



Northeast Temperate Network Forest Health Monitoring Report

2010

Natural Resource Report NPS/NETN/NRR—2011/399



ON THE COVER

Old growth stand on Bernard Mountain in Acadia National Park
Photograph by: K. Miller

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Contents

	Page
Figures.....	v
Tables	vi
Executive Summary	vii
Acknowledgements.....	x
Introduction.....	1
Methods.....	2
Ecological Integrity Scorecard.....	5
Coarse Woody Debris and Snag Abundance	5
Tree Regeneration	9
Tree Condition and Forest Pests.....	12
Invasive Exotic Plant Indicator Species	13
Soil Chemistry.....	15
Biotic Homogenization and Understory Dynamics	17
Background	17
Methods.....	17
Results and Discussion.....	18
Landscape Context.....	23
Acadia National Park	24
Marsh-Billings-Rockefeller National Historical Park.....	25
Minute Man National Historical Park	25
Morristown National Historical Park	25

Contents (continued)

	Page
Roosevelt-Vanderbilt National Historic Sites	26
Saint-Gaudens National Historic Site	26
Saratoga National Historical Park	26
Weir Farm National Historic Site.....	27
Management Implications.....	31
Acadia National Park	31
Marsh-Billings-Rockefeller National Historical Park.....	31
Minute Man National Historical Park	31
Saint-Gaudens National Historic Site	31
Saratoga National Historical Park	32
Literature Cited	33
Appendix A. Protocol implementation for the 2010 field season.....	38
Appendix B. Indicator species used for seedling ratio.	41
Appendix C. Exotic forest pest detections near NETN parks.....	43
Appendix D. Key invasive exotic plant indicator species of forest, woodland and successional ecosystems in the northeastern U.S.that were used in the NETN Ecological Integrity Scorecard.....	45
Appendix E. Landscape Context maps for NETN parks.	47

Figures

	Page
Figure 1. Plot layout showing square tree plot with three nested 2-m radius regeneration microplots, eight 1-m ² vegetation quadrats, and three 15-m coarse woody debris (CWD) transects.....	4
Figure 2. Mean seedling and sapling density (stems/ha) based on data collected from 2007-2010. .	11
Figure 3. Proportion of plