretive" they are fairly easy to detect using coverboards. At Cape Cod National Seashore, northern ringneck snakes represented 74% of all snake captures under coverboards during a 3-year period, with a capture rate of 0.0121 captures/board check (81 captures/6674 board checks) (R. Cook, unpublished data). During this survey at MIMA, coverboards identical to those used at Cape Cod and deployed in the same fashion were checked 702 times without producing any northern

ringneck snakes. Had the capture rate at MIMA equaled that of Cape Cod, the sampling effort at MIMA would have lead to 8.5 captures. Given these efforts, plus all the log rolling that lead to 70 captures of red-backed salamanders during TCS, there does not appear to be a lack of sampling effort. Thus, the lack of any records at MIMA suggests that northern ringneck snakes do not occur here, or are at best very rare. As with several other secretive snake species, more intensive sampling with coverboards may be needed to better determine their status here.

Species Accounts: Potentially-occurring species never recorded at or adjacent to Minute Man NHP

Blue-spotted Salamander (*Ambystoma laterale*) complex

The blue-spotted salamander ranges west across the Northeast through the Great Lakes states to Minnesota and into Canada, as far north as Hudson's Bay and east through the Maritime Provinces. Across much of this range, which is limited to glaciated areas, the blue spotted salamander hybridizes with the Jefferson salamander (*Ambystoma jeffersonianum*), a species whose range extends south and southwest from Southwestern New England to Southern Indiana and Kentucky (Klemens 1993, Petranks 1998). Hybrids of blue spotted and Jefferson salamanders have been found from Southern Canada (Southern Ontario to the Maritimes) and Northern New England south through New York and New Jersey and the upper Midwestern United States (Lowcock 1989, Bogart and Klemens 1997, 2008).

Hybrids exhibit a wide array of colors and patterns, making visual identification difficult. Recent work by Bogart and Klemens (1997, 2008), based on cellular and molecular techniques, indicates that hybrids occur as unisexual (nearly all female) diploid, triploid, and tetraploid individuals. Most populations are a mix of predominantly unisexual hybrids, mostly triploids, and a relatively small number of diploid, sexual individuals of one or the other species, but never both. Pure diploid populations are uncommon. Populations of hybrids are maintained by breeding between the unisexual hybrids and individuals of one of the diploid sexual species in which the unisexuals steal genetic material from the sexual sperm donors. Based on the dominant alleles and diploid sexual species present, populations in the Northeast are classified as pure diploid *A. jeffersonianum*, pure diploid *A. laterale*, *A. jeffersonianum* complex, and *A. laterale* complex. In Massachusetts, *A. jeffersonianum* complex populations occur west of the Connecticut River, *A. laterale* complex are found in the central and northeastern part of the state, and pure diploid *A. laterale* are found in the southeast, near Rhode Island (Bogart and Klemens 1997, 2008).

Blue-spotted salamanders are among the earliest of spring breeding amphibians and often migrate to ponds when they are still largely covered in ice. Females scatter their eggs, attaching them singly or in small clusters to grass blades, often at the base of tussocks in their breeding wetlands, then leave the pond and return to adjacent woodlands where they spend most of the year (Petranks 1998). Hybrid populations share the ecology and distribution of the parental (diploid) species to which they are genetically closest. In New England, *A. jeffersonianum* breed in vernal ponds and are found primarily in deciduous forests in steep terrain, whereas *A. laterale* prefer wooded swamps in low elevation woodlands and are more tolerant of habitat disturbance (Klemens 1993).

The blue-spotted salamander complex is listed as a "Species of Special Concern" in Massachusetts and is limited to Bristol, Essex, Middlesex, Norfolk, and Eastern Worcester Counties (Cardoza and Mirick 2009). Although there is historical confusion over species identification and taxonomy (e.g. see Dunn 1930), early naturalists considered what we would now call Jefferson's or blue-spotted complex salamanders to be uncommon in Massachusetts (Storer 1840, Allen 1868), whereas Carnegie (1914) simply noted its presence in Concord, MA. By the late 1960's, however, local herpetologists better understood the distinction between Jefferson's and blue-spotted salamanders, and their distributions within the state, as well as best methods to detect them. Thus, Lazell (1968, 1970) reported blue-spotted salamanders and their hybrids from eight towns in Middlesex County, including Concord, Lincoln, Acton, and Sudbury

and Greer et al. (1973) considered blue-spotted salamanders to be generally less common in the Concord region than the abundant spotted salamander. In the 1990's Massachusetts Herp Atlas project, the blue-spotted salamander was the 15th most recorded native species, accounting for 7 of 270 records in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km², Jackson et al. 2010). In the late 1990's, Burne (2000) documented blue-spotted salamanders in 8 of 78 (10%) vernal pools he sampled in the Concord area.

Blue-spotted salamanders were not recorded in any prior surveys at MIMA (Martinez 1992, Thomas 1992, Windmiller and Walton 1992), nor were they recorded in the present one. They do occur at Great Meadows NWR (pers. comm., E. McGourty, Wildlife Biologist, Eastern Massachusetts NWR complex, 1 October 2010), but there are no data on their rarity or abundance. The lack of any records at MIMA suggests that blue-spotted salamanders do not occur here. Reasons for its current absence are uncertain, but may be a combination of it being inherently uncommon, as well as the negative impacts of urbanization discussed previously for the closely related spotted salamander.

Four-toed Salamander (*Hemidactylium scutatum*)

The four-toed salamander ranges over Eastern North America from Nova Scotia and Southern Ontario south to Louisiana and the Florida panhandle, but it is far more continuously distributed in the northern portion of this range (Conant and Collins 1998). It ranges across Southern New York and Southern New England, into Southern Vermont and New Hampshire, and extends north along the coast into Maine (Petranka 1998).

The four-toed salamander gets its common name from the four toes on its hind foot while most salamanders have five toes on each hind foot. As an adult it is a terrestrial species inhabiting woodlands adjacent to swamps, bogs, and wetlands that serve as breeding sites. Females typically mate in the fall and migrate to their nesting wetlands in early spring, while the males remain in the woodlands. Females are frequently found in spring in sphagnum moss "cliffs" overhanging standing water, where they deposit their eggs, often communally, and remain with them until hatching occurs. Upon hatching, the larvae wiggle down through the moist sphagnum and drop into the water below, where they undergo a typical aquatic larval stage and metamorphose in about six weeks (Petranka 1998).

The four-toed salamander is now considered fairly common in Massachusetts and is distributed statewide with possible exception to Suffolk County (Cardoza and Mirick 2009). However, the historic record here is uncertain and reflects the fact that this species has specialized behavior and habitat needs that make it seemingly hard to find (Burgason 1999). The encounter rate of four-toed salamanders under woody cover is relatively low, even next to wetlands where they are present (Cook, unpubl. data) and searching for nests and females within sphagnum hummocks at breeding ponds in early spring appears to be the only efficient survey method (Chalmers 2004, Corser and Dodd 2004). Where they do occur, they are relatively easy for experienced people to find using this method (Cook et al. 2006a). Thus, although none of the early Massachusetts naturalists reported four-toed salamanders (Storer 1840, Allen 1868, Carnegie 1914), Greer et al. (1973) considered this species "rarely seen" but suspected this was due to a lack of search effort. In the 1990's Massachusetts Herp Atlas project, there were no records of four-toed salamanders in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km², Jackson et al. 2010), nor were any recorded in any of the 78 vernal ponds sampled by Burne (2000).

Four-toed salamanders were not recorded in any prior surveys at MIMA (Martinez 1992, Thomas 1992, Windmiller and Walton 1992), nor were they recorded in the present one. They have not been recorded at Great Meadows NWR either (pers. comm., E. McGourty, Wildlife Biologist, Eastern Massachusetts NWR complex, 1 October 2010). As noted above, due to their small size and secretive habits outside of the nesting season, four-toed salamanders go undetected in many locations where they exist. The lack of records of this species at MIMA may be a result of inadequate sampling, but may also reflect a scarcity of appropriate habitat. Searches of sphagnaceous wetlands in May, when females are guarding nests, are needed to more definitely determine the status of this species in the park.

Northern Dusky Salamander (*Desmognathus fuscus*)

The northern dusky salamander is widespread in the Northeast United States, extending south via the Appalachian Mountains (Conant and Collins 1998). This stream salamander is found under rocks and logs in the water and along the edge of cool woodland streams, springs, and seeps, particularly within mature forests. Females typically deposit egg clusters in a scooped out depression under rocks or logs along the edge of a stream, and will brood the eggs for a period of time before they hatch. Larval development takes place in the stream and metamorphosis occurs in 7-11 months (Petranka 1998, Gibbs et al. 2007).

The northern dusky salamander is widely distributed in Southern New England (Klemens 1993), including all but Southeastern Massachusetts (Cardoza and Mirick 2009). Northern dusky salamanders were historically considered rare in Massachusetts (Storer 1840, Allen 1868), although unfamiliarity with the species and how to find it may be factors in those early accounts. In early 20th century Concord, Carnegie (1914) noted they were uncommon in brooks and in mid-century, Greer et al. (1973) considered northern dusky salamanders to be rare in the Concord area. In the 1990's Massachusetts Herp Atlas project, there were no records of northern dusky salamanders in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²; Jackson et al. 2010). Thomas (1992) noted that although common in Massachusetts, northern dusky salamanders were not found at MIMA and suggested that habitat is limited for this species. In spite of extensive search since the 1990's, there are no recent records of northern dusky salamanders from Concord, MA and they are rare in the Concord area, only known to occur on fairly steep hillside seeps in Sudbury and Framingham (pers. comm., Bryan Windmiller, independent consultant, 3 March 2011).

Northern dusky salamanders have declined in many areas of the Northeast (Klemens 1993). Urbanization eliminates springs and seeps that flow into streams, more so than the stream itself, and because of its affinity for these micro-habitats, the northern dusky salamander is more affected by, and less tolerant of urbanization than the northern two-lined salamander (Klemens 1993). Northern dusky salamanders have also declined in non-urban protected areas, such as Acadia National Park, where mercury contamination appears to have driven it to near extirpation (Bank et al. 2006). Although mercury deposition is occurring in the vicinity of MIMA (Chalmers et al. 2005), excessive mercury levels are not considered a problem here (James-Pirri 2009). Thus, the absence of northern dusky salamander at MIMA may be due to a current lack of habitat. However, this may be due, at least in part, to the loss and degradation of stream habitat and water quality due to urbanization (James-Pirri 2009). As best as we can determine, Northern dusky salamanders were historically uncommon in the greater Concord area (Table 20) and have declined to the point of being rare at best, with no modern records at MIMA.

Fowler's Toad (*Anaxyrus fowleri*)

Fowler's toad is widespread in the Eastern U.S., and in the Northeast is found mostly along the coastal plain, extending inland up river valleys (Klemens 1993). Fowler's toads are primarily terrestrial, foraging and hibernating on land and migrating to wetlands to breed. They are habitat specialists found primarily in sparsely vegetated, sandy areas (Breden 1988) and breed in both permanent and temporary freshwater wetlands, avoiding those with a canopy of woody vegetation (Tupper and Cook 2008).

Although considered statewide in distribution in Massachusetts (Cardoza and Mirick 2009), Fowler's toad is primarily a species of the coast and Connecticut River Valley, whose range extended inland in response to forest clearing (Lazell 1976, Klemens 1993). The historic status of Fowler's toad is uncertain because early naturalists (Storer 1840, Allen 1868) did not realize that American and Fowler's toad were two different species and only recognized the former. Their accounts appear to be a composite of the two species, which naturally tended to occupy different habitat types and breed at different times. Where their ranges overlap, these differences tend to separate them locally. However, landscape changes such as colonial-era land clearing helped break down the isolation between these two species and lead to hybridization (Lazell 1976).

Carnegie (1914) recognized both species and considered both common in early 20th century Concord. However, by mid-20th century, Greer et al. (1973) state that none of them have seen it in the Concord Area. In the 1990's Massachusetts Herp Atlas project, there was only a single record of Fowler's toad in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²; Jackson et al. 2010). Burne (2000) did not document any Fowler's toads in the 78 vernal pools he sampled in the Concord area nor were any recorded during surveys at MIMA in this era (Martinez 1992, Thomas 1992, Windmiller and Walton 1992). None were recorded at MIMA in the current survey, nor have any been recorded during anuran calling surveys conducted at Great Meadows National Wildlife Refuge from 2005-2010 (USFWS unpubl. data).

Considering this species' distinctive call which cannot be confused with any other anuran in Eastern Massachusetts, the paucity of modern records in the greater Concord area indicates that Fowler's toad does not occur at MIMA. Although this species was common in early 20th century Concord area (Table 20), it appears to have declined dramatically by the mid-20th century. Fowler's toads have declined in the Northeast due to habitat loss, pesticides (Lazell 1976), and hydrologic alterations (Tupper et al. 2007), and these factors may be at play in Eastern Massachusetts. However, it is also likely that the presence of this species in the Concord area was the result of colonial-era land clearing and their prior abundance here an artifact. Given the re-forestation that has been occurring in Massachusetts since the mid-19th century (Foster et al. 2002) and the fact that American toads have not declined as dramatically in the vicinity of MIMA as Fowler's toads, even though they are also sensitive to pesticides and hydrologic alterations, the decline of Fowler's toad here may be part of a shift back to dominance by species associated with the original forested landscape.

Eastern Box Turtle (*Terrapene c. carolina*)

Eastern box turtles occur from Georgia and Northern Alabama and Mississippi northward into Southern Illinois and eastward (Conant and Collins 1998). In the Northeast and New England, eastern box turtles are largely restricted to the coastal plain and major river valleys and do not

extend far into Northern New England (Klemens 1993). Eastern box turtles hibernate by burrowing down into the soil, and winter mortality may be the most significant natural cause of adult mortality (Ernst et al. 1994). Thus, in the Northeast where eastern box turtles are at their northern range limit, their distribution and abundance correlates with well drained, sandy soils.

The eastern box turtle is a terrestrial species that typically occurs in areas that are a mix of woodland and open habitat. Habitat diversity provides the ability to shift habitats seasonally in response to changes in temperature and humidity (Reagan 1974), and, as with all turtles, well drained open habitats provide nesting sites. This long-lived species is known to live more than a century (Graham and Hutchison 1969). Eastern box turtles are frequently found foraging following spring and summer rains, and they will feed on slugs, fruits, vegetation and carrion. The terrestrial nature of eastern box turtles results in their being more widely dispersed across the landscape than aquatic amphibians and reptiles. They often engage in seasonal movements for nesting, hibernation, or feeding, and some individuals are transients that do not establish home ranges (Dodd 2001). All this movement across the landscape places eastern box turtles at relatively greater risk of becoming road kill (Gibbs and Shriver 2002) or being collected for a pet in urban areas, which, in conjunction with their late maturity and low rate of reproduction, make their populations unable to sustain the heavy adult mortality typical in urban areas. Thus, eastern box turtle populations do not fare well on the highly fragmented landscapes found in urban/suburban areas (Schlauch 1976, Mitchell and Klemens 2000) and are declining in many parts of their range (Dodd 2001).

Eastern box turtles were historically considered widespread and common in Massachusetts (Storer 1840, Allen 1868), but more recent analysis indicates their distribution was more restricted, encompassing approximately 38% of the state (Erb 2011). Eastern box turtles historically were continuously distributed in Southeastern Massachusetts-Cape Cod and the Connecticut River Valley, patchily distributed in the northeast (Essex and Middlesex Counties), and essentially absent from the Berkshires and central Massachusetts (Willey 2009). They were rare in early 20th century Concord (Ricketson 1911) and Greer et al. (1973) also considered them rare and local in Concord. In the 1990's Massachusetts Herp Atlas project, eastern box turtle accounted for three of 270 records (1.1%) in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km²; Jackson et al. 2010) No eastern box turtles were recorded in prior surveys at MIMA (Windmiller and Walton 1992), nor were any recorded in the present survey or at Great Meadows NWR (pers. comm., E. McGourty, Wildlife Biologist, Eastern Massachusetts NWR complex, 1 October 2010).

The eastern box turtle is a very familiar species whose movements, especially when crossing roads, make its presence in an area fairly conspicuous, so the lack of any records at MIMA suggests it is absent here or extremely rare. Moreover, there are relatively few modern records of eastern box turtle in Concord and adjoining towns (Willey 2009). The eastern box turtle is listed as a Species of Special Concern in Massachusetts, where land use changes have resulted in the loss of over 1/3 of its estimated historic range and fragmented much of what still remains (Erb 2011). Thus, although MIMA lies close to the species' northern range limit and eastern box turtles naturally occurred in this area in low population densities, it is also clear that habitat fragmentation and road kill have led to their decline in and around MIMA (Willey 2009, Erb 2011).

Wood Turtle (*Gleptemys insculpta*)

The wood turtle occurs in Southeastern Canada, the Northeast United States and northern regions of the Midwestern United States (Conant and Collins 1998). In the Northeast it is largely absent from coastal and pine barren habitats (Klemens 1993). It is a semi-aquatic stream-dependant species, spending the majority of the fall and winter months hibernating along deep pools, under overhanging root masses or logs. After emerging from hibernation it spends the spring in and along the stream, but may move into adjacent terrestrial habitats in the summer months to nest and feed (Ernst et al. 1994). In Massachusetts it prefers slow moving, mid-sized streams with sandy bottoms and heavily vegetated banks (MA NHESP 2007). Wood turtles are capable of long-distance movements, which generally follow stream and river courses (Castellano et al. 2009).

Early naturalists considered the wood turtle to be fairly common and widespread in Massachusetts (Storer 1840, Allen 1868). In 1857, Henry David Thoreau reported seeing 13 individuals along the shore of a temporary pond in Concord (Greer et al. 1973) and about this same point in time in Lancaster, MA (ca. 30 km west of MIMA), over 100 were collected by a few people in an afternoon (Babcock 1919). Wood turtles remained abundant into the early 20th century and were “common in the brooks” in the Concord area (Ricketson 1911). However by the mid-20th century, their decline in the Concord region was apparent and encounters with them had become infrequent (Greer et al. 1973). In the 1990’s Massachusetts Herp Atlas project, wood turtle accounted for three of 270 (1.1%) native species records in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km², Jackson et al. 2010). No wood turtles were recorded in prior surveys at MIMA (Windmiller and Walton 1992), nor were any recorded in the present survey or have they been recorded at Great Meadows NWR (USFWS 2005).

Wood turtles are considered one of the most endangered freshwater turtles of North America and are a Species of Special Concern in Massachusetts. Threats include dam construction, agriculture, hay mowing, development of stream banks, road kill, pet collection, and inflated rates of predation in suburban and urban areas (MA NHESP 2007, Castellano et al. 2009). Similar to Blanding’s and box turtle, demographic traits such as delayed sexual maturity, high adult survival, and low survival of nests and young, make populations of wood turtles very sensitive to human caused increases in mortality (MA NHESP 2007).

Wood turtles have clearly declined in the Concord region over the course of the 20th century. Given their preference for mid-sized streams, it is likely they once occurred in the Concord River and Mill Brook Mouth in the North Bridge Unit, whereas the sections of Mill Brook and Elm Brook in the Battle Road Unit would not have been as suitable. Although some of the stream habitat at MIMA still appears suitable for wood turtles, viable populations require unpolluted, undeveloped rivers set within large, unfragmented riparian areas (Compton et al. 2002). This type of landscape no longer exists at MIMA.

Smooth Green Snake (*Liochlorophis vernalis*)

The smooth green snake occurs primarily from Southern Canada through the Northeastern and upper Mid-western United States with many scattered disjunct populations further west (Conant and Collins 1998). It occurs throughout most of New York State (Gibbs et al. 2007) and New England, although in New England it is now most common in coastal areas (Klemens 1993). It occurs statewide in Massachusetts (Mirick 2009). Smooth green snakes occur in a variety of

open, unforested habitats and open woodlands and feed exclusively on arthropods, such as spiders and various insects (Klemens 1993, Ernst and Ernst 2003).

Smooth green snakes were historically considered common in Massachusetts (Storer 1840) although Allen (1868) noted they were less common than formerly. They were “fairly common” in early 20th century Concord (Ricketson 1911) and they remained locally common in open fields and clearings into the mid-20th century (Greer et al. 1973). In the 1990’s Massachusetts Herp Atlas project, there were no records of smooth green snakes in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km², Jackson et al. 2010) nor were any recorded at MIMA at this time (Windmiller and Walton 1992). There were no records of smooth green snake in the present survey nor have they been recorded at Great Meadows NWR (USFWS 2005).

In New England, smooth green snakes are believed to have expanded in distribution and abundance due to agricultural clearing during colonial times, but have been in a general decline during the second half of the 20th century (Mirick 2009). Part of this decline is a return to their pre-colonial status, as woodlands returned following agricultural abandonment in the 19th century. However, pesticides, which affect them directly and by eliminating their arthropod prey, and habitat loss to urban and suburban development, are also factors in their decline (Klemens 1993). It is likely that all these factors have contributed to the decline of smooth green snakes in the vicinity of Concord. However, considering the amount of field habitat present, it is hard to ascribe their absence from MIMA to a lack of grassy habitat and, as noted for other snake species, more intensive sampling is needed to better determine if this species is truly absent from MIMA.

Northern Brown Snake (*Storeria d. dekayi*)

The brown snake is a species that ranges throughout most of the eastern half of the United States and into Eastern Mexico (Ernst and Ernst 2003). The sub-species found in Massachusetts, the northern brown snake, occurs from South Carolina northward into central New England, southern Canada, and westward to lower Michigan and Ohio (Conant and Collins 1998). It is widespread throughout New York and New England (Klemens 1993, Gibbs et al. 2007). Northern brown snakes are widespread and common throughout Massachusetts and occur in a broad range of habitats, from woodlands to grasslands and other open, disturbed habitats, where they feed primarily on worms and slugs (Mirick 2009).

Northern brown snakes were historically considered common in Massachusetts (Storer 1840, Allen 1868). In the early 20th century they were “common under flat stones” in the Concord area (Ricketson 1911) and they remained common in the region into the mid-20th century (Greer et al. 1973). In the 1990’s Massachusetts Herp Atlas project, northern brown snakes accounted for three of 270 (1.1%) native species records in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km², Jackson et al. 2010). None were recorded at MIMA in prior surveys (Windmiller and Walton 1992) nor were any recorded in the present. They are present at Great Meadows NWR (pers. comm., E. McGourty, Wildlife Biologist, Eastern Massachusetts NWR complex, 1 October 2010), but there are no data on population size or density.

Considering that northern brown snakes are readily detected under cover objects, the lack of any records under coverboards at MIMA suggests that northern brown snakes may not occur here. Reasons for their absence are unclear, given their well known urban tolerance and ability to

persist in small habitat patches (Schlauch 1976, Klemens 1993). Its seeming rarity in the Concord region is also hard to explain, although behaviorally they are inconspicuous and may be under-represented in Herp Atlas records. As noted for other snake species, more intensive sampling would better determine if northern brown snakes are truly absent from MIMA.

Northern Red-bellied Snake (*Storeria o. occipitomaculata*)

The northern red-bellied snake is widely distributed over most of the Eastern United States, extending north into Southern Canada (Conant and Collins 1998). In Southern New England, they are more frequently found in upland areas than at low elevation sites near the coast. In these uplands, northern red-bellied snakes tend to replace northern brown snake, except in disturbed habitats (Klemens 1993). Northern red-bellied snakes are found throughout most of Massachusetts and can be locally abundant at some sites and absent from seemingly similar sites nearby (Mirick 2009). It occurs predominately in moist woodlands and is fairly secretive, hiding under rocks or logs and within rotten logs (Ernst and Ernst 2003).

Accounts from early naturalists suggest that the northern red-bellied snake was moderately common in mid-19th century Massachusetts (Storer 1840, Allen 1868). However, in the early 20th century it was “rather uncommon” in the Concord area (Ricketson 1911) and by mid-20th century, it was “one of the rarest snakes in the area” (Greer et al. 1973). In the 1990’s Massachusetts Herp Atlas project, northern red-bellied snake accounted for two of 270 (0.7%) native species records in the nine Herp Atlas quads centered on MIMA (an area of approximately 1,350 km², Jackson et al. 2010). None were recorded at MIMA in prior surveys (Windmiller and Walton 1992) nor were any recorded in the present. They are present at Great Meadows NWR (pers. comm., E. McGourty, Wildlife Biologist, Eastern Massachusetts NWR complex, 1 October 2010), but there are no data on population size or density.

The propensity of this species in Southern New England for wooded upland sites above 500 ft elevation (Dunn 1930, Klemens 1993) may explain its historic and present rarity in the Concord region. In addition, its presence at MIMA may be limited by a lack of large patches of woodlands (Windmiller and Walton 1992). Thus, MIMA appears to be a marginal site for this species and it is rare at best and quite possibly absent. As with the smooth green snake and the northern brown snake, more intensive sampling may be needed to better confirm its status.

Literature Cited

- Adams, M. J. 1999. Correlated factors in amphibian decline: Exotic species and habitat change in western Washington. *Journal of Wildlife Management* 63:1162-1171.
- Albright, J. 1999. Bullfrog. In: Hunter, M. L., A. J. K Calhoun., and M. McCollough. *Maine Amphibians and Reptiles*. The University of Maine Press, Orono, ME. pp. 90-93.
- Allen, J.A. 1868. Catalogue of the reptiles and batrachians found in the vicinity of Springfield, Massachusetts, with notices of all the other species known to inhabit the state. *Proceedings of the Boston Society of Natural History* 12:171-204.
- Andrews, K.M. and J.W. Gibbons. 2005. How do highways influence snake movement? Behavioral responses to roads and vehicles. *Copeia* 4:772-782.
- Andrews, K.M, J.W. Gibbons, and D.M. Jochimsen. 2008. Ecological effects of roads on amphibians and reptiles: A literature Review. *Urban Herpetology*. J.C. Mitchell, R.E. Jung Brown and B. Bartholomew, editors *Herpetological Conservation* 3:121-143. Society for the Study of Amphibians and Reptiles.
- August, P., C. LaBash, and I. Keniski. 1992. Ecological reconnaissance of the Minuteman National Historical Park. Unpublished report to the National Park Service, Minuteman National Historical Park Natural Resource Files. National Park Service. Concord, MA.
- Babbitt, K.J., M.J. Baber, and T.L Tarr, 2003. Patterns of larval amphibian distribution along a wetland gradient. *Canadian Journal of Zoology* 81:1539-1552.
- Babcock, H.L. 1919. The turtles of New England. *Memoirs of the Boston Society of Natural History* 8(3):325-431.
- Baldwin, E.A., M.N. Marchand, and J.A. Litvitis. 2004. Terrestrial habitat use by nesting painted turtles in landscapes with different levels of fragmentation. *Northeastern Naturalist* 11: 41-48.
- Baldwin, R.F., A.J.K. Calhoun, and P.G. DeMaynadier. 2006. Conservation planning for amphibian species with complex habitat requirements: A case study using movements and habitat selection of the Wood Frog *Rana sylvatica*. *Journal of Herpetology* 40:442-453.
- Bank, M. S., C. S. Loftin, and R. E. Jung. 2005. Mercury bioaccumulation in northern two-lined salamanders from streams in the northeastern United States. *Ecotoxicology* 14:181-191.
- Bank, M. S., J. B. Crocker, S. Davis, D. K. Brotherton, R. Cook, J. Behler, and B. Connery. 2006. Population decline of northern dusky salamanders at Acadia National Park, Maine, USA. *Biological Conservation* 130:230-238.

- Bank, M. S., J. Crocker, B. Connery, and A. Amirbahman. 2007. Mercury bioaccumulation in green frog (*Rana clamitans*) and bullfrog (*Rana catesbeiana*) from Acadia National Park, Maine, USA. *Environmental Toxicology and Chemistry* 26:118-125.
- Beaudry, F., P.G. DeMaynadier, and M.L. Hunter. 2010. Identifying hot moments in road-mortality risk for freshwater turtles. *Journal of Wildlife Management* 74(1):152-159.
- Behler, J. L., and F. W. King. 1979. The Audubon Society Field Guide to North American Reptiles and Amphibians. Alfred A. Knopf, NY.
- Berven K.A. 1990. Factors affecting population fluctuation in larval and adult stages of the wood frog (*Rana sylvatica*). *Ecology* 71:1599-1608.
- Berven, K. A., and T. A. Grudzien. 1990. Dispersal in the wood frog (*Rana sylvatica*): implications for genetic population structure. *Evolution* 44:2047-2056.
- Blaustein, A. R. 1994. Chicken little or Nero's fiddle? A perspective on declining amphibian populations. *Herpetologica* 50:85-97.
- Blaustein, A. R., P. D. Hoffman, D. G. Hokit, J. M. Kiesecker, S. C. Walls, and J. B. Hays. 1994. UV repair and resistance to solar UV-B in amphibian eggs: a link to population declines? *Proceedings of the National Academy of Sciences*. 91:1791-1795.
- Bogart, J. P. and M. W. Klemens. 1997. Hybrids and genetic interactions of mole salamanders (*Ambystoma jeffersonianum* and *A. laterale*) (Amphibia: Caudata) in New York and New England. *American Museum Novitates* 3218:1-78.
- Bogart, J. P. and M. W. Klemens. 2008. Additional distributional records of *Ambystoma laterale*, *A. jeffersonianum* (Amphibia: Caudata) and their unisexual kleptogens in northeastern North America. *American Museum Novitates*. 3627:1-58.
- Breden, F. 1988. The natural history and ecology of Fowler's toad, *Bufo woodhousei fowleri* (Amphibia: Bufonidae) in the Indiana Dunes National Lakeshore. *Fieldiana Zoology* 49:1-16.
- Brotherton, D.K., R.P. Cook, and J.L. Behler. 2005a. Weir Farm National Historical Park, Amphibian and Reptile Inventory, March-September 2000. Technical Report NPS/NER/NRTR-2005/029. National Park Service. Boston, MA.
- Brotherton, D.K., J.L. Behler, and R.P. Cook. 2005b. Acadia National Park, Amphibian and Reptile Inventory, March-September 2001. Technical Report NPS/NER/NRTR-2005-007. National Park Service, Woodstock, VT.
- Brotherton, D.K., J.L. Behler, and R.P. Cook. 2005c. Morristown National Historical Park, Amphibian and Reptile Inventory, March-September 2000. Technical Report NPS/NER/NRTR-2005-013. National Park Service, Woodstock, VT.

- Burgason, B. N. 1999. Four-toed salamander. In: Hunter, M. L., A. J. K Calhoun, and M. McCollough. Maine Amphibians and Reptiles. The University of Maine Press, Orono, ME. pp. 62-65.
- Burne, M.R. 2000. Conservation of vernal pool-breeding amphibian communities: habitat and landscape associations with community richness. M.S. Thesis. University of Massachusetts, Amherst. 59 pp.
- Burton, T. M., and G. E. Likens. 1975. Salamander populations and biomass in the Hubbard Brook Experimental Forest, New Hampshire. *Copeia* 3:541-546.
- Bury, R. B., and M. G. Raphael. 1983. Inventory methods for amphibians and reptiles. In: J. F. Bell and T. Atterbury (eds.), Renewable Resources Inventories for Monitoring Changes and Trends. Oregon State University, Corvallis, OR. pp. 416-419.
- Butler, B. 1992. Bay State Blanding's Turtles. *Massachusetts Wildlife* 42(3):17-25.
- Byers, D. L. and J. C. Mitchell. 2005. Sprawl and species with limited dispersal abilities. In: E. A. Johnson and M. W. Klemens (eds.), *Nature in Fragments: The Legacy of Sprawl*, pp. 157-180. Columbia University Press, New York, NY.
- Cagle, F. R. 1939. A system of marking turtles for future identification. *Copeia* 1939:170-173.
- Cardoza, J. E. and P. G. Mirick. 2009. State Reptiles and Amphibians List. 3rd ed.2000, Revised 2009. Fauna of Massachusetts Series No. 3, Massachusetts Division of Fisheries and Wildlife. http://www.mass.gov/dfwle/dfw/wildlife/facts/reptiles/herp_list.htm#list Last accessed 24 January 2011.
- Carnegie, T.M. III. 1914. A list of Batrachia collected at Concord, Massachusetts. *Proceedings of the Thoreau Museum of Natural History*. Middlesex School, Concord, MA 1:14-15.
- Carr, L.W. and L. Fahrig. 2000. Effect of road traffic on two amphibian species of differing vagility. *Conservation Biology* 15: 1071-1078.
- Castellano, C.M., J.L. Behler, and G. Amato. 2009. Genetic diversity and population genetic structure of the Wood Turtle (*Glyptemys insculpta*) at Delaware Water Gap National Recreation Area, USA. *Conservation Genetics* 10:1783-1788.
- Chalmers, R. J. 2004. Wetland and nest scale habitat use by the four-toed salamander (*Hemidactylium scutatum*) in Maine, and a comparison of survey methods. M.S. thesis, University of Maine, Orono.
- Chalmers, A., M. A. Nilles, D. P. Krabbenhoft, and E. Prestbo. 2005. Analysis of mercury wet-deposition data collected with a newly designed sampler, Boston, Massachusetts Metropolitan Area, 2002–04: U.S. Geological Survey Open-File Report 2005–1368, 17 p.

- Clark, P.J., J.M. Redd, B.G. Tavernia, B.S. Windmiller, and J.V. Regosin. 2008. Urbanization effects on spotted salamander and wood frog presence and abundance. Urban Herpetology. J.C. Mitchell, R.E. Jung Brown and B. Bartholomew, editors Herpetological Conservation 3:67-75. Society for the Study of Amphibians and Reptiles.
- Compton, B.W., J.M. Rhymer, and M.M. McCollough. 2002. Habitat selection by wood turtles (*Clemmys insculpta*): An application of paired logistic regression. Ecology 83:833-843.
- Conant, R. and J. T. Collins. 1998. A Field Guide to Reptile and Amphibians: Eastern and Central North America. 3rd Edition Expanded. Boston: Houghton Mifflin Co.
- Congdon, J. D., Breitenbach, G. L., van Loben Sels, R. C., and Tinkle, D. W. 1987. Reproduction and nesting ecology of snapping turtles (*Chelydra serpentina*) in southeastern Michigan. Herpetologica 43:39-54.
- Congdon, J. D., S. W. Gotte, and R. W. McDiarmid. 1992. Ontogenetic changes in habitat use by juvenile turtles, *Chelydra serpentina* and *Chrysemys picta*. Canadian Field Naturalist 106:241-248.
- Congdon, J.D., A.E. Dunham, and R.C. van Loben Sels. 1994. Demographics of common snapping turtles (*Chelydra serpentina*): Implications for conservation and management of long-lived organisms. Amer. Zool. 34: 397-408.
- Cook, R. P. 1978. Effects of acid precipitation on embryonic mortality of spotted salamanders (*Ambystoma maculatum*) and Jefferson salamanders (*Ambystoma jeffersonianum*) in the Connecticut Valley of Massachusetts. MS Thesis, University of Massachusetts, Amherst.
- Cook, R. P., J. Portnoy, D. Murphy, M. Schult, A. Goodstine, and L. Bratz. 2006a. Preliminary report on the distribution and abundance of four-toed salamanders (*Hemidactylum scutatum*) at Cape Cod National Seashore, with emphasis on the Herring River drainage. Technical Report, Long-term Coastal Ecosystem Monitoring Program, Cape Cod National Seashore, Wellfleet, MA.
- Cook, R. P., M. Schult, A. Goodstine, and G. Radik. 2006b. Monitoring of pond breeding amphibians at Cape Cod National Seashore, 2005. Technical Report, Long-term Coastal Ecosystem Monitoring Program, Cape Cod National Seashore, Wellfleet, MA.
- Cook, R. P., K. M. Boland, S. J. Kot, J. Borgmeyer, and M. Schult. 2007. Inventory of aquatic turtles at Cape Cod National Seashore with recommendations for long term monitoring. Technical Report NPS/NER/NRTR-2007/091. National Park Service, Boston, Massachusetts.
- Cook, R.P., D.K. Brotherton, and J.L. Behler. 2008. Saint-Gaudens National Historical Park, Amphibian and Reptile Inventory, March-September 2001. Technical Report NPS/NER/NRTR-2008-120. National Park Service, Woodstock, VT.

- Cook, R. P., D. K. Brotherton, and J. L. Behler. 2010a. Inventory of Amphibians and Reptiles at the William Floyd Estate, Fire Island National Seashore. Natural Resource Technical Report NPS/NCBN/NRTR—2010/380 National Park Service, Fort Collins, Colorado.
- Cook, R. P., D. K. Brotherton, and J. L. Behler. 2010b. Saugus Iron Works National Historic Site amphibian and reptile inventory: March – September 2001. Natural Resource Report NPS/NETN/NRR—2010/248. National Park Service, Fort Collins, Colorado.
- Cook, R. P., D. K. Brotherton, B. Timm, and J. L. Behler. 2011a. Inventory of Amphibians and Reptiles at Saratoga National Historic Site. Natural Resource Technical Report NPS/NCBN/NRTR—201X/XXX National Park Service, Fort Collins, Colorado.
- Cook, R.P., T. Tupper, P.W.C. Paton, and B. Timm. 2011b. Effects of temperature and temporal factors on anuran detection probabilities at Cape Cod National Seashore: Implications for Long-Term Monitoring. *Herpetological Conservation and Biology* 6(2):25-39.
- Corser, J. D., and C. K. Dodd. 2004. Fluctuations in a meta-population of nesting four-toed salamanders, *Hemidactylium scutatum*, in the Great Smoky Mountains National Park, USA, 1999-2003. *Natural Areas Journal* 24:135-140.
- Crouch, W. B. and P. W. C. Paton. 2000. Using egg mass counts to monitor wood frog populations. *Wildlife Society Bulletin* 28:895-901.
- Crouch, W. B. and P. W. C. Paton. 2002. Assessing the use of call surveys to monitor breeding anurans in Rhode Island. *Journal of Herpetology* 36:185-192.
- Cushman, S.A. 2006. Effects of habitat loss and fragmentation on amphibians: A review and prospectus. *Biological Conservation* 128:231-240.
- Daszak, P., L. Berger, A. A. Cunningham, A. D. Hyatt, D. E. Green, and R. Speare. 2000. Emerging Infectious Diseases and Amphibian Population Declines. *Center for Disease Control*. Vol. 5, No. 6.
- Dodd, C. K. 2001. North American Box Turtles: A Natural History. Univ. of Oklahoma Press. Norman, OK.
- Dunn, E.R. 1930. Reptiles and amphibians of Northampton and vicinity. *Bulletin of the Boston Society of Natural History* 57:3-8.
- Dunson, W. A., R. L. Wyman, and E. S. Corbett. 1992. A symposium on amphibian declines and habitat acidification. *Journal of Herpetology* 26:349-352.
- Egan, R.S. and P.W.C. Paton. 2004. Within-pond parameters affecting oviposition by wood frogs and spotted salamanders. *Wetlands* 24(1):1-13.
- Egan, R.S. and P.W.C. Paton. 2008. Multiple scale habitat characteristics of pond-breeding amphibians across a rural-urban gradient. *Urban Herpetology*. J.C. Mitchell, R.E. Jung

- Brown and B. Bartholomew, editors *Herpetological Conservation* 3:53-65. Society for the Study of Amphibians and Reptiles.
- Eigenbrod, F., S.J. Hecnar, and L. Fahrig. 2008. The relative effects of road traffic and forest cover on anuran populations. *Biological Conservation* 141:35-46.
- Erb, L. 2011. Eastern Box Turtle Conservation Plan For Massachusetts. Massachusetts Division of Fisheries & Wildlife, Natural Heritage & Endangered Species Program. Westborough, MA.
- Ernst, C. H., J. E. Lovich, and R. W. Barbour. 1994. *Turtles of the United States and Canada*. Smithsonian Institution Press, Washington DC.
- Ernst, C. H. and E. M. Ernst. 2003. *Snakes of the United States and Canada*. Smithsonian Institution Press, Washington DC.
- Farris, C. N. and K. Chapman. Not dated. Level I water quality inventory – Minute Man NHP. National Park Service, Northeast Field Area, New England Support Office (NESO).
- Foster, D.R., G. Motzkin, D. Bernardos, and J. Cardoza. 2002. Wildlife dynamics in the changing New England landscape. *Journal of Biogeography* 29:1337-1357.
- Fowle, S. 2001. Guidelines for protecting Blanding's turtles and their habitats in Massachusetts. Natural Heritage and Endangered Species Program. Massachusetts Division of Fisheries and Wildlife, Westborough, MA.
- Gagne, S.A. and L. Fahrig. 2007. Effect of landscape context on anuran communities in breeding ponds in the National Capital Region, Canada. *Landscape Ecology* 22:205-215.
- Germaine, S. S., and B. F. Wakeling. 2001. Lizard species distributions and habitat occupation along an urban gradient in Tucson, Arizona, USA. *Biological Conservation* 97:229-237.
- Gibbs, J. P. 1998. Distribution of woodland amphibians along a forest fragmentation gradient. *Landscape Ecology* 13:263-268.
- Gibbs, J. P. and W. G. Shriver. 2002. Estimating the effects of road mortality on turtle populations. *Conservation Biology* 16:1647-1652.
- Gibbs, J. P., K. K. Whiteleather, and F. W. Schueler. 2005. Changes in frog and toad populations over 30 years in New York State. *Ecological Applications* 15(4): 1148-1157.
- Gibbs, J. P., A. R. Breisch, P. K. Ducey, G. Johnson, J. L. Behler, and R. C. Bothner. 2007. *The amphibians and reptiles of New York State*. Oxford University Press, NY.
- Godfrey, P. J., M. D. Mattson, M. F. Walk, P. A. Kerr, O.T. Zajicek and A. Ruby III.

1996. The Massachusetts acid rain monitoring project: Ten years of monitoring Massachusetts lakes and streams with volunteers. Publication 171. Water Resources Research Center, University of Massachusetts, Amherst, Massachusetts. 307 pp.
- Graham, T.E. 1995. Habitat use and population parameters of the spotted turtle, *Clemmys guttata*, a species of special concern in Massachusetts. *Chelonian Conservation and Biology*. 1: 207-214.
- Graham, T.E., and V.H. Hutchison. 1969. Centenarian box turtles. *International Turtle and Tortoise Society Journal* 3(3):25-29.
- Grant, B. W., A. D. Tucker, J. E. Lovich, A. M. Mills, P. M. Dixon and J. W. Gibbons. 1992. The use of coverboards in estimating patterns of reptile and amphibian biodiversity. In: D. R. McCullough and R. H. Barrett (eds.). *Wildlife 2001: Populations*, pp. 379-403. Elsevier Science Publication, Inc. London, England.
- Greer, A.E., Jr., T.S. Doyle, and P. Arnold. 1973. An annotated checklist of the amphibians and reptiles of Concord, Carlisle, and Bedford, Massachusetts. Harvard University, Cambridge, Massachusetts. Concord Field Station, Guide to Resources No. 4, 22pp.
- Grgurovic, M., and P. R. Sievert. 2005. Movement patterns of Blanding's turtles (*Emydoidea blandingii*) in the suburban landscape of eastern Massachusetts. *Urban Ecosystems* 8:201-211.
- Guerry, A.D. and M.L. Hunter, Jr. 2002. Amphibian distributions in a landscape of forests and agriculture: an examination of landscape composition and configuration. *Conservation Biology* 16: 45-754.
- Hager, H. A. 1998. Area-sensitivity of reptiles and amphibians: are there indicator species for habitat fragmentation? *Ecoscience* 5:139-147.
- Harless, M., and H. Morlock. 1989. *Turtles: Perspectives and Research*. Robert E. Krieger Publishing Company, Inc. Malabar, FL.
- Healy, W. R. 1974. Population consequences of alternative life histories in *Notophthalmus v. viridescens*. *Copeia* 1974:221-229.
- Herrmann, H.L., K.J. Babbitt, M.J. Baber, and R.G. Congalton. 2005. Effects of landscape characteristics on amphibian distribution in a forest-dominated landscape. *Biological Conservation* 123: 139-149.
- Heyer, R. W., M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, M. S. Foster. 1994. *Measuring and Monitoring Biological Diversity – Standard Methods for Amphibians*. Smithsonian Institution Press, Washington DC.

- Hinshaw, S. 1999. Northern leopard frog. In: Hunter, M. L., A. J. K Calhoun, and M. McCollough. Maine Amphibians and Reptiles. The University of Maine Press, Orono, ME. pp. 101-106.
- Homan, R. N., B. S. Windmiller, and J. M. Reed. 2004. Critical thresholds associated with habitat loss for two vernal pool-breeding amphibians. *Ecological Applications* 14:1547-1553.
- Howe, R.H. Jr. 1911. The second record for Blanding's turtle in Concord, Mass. *Science* 34:272.
- Hurlbert, S. H. 1970. Predator responses to the vermilion-spotted newt (*Notophthalmus viridescens*). *Journal of Herpetology* 4:47-55.
- Husting, E. L. 1965. Survival and breeding structure in a population of *Ambystoma maculatum*. *Copeia* 1965:352-362.
- Hyla Ecological Services. 1993. A proposed trail system in Minuteman National Historic Park, Lincoln, Massachusetts. Notice of intent and application filed with Lincoln, MA Conservation Commission.
- Jackson, S.D., R.M. Richmond, T.F. Tynning and C.W. Leahy (eds). 2010. *Massachusetts Herpetological Atlas 1992-1998*, Massachusetts Audubon Society & University of Massachusetts (www.massherpatlas.org). Last accessed 24 January 2011.
- James-Pirri, M.-J. 2009. Natural Resource Assessment for Minute Man National Historical Park. Natural Resources Report NPS/NER/NRR—2009/022. National Park Service. Boston, MA.
- Johnson, E.A. and M.W. Klemens. 2005. The impacts of sprawl on biodiversity. In: E.A. Johnson and M.W. Klemens (eds.), *Nature in Fragments: The Legacy of Sprawl*, pp. 18-53. Columbia University Press, New York, NY.
- Johnson, L.M. 2009. Reproductive ecology, demography, and causes of mortality in a population of eastern musk turtle, *Sternotherus odoratus* (Latreille), in central Massachusetts. MS thesis, Antioch University of New England.
- Johnson, J. R., J. H. Knouft, and R. D. Semlitsch. 2007. Sex and seasonal differences in the spatial distribution of gray treefrog (*Hyla versicolor*) populations. *Biological Conservation* 140:250-258.
- Joyal, L.A., M. McCollough, and M.L. Hunter. 2001. Landscape ecology approaches to wetland species conservation: a case study of two turtle species in Southern Maine. *Conservation Biology* 15:1755-1762.

- Karraker, N.E. and J.P. Gibbs. 2009. Amphibian production in forested landscapes in relation to wetland hydroperiod: A case study of vernal pools and beaver ponds. *Biological Conservation* 142:2293-2302.
- Karraker, N.E., J.P. Gibbs, J.R. Vonesh. 2008. Impacts of road deicing salt on the demography of vernal pool-breeding amphibians. *Ecological Applications*. 18:724-734.
- Kjoss, V.A. and J. A. Litvaitis. 2001. Community structure of snakes in a human-dominated landscape. *Biological Conservation* 98: 285-292.
- Klemens, M. W. 1985. Survivors in megalopolis: Reptiles of the urban Northeast. *Discovery* 18:22-25.
- Klemens, M. W. 1993. Amphibians and reptiles of Connecticut and adjacent regions. State Geological and Natural History Survey of Connecticut, Bulletin 112.
- Klemens, M.W., R.P. Cook, and D.J. Hayes. 1992. Herpetofauna of Roosevelt-Vanderbilt National Historic Sites Hyde Park, New York, with emphasis on Blanding's Turtle (*Emydoidea blandingii*). Technical Report NPS/NAROSS/NRTR-92-08. National Park Service, Boston, Massachusetts.
- Knapp, R.A., and K.R. Matthews. 2000. Non-native fish introductions and the decline of the Mountain Yellow-legged Frog from within protected areas. *Conservation Biology* 14:428-438.
- Kolozsvary, M. B., and R. K. Swihart. 1999. Habitat fragmentation and the distribution of amphibians: patch and landscape correlates in farmland. *Canadian Journal of Zoology* 77:1288-1299.
- Kupferberg, S. 1994. Bullfrogs (*Rana catesbeiana*) invade a northern California watershed: impact on native frogs and hydrologic factors affecting establishment. *American Zoologist* 34:8A.
- Kurzava, L. M., and P. J. Morin. 1994. Consequences and causes of geographic variation in the body size of a keystone predator, *Notophthalmus viridescens*. *Oecologia* 99:221-280.
- Lacki, M. J., J. W. Hummer, and H. J. Webster. 1992. Mine-drainage treatment wetland as habitat for herpetofaunal wildlife. *Environmental Management* 16:513-520.
- Lazell, J.D. 1968. Genetic puzzle: Blue-spotted salamander. *Massachusetts Audubon* 53(2):20-25.
- Lazell, J.D. 1970. New range records: Blue-spotted salamanders. *Massachusetts Audubon* 54(3):1-2.
- Lazell, J. D. 1974. Reptiles & Amphibians in Massachusetts. Massachusetts Audubon Society, Lincoln, MA.

- Lazell, J. D. 1976. This Broken Archipelago: Cape Cod and the islands, amphibians and reptiles. Demeter Press (Quadrangle: The New York Times Book Co.), New York, NY.
- Levell, J. P. 2000. Commercial exploitation of Blanding's turtle, *Emydoidea blandingii*, and the wood turtle, *Clemmys insculpta*, for the live animal trade. Chelonian Conservation and Biology 3:665-674.
- Lewis, T.L., J. M. Ullmer, and J. L. Mazza. 2004. Threats to spotted turtle (*Clemmys guttata*) habitat in Ohio. The Ohio Journal of Science 104:65-71.
- Likens, G.E., C.T. Driscoll, and D.C. Buso. 1996. Long-term effects of acid rain: Response and recovery of a forest ecosystem. Science 272 (5259):244-246.
- Longcore, J. R., J. E. Longcore, A. P. Pessier, and W. A. Halteman. 2007. Chytridiomycosis widespread in anurans of Northeastern United States. Journal of Wildlife Management 71:435-442.
- Lowcock, L.A. 1989. Biogeography of hybrid complexes of *Ambystoma*: interpreting unisexual-bisexual genetic data in space and time. In: R.M. Dawley and J.P. Bogart (eds.), Evolution and ecology of unisexual vertebrates. New York State Museum Bulletin 466:180-206.
- Marchand, M.N., and J.A. Litvaitis. 2004. Effects of habitat features and landscape composition on the population structure of a common aquatic turtle in a region undergoing rapid development. Conservation Biology 18:758-767.
- Massachusetts Natural Heritage and Endangered Species Program. 2007. Wood Turtle *Glyptemys insculpta*. Massachusetts Division of Fisheries & Wildlife, Natural Heritage & Endangered Species Program. Westborough, MA.
- Massachusetts Natural Heritage and Endangered Species Program. 2009. Draft mowing advisory guidelines in turtle habitat: pastures, successional fields, and hayfields. http://www.mass.gov/dfwele/dfw/nhesp/conservation/pdf/mowing_guidelines.pdf. Link checked on 20 March 2011
- Mass Highways. 2006. Wildlife Accomodation. Massachusetts Highway Department Project Development and Design Guidebook. Chapter 14. Massachusetts Executive Office of Transportation. Boston, MA. http://www.mhd.state.ma.us/downloads/designGuide/CH_14.pdf, last accessed March 21, 2011.
- Martinez, J. 1992. Minuteman Park Report-vernal pool survey, spring 1992. Minuteman National Historical Park Natural Resource Files. National Park Service. Concord, MA.
- McDonough, C. and P.W.C. Paton. 2007. Salamander dispersal across a forested landscape fragmented by a golf course. Journal of Wildlife Management 71:1163-1169.

- Milam, J.C. and S.M. Melvin. 2001. Density, habitat use, movements, and conservation of spotted turtles (*Clemmys guttata*) in Massachusetts. *Journal of Herpetology* 35: 418-427.
- Mirick, P.G. 2009. Field guide to the Reptiles of Massachusetts. Editor. Massachusetts Wildlife 59(2):4-45.
- Mitchell, J. C. ,and M. W. Klemens. 2000. Primary and secondary effects of habitat alteration. In: *Turtle Conservation*, p. 5-32. Klemens, M. W., Ed, Smithsonian Institution Press. Washington, DC.
- Mitchell, B.R., W. G. Shriver, F. Dieffenbach, T. Moore, D. Faber-Langendoen, G. Tierney, P. Lombard, and J. Gibbs. 2006. Northeast Temperate Network Vital Signs Monitoring Plan. Technical Report NPS/NER/NRTR--2006/059. National Park Service, Northeast Temperate Network, Woodstock, Vermont.
- Moriarty, J. J. 2004. Amphibian and reptile diversity and distribution in the United States. <http://cgee.hamline.edu/frogs/science/StateA&R.pdf> , last accessed 15 March 2011.
- Nelson, G. L. and B. M. Graves. 2004. Anuran population monitoring: Comparison of the North American amphibian monitoring program's calling index with mark-recapture estimates for *Rana clamitans*. *Journal of Herpetology* 38: 355-359.
- Pechmann, J.H.K., D.E. Scott, J.W. Gibbons, and R.D. Semlitsch. 1989. Influence of wetland hydroperiod on diversity and abundance of metamorphosing juvenile amphibians. *Wetland Ecology and Management* 1(1):3-11.
- Pechmann, J. H. K., and H. W. Wilbur. 1994. Putting declining amphibian populations in perspective: Natural fluctuations and human impacts. *Herpetologica* 50:65-84.
- Petranka, J. W. 1998. Salamanders of the United States and Canada. Smithsonian Institution Press, Washington, DC.
- Petranka, J.W., M. E. Eldridge, and K. E. Haley. 1993. Effects of timber harvesting on southern Appalachian salamanders. *Conservation Biology* 7:363-370.
- Porej, D., M. Micacchion, and T.E. Hetherington. 2004. Core terrestrial habitat for conservation of local populations of salamanders and wood frogs in agricultural landscapes. *Biological Conservation* 120:399-409.
- Porter, K. R. 1972. *Herpetology*. Saunders Publishing, Philadelphia, PA.
- Pough, F. H., and M. B. Pough 1968. The systematic status of painted turtles (*Chrysemys*) in the northeastern United States. *Copeia* 1968:612-618.

- Pough, F. H., E. M. Smith, D. H. Rhodes, and A. Collazo. 1987. The abundance of salamanders in forest stands with different histories of disturbance. *Forest Ecology and Management* 20:1-9.
- Pough, F. H., R. M. Andrews, J. E. Cadle, M. L. Crump, A. H. Savitsky, and K. D. Wells. 2004. *Herpetology*. Prentice Hall, Upper Saddle River, NJ.
- Reagan D. P. 1974. Habitat selection in the three-toed box turtle, *Terrapene carolina triunguis*. *Copeia* 1974: 512-527.
- Regosin, J.V., B.S. Windmiller, and J.M.Reed. 2003. Terrestrial habitat use and winter densities of the wood frog (*Rana sylvatica*). *Journal of Herpetology* 37:390-394.
- Regosin, J.V., B.S. Windmiller, R.N. Homan, and J.M.Reed. 2005. Variation in terrestrial habitat use by four pool-breeding amphibian species. *Journal of Wildlife Management* 69(4):1481-1493.
- Ricketson, O. G., Jr. 1911. A list of Reptilia collected at Concord, Massachusetts. *Proceedings of the Thoreau Museum of Natural History, Middlesex School, Concord, MA* 1:11-13.
- Roe, A.W. and K.L.Grayson. 2008. Terrestrial movements and habitat use of juvenile and emigrating adult Eastern red-spotted newts, *Notophthalmus viridescens*. *Journal of Herpetology* 42(1):22-30.
- Rothermal, B.B. and R.D. Semlitsch. 2006. Consequences of forest fragmentation for juvenile survival in spotted (*Ambystoma maculatum*) and marbled (*Ambystoma opacum*) salamanders. *Canadian Journal of Zoology* 84:797-807.
- Rubbo, M. J., and J. M. Kiesecker. 2005. Amphibian breeding distribution in an urbanized landscape. *Conservation Biology* 19:504-511.
- Schlauch, F.C. 1976. City snakes, suburban salamanders. *Natural History* 85:46-53.
- Scott, T. A., W. Wehtje, and M. Wehtje. 2001. The need for strategic planning in passive restoration of wildlife populations. *Restoration Ecology* 9:262-271.
- Semlitsch R. D. 2003. Conservation of pond breeding amphibians. In: R.D. Semlitsch (ed.) *Amphibian Conservation*, pp. 8-23. Smithsonian Institution Press, Washington, DC.
- Sievert, P. R., B. W. Compton, and M. Grgurovic. 2003. Blanding's turtle (*Emydoidea blandingii*) conservation plan for Massachusetts. Report for the MA Natural Heritage and Endangered Species Program. Westborough, MA. 61pp.
- Singler A. and B. Graber. 2005. editors. *Massachusetts Stream Crossing Handbook*. Massachusetts Riverway Program. Commonwealth of Massachusetts, Executive Office of Environmental Affairs, Department of Fish and Game, Boston, MA.

- Skelly, D.K., E.A. Werner, and S.A. Cortwright. 1999. Long-term distributional dynamics of a Michigan amphibian assemblage. *Ecology* 80:2326-2337.
- Skelly, D. K., L.K. Freidenburg, and J. M. Kiesecker. 2002. Forest canopy and the performance of larval amphibians. *Ecology* 83:983-992.
- Skidds, D.E., F.C. Golet, P.W.C. Paton, and J.C. Mitchell. 2007. Habitat correlates of reproductive effort in wood frogs and spotted salamanders in an urbanizing watershed. *Journal of Herpetology* 41:439-450.
- Steen, D.A. and J.P. Gibbs. 2003. Effects of roads on the structure of freshwater turtle populations. *Conservation Biology* 18:1143-1148.
- Steen, D.A. and J.P. Gibbs. 2005. Potential influence of the terrestrial landscape on the distribution of pond-breeding eastern newts, *Notophthalmus viridescens*. *Applied Herpetology* 2:425-428.
- Storer, D.H. 1840. A report on the reptiles of Massachusetts. *Boston Journal of Natural History* 3(1): 1-64.
- Stumpel, A. H. P. 1992. Successful reproduction of introduced bullfrogs *Rana catesbeiana* in northwestern Europe: A potential threat to indigenous amphibians. *Biological Conservation* 60:61-62.
- Thomas, L. A., 1992. A salamander survey at Minute Man National Historical Park. Minute Man National Historical Park Natural Resource Files. National Park Service. Concord, MA.
- Tupper, T.A. and R.P.Cook. 2008. Habitat variables influencing breeding effort in northern clade *Bufo fowleri*: Implications for conservation. *Applied Herpetology* 5:101-119.
- Tupper, T. A., R. P. Cook, B. C. Timm, and A. Goodstine. 2007. Improving call surveys for detecting Fowler's toad, *Bufo fowleri*, in Southern New England, USA. *Applied Herpetology* 4:245-259.
- Tupper, T.A., J.W. Streicher, S.E. Greenspan, B.C. Timm, and R.P. Cook. 2011. Detection of *Batrachochytridium dendrobatidis* in Anurans of Cape Cod National Seashore, Barnstable County, Massachusetts, USA. *Herpetological Review* 42(1):62-65.
- USFWS. 2005. Great Meadows National Wildlife Refuge. Final Comprehensive Conservation Plan. U. S. Fish and Wildlife Service, Sudbury, MA.
- Weldon, C., L. H. duPreez, A. D. Hyatt, M. Reinhold, and R. Speare. 2004. Origin of the amphibian chytrid fungus. *Emerging Infectious Diseases* 10:2100-2105.

- Willey, L. 2009. An observational database of Eastern Box Turtles in Massachusetts: A compilation of turtles observed throughout the state. Report for Massachusetts Division of Fisheries & Wildlife, Natural Heritage & Endangered Species Program. Westborough, MA.
- Windmiller, B. 1996. The pond, the forest, and the city: spotted salamander ecology and conservation in a human-dominated landscape. Ph.D. Dissertation, Tufts University, Boston, Massachusetts.
- Windmiller, B. and R.K. Walton, 1992. Minute Man National Historical Park: A survey of selected fauna with recommendations for wildlife conservation and habitat management. Minute Man National Historical Park, National Park Service. Concord, MA.
- Windmiller, B., R.N. Homan, J.V. Regosin, L.A. Willitts, D.L. Wells, and J.M. Reed. 2008. Breeding amphibian population declines following loss of upland forest habitat around vernal pools in Massachusetts, USA. *Urban Herpetology*. J.C. Mitchell, R.E. Jung Brown and B. Bartholomew, editors *Herpetological Conservation* 3:41-51. Society for the Study of Amphibians and Reptiles.
- Wright, A. H. and A. A. Wright. 1949. Handbook of Frogs and Toads of the United States and Canada. Comstock Publishing Associates. Ithaca, New York.
- Zampella, R. A. and J.F. Bunnell. 2000. The distribution of anurans in two river systems of a coastal plain watershed. *Journal of Herpetology* 34:210-221.
- Zampella, R. A., J.F. Bunnell, K.J. Laidig, and N.A. Procopio III. 2010. Aquatic degradation in shallow coastal plain lakes: Gradients of thresholds? *Ecological Indicators* 10:303-310.
- Zweifel, R. G. 1989. Long-term ecological studies on a population of painted turtles, *Chrysemys picta*, on Long Island, New York. *American Museum Novitates* 2952: 1-55.

Appendix A. Historic and current records of amphibians and reptiles from Minute Man National Historical Park and vicinity. Herp Atlas data are for blocks that MIMA falls within, i.e. Quad 67, blocks 1, 2, 5.

Species	early 20th century	Greer 1973	MIMA 1992-1994	Herp Atlas 1992-1995	Current
Jefferson/Blue-spotted Salamander	X ¹	X			
Spotted Salamander	X ¹	X	X ^{3,4,5}	X	X
Red-spotted Newt (Red Eft)	X ¹	X	X ^{3,4}	X	X
Northern Dusky Salamander		X			
Northern Two-lined Salamander	X ¹	X	X ^{3,4}	X	X
Eastern Red-backed Salamander	X ¹	X	X ^{3,4,5}	X	X
Four-toed Salamander		X			
Salamander Sub-totals	5	7	4	4	4
Eastern American Toad	X ¹	X	X ⁴	X	X
Fowler's Toad	X ¹	X			
Gray Treefrog	X ¹	X	X ⁴	X	X
Northern Spring Peeper	X ¹	X	X ^{4,5}	X	X
American Bullfrog	X ¹	X	X ^{4,5}	X	X
Northern Green Frog	X ¹	X	X ^{4,5}	X	X
Pickerel Frog	X ¹	X	X ⁴	X	X
Northern Leopard Frog	X ¹	X		X	X
Wood Frog	X ¹	X	X ^{4,5}	X	X
Anuran Sub-totals	9	9	7	8	8
Common Snapping Turtle	X ²	X	X ⁴	X	X
Stinkpot	X ²	X	X ⁴	X	
Painted Turtle	X ²	X	X ⁴	X	X
Spotted Turtle	X ²	X	X ⁶		X
Wood Turtle	X ²	X			
Blanding's Turtle	X ²	X		X	X ⁶
Eastern Box Turtle	X ²	X			
Turtle Sub-totals	7	7	4	4	4
Northern Black Racer	X ²	X	X ⁴		
Northern Ringneck Snake	X ²	X		X	
Eastern Milk Snake	X ²	X	X ⁴		X
Smooth Green Snake	X ²	X			
Northern Water Snake	X ²	X		X	X ⁷
Northern brown snake	X ²	X			
Northern Red-bellied Snake	X ²	X			
Common Garter Snake	X ²	X	X ⁴	X	X
Eastern Ribbon Snake	X ²	X	X ⁴		
Snake Sub-totals	9	9	4	3	3
Total Species	30	32	19	19	19

¹Carnegie 1914; ²Ricketson 1911; ³Thomas 1992; ⁴Windmiller and Walton 1992; ⁵Martinez 1992; ⁶Bryan Windmiller, pers. comm.; ⁷Robert Zaremba, pers. comm.

Appendix B. Cross-reference of the names used to identify Minute Man National Historical Park wetland survey sites in this report and three reports published in 1992.

WCS/NPS 2011	Thomas 1992	Windmiller and Walton 1992	Martinez 1992	Habitat	Species Found
Cook's Pond	A	Cook's Pond	01-130	Pond, permanent	AMMA, BUAM, HIVE, NOVI, RACA, RACL, RAPA, RASY
Whittemore Pond	B	Whittemore pond		Pond, vernal	AMMA, BUAM, CHPI, CHSE, HIVE, NOVI, RACL, RAPA, RASY
VC Vernal Pond, NW	C	Pool in wetland, N of Visitor Center		Pond, permanent	AMMA, RASY
Folly Pond	D	Folly Pond	02-136	Pond, permanent	CHPI, HIVE, NOVI, RACA, RACL, RAPA
Black Gum Swamp Pond	E	Small pond N. of 2A	03-103	Pond, permanent	AMMA, RACL, RASY
Virginia Road Pond	F	Vernal pool S. of Virginia Rd.		Pond, vernal	AMMA, CHSE, RACA, RACL, RASY
ElmBrook	G	Elm Brook, just N. of 2A		Stream	EUBI
Pond J	J		01-105	Ponded stream	none recorded
CranberryBog	K	Cranberry Bog, S. of 2A		Pond, permanent	CHSE, HIVE, RACL
Pond L	L		02-133	Pond, vernal	none recorded
VC VernalPond, South	M	Wetland S. of Battle Rd. VC	01-110	Pond, vernal	RACL
Pond O	O	Pond S. of 2A, E. of Sunnyside		Pond, vernal	RACA, RACL
Pond P	P		03-104	Pond, vernal	none recorded
VC Permanent Pond		Pond by Battle Rd Visitor Center		Pond, permanent	CHPI
Palumbo Ditches		Palumbo Farm Ditches	04-119A,B,C?	Ditches	BUAM, RACL, RASY
PondS.of Folly		Small pond, S. of Folly Pond	02-142	Pond, vernal	RACL
Palumbo Pond		Palumbo Farm Pond	04-119S?	Pond, Farm	CHPI, CHSE, CLGU, RACL, RASY
Nelson Pond				Pond, Farm	No info available
Irrigation pond b			03-120A	Ponded stream	unid. tadpole
Irrigation pond a				Ponded stream	CLGU
Pond4-121			04-121	Pond, vernal	RACA, RACL
Mill Brook-Palumbo		Mill Brook-adj. to Palumbo	04-119	Stream	EMBL, PLCI
Mill Brook-Wayside		Mill Brook-south of Wayside		Ponded stream	BUAM, HIVE
Mill Brook-mouth		Mill Brook-at mouth		Stream	STOD
Concord River		Concord River		River	CHPI, CHSE

Appendix C. Habitat categories and types surveyed at Minute Man National Historical Park.

Habitat Category	Habitat Type	Description
STREAM	Permanent Stream	Narrow (<3m wide), flowing body of water with water flowing throughout the year.
	Intermittent Stream	Narrow (<3m wide), flowing body of water that dries up for a period of time during the year.
WETLAND	Temporary Pond	Open or closed canopy body of water that holds water for part of the year, drying during late summer months, and is void of fish. Identified by water stained leaves and buttressed tree trunks (i.e., Pin Oak (<i>Quercus palustris</i>); Black Gum (<i>Nyssa sylvatica</i>)). Invertebrates present include fairy shrimp, predacious diving beetles, copepods, cladocerans, and caddisfly larvae.
	Permanent Pond	Open body of water (<2 ha), holds water the entire year, and fish are usually present. Borders of the pond are well defined.
UPLAND	Deciduous Forest	Forest dominated by deciduous trees (i.e., oak (<i>Quercus</i> spp.); maple (<i>Acer</i> spp.); birch (<i>Betula</i> spp.)).
	Field	Open area dominated by grasses and sedges.

Appendix D. Coordinates for 32 standardized amphibian and reptile survey sites and five incidental encounter (IE) localities at Minute Man National Historical Park. For streams and coverboards (CB), the pair of coordinates are start and end points of linear features. For fields and ponds, the single point is a central point in what is actually a polygon feature.

Site	Survey Method	UTM X	UTM Y	UTM X	UTM Y
Black Gum Swamp Pond	ACS, EMC, TCS, TTS, MTS	310972	4702535		
Burke House	IE	308936	4703526		
Concord River	IE	306739	4704531		
Cook's Pond	ACS, EMC, TCS, TTS, MTS	313917	4702144		
Cranberry Bog	ACS, EMC, TCS, TTS, MTS	313504	4701953		
Elm Brook North	Stream TCS	310662	4702843	310509	4702598
Elm Brook South	Stream TCS	310509	4702598	310501	4702521
Fiske Hill Field	TCS				
CB Array #1	CB	314152	4701953	314120	4701966
CB Array #2	CB	314093	4701856	314061	4701844
Folly Pond	ACS, EMC, TCS, TTS, MTS	312232	4702044		
Folly Pond Woodland	IE	312201	4702130		
Historic Fields	TCS				
CB Array #1	CB	309273	4703617	309050	4703441
CB Array #2	CB	309697	4703637	309509	4703637
CB Array #3	CB	309823	4703417	309803	4703433
CB Array #4	CB	309821	4703249	309848	4703223
Irrigation Pond A	ACS, EMC, TCS, TTS, MTS	309504	4703662		
Meriam Field	IE	309026	4703535		
Mill Brook Mouth	Stream TCS, TTS	306631	4704398	306780	4704338
Mill Brook North	Stream TCS	309504	4703662	308938	4703385
Mill Brook South	Stream TCS	308748	4703101	308820	4703019
Mill Brook Wayside	ACS	303077	4703196		
Mill Brook West	Stream TCS	308840	4703299	308748	4703101
Nelson House	IE	313170	4702317		
Nelson Pond	ACS, EMC, TCS, TTS, MTS	308767	4703028		
North Bridge Field	TCS, CB	306661	4704636	306652	4704600
Palumbo Ditches	EMC, TCS, TTS, MTS	308964	4703130		
Palumbo Field	TCS, CB	309064	4703102	309086	4703137
Palumbo Pond	ACS, EMC, TCS, TTS, MTS	309008	4703230		
Pond 4-121	ACS	309352	4702974		
Pond O	ACS, EMC, TCS, TTS, MTS	310956	4702473		
Virginia Road Pond	ACS, EMC, TCS, TTS, MTS	310956	4702686		
Visitor's Center Permanent Pond	ACS, EMC, TCS, TTS, MTS	313255	4702180		
Visitor's Center Vernal Pond	ACS, EMC	313342	4702051		
Whittemore Pond	ACS, EMC, TCS, TTS, MTS	313579	4702188		
Woodland #2	TCS, CB	307030	4704504	307054	4704492
Woodland #3	TCS				
CB Array #1	CB	309452	4703457	309480	4703425
CB Array #2	CB	309548	4703482	309562	4703483

Appendix D. Coordinates for 32 standardized amphibian and reptile survey sites and five incidental encounter (IE) localities at Minute Man National Historical Park. For streams and coverboards (CB), the pair of coordinates are start and end points of linear features. For fields and ponds, the single point is a central point in what is actually a polygon feature (continued).

Site	Survey Method	UTM X	UTM Y	UTM X	UTM Y
Woodland #4	TCS, CB	309303	4703075	309352	4702974
Woodland #6	TCS, CB	311286	4702674	311262	4702667
Woodland #8	TCS, CB	311464	4702320	311437	4702308
Woodland #11	TCS, CB	314233	4702067	314244	4702021
Woodland #12	TCS, CB	313898	4701927	313939	4702059

Appendix E. Summary of measurements for snakes captured at Minute Man National Historical Park in 2001.

Species	Date	Location	Board #	Type	SVL (mm)	TL (mm)	Sex
Eastern Milk Snake	5/18	Fiske Hill Field 1	71	metal	686	809	Male
	5/18	Fiske Hill Field 1	71	metal	854	932	Female
Common Garter Snake	9/13	Fiske Hill Field Array #1	68	wood	222	285	Unknown
	8/23	Fiske Hill Field Array #1	68	wood	349	463	Male
	8/26	Fiske Hill Field Array #1	68	wood	358	485	Male
	8/23	Fiske Hill Field Array #1	71	metal	411	462	Female
	8/26	Fiske Hill Field Array #2	73	metal	199	254	Unknown
	8/26	Fiske Hill Field 2	76	wood	406	531	Male
	4/21	Folly Pond	-	-	335	440	Unknown
	5/17	Historic Field Array #1	82	wood	202	246	Unknown
	5/17	Historic Field Array #1	82	wood	229	282	Unknown
	5/19	Historic Field Array #1	83	metal	206	255	Unknown
	5/19	Historic Field Array #1	83	metal	405	459	Unknown
	5/19	Historic Field Array #1	83	metal	422	559	Male
	5/19	Historic Field Array #1	84	wood	194	242	Unknown
	5/19	Historic Field Array #1	86	wood	-	-	Recapture
	5/19	Historic Field Array #1	86	wood	164	212	Unknown
	5/19	Historic Field Array #1	86	wood	202	250	Unknown
	5/17	Historic Field Array #1	86	wood	226	287	Unknown
	6/19	Historic Field Array #1	87	metal	227	276	Male
	5/19	Historic Field Array #2	89	metal	-	-	Recapture
	5/19	Historic Field Array #2	89	metal	-	-	Recapture
	5/17	Historic Field Array #2	89	metal	201	245	Unknown
	5/19	Historic Field Array #2	89	metal	259	339	Unknown
	5/19	Historic Field Array #2	90	wood	203	261	Unknown
	5/19	Historic Field Array #2	90	wood	249	307	Unknown
	5/17	Historic Field Array #2	91	metal	554	702	Unknown
	8/27	Historic Field Array #4	105	metal	440	552	Male
	6/19	Historic Field Array #4	105	metal	427	553	Female
	4/21	Irrigation Pond A	-	-	473	617	Male
	4/14	Nelson House	-	-	382	508	Male
	4/14	Nelson House	-	-	345	446	Unknown
	4/14	Nelson House	-	-	415	542	Male
	4/17	Nelson House	-	-	312	392	Unknown
	4/17	Nelson House	-	-	335	435	Unknown
	5/18	Palumbo Field	127	metal	443	572	Male
	8/24	Palumbo Field	128	wood	-	-	Escaped
	5/17	Woodland #3	15	metal	197	262	Unknown
	8/24	Woodland #6	39	metal	284	369	Unknown
	6/21	Woodland #8	45	metal	208	267	Unknown

Appendix F. Summary of measurements for turtles captured at Minute Man National Historical Park in 2001.

Species	Site	Date	Sex	Notch Code	CL ¹ (mm)	CW ² (mm)	PL ³ (mm)	PW ⁴ (mm)	Wt ⁵ (g)
Painted Turtle	Nelson Pond	5/16	F	R1,2	140	107	132	86	365
		5/19	-	R2,3	89	74	79	60	105
	Palumbo Ditches	5/16	M	R3	124	90	114	71	235
	Palumbo Pond	4/17	M	R1	135	92	115	75	295
		4/17	F	R2	146	110	137	106	475
		5/17	-	R1,3	94	79	90	62	-
		5/18	F	L9	161	127	156	100	578
		6/19	F	R4	158	116	145	96	463
		6/19	M	R1,4	137	97	124	75	281
		6/20	F	R2,4	166	116	151	95	534
		6/22	M	R8	125	93	112	73	235
Common Snapping Turtle	Cook's Pond	6/20	F	R10 – L8	248	209	191	198	>2500
		6/20	M	R8,10 – L8	188	144	132	134	>1000
	Cranberry Bog	6/19	F	R9,11	173	133	124	123	>1000
		6/19	M	R8,11	319	276	237	241	>2500
	Folly Pond	6/19	F	R9 – L8	258	207	181	180	>2500
		6/19	M	L8	340	274	243	244	>2500
		6/19	M	R8 – L8	339	275	236	248	>2500
	Meriam Field	6/20	F	R9,10 – L8	312	242	231	218	>2500
	Mill Brook Mouth	8/24	M	R10 – L10	419	353	307	332	>2500
	Nelson Pond	5/16	F	R8	306	239	212	209	>2500
	Palumbo Ditches	5/19	-	R8,10	116	94	89	87	360
		5/20	M	R11	284	229	189	203	>2500
	Palumbo Pond	5/16	F	R9	394	332	271	298	>2500
	Palumbo Pond	5/16	-	R8,9	220	182	156	162	2490
		6/20	F	R8,9 – L8	366	294	252	275	>2500
		6/21	M	R9,11 – L8	387	334	271	302	>2500
		6/21	F	R8,9,10 – L8	299	244	215	217	>2500
	VC Permanent Pond	5/17	F	R10	251	215	187	194	>2500
		6/19	M	R9,10	242	188	158	182	>2500
Spotted Turtle	Cranberry Bog	6/21	F	R1	116	84	104	62	222

¹CL = carapace length; ²CW = carapace width; ³PL = plastron length; ⁴PW = plastron width; ⁵Wt = weight

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 406/111539, November 2011

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov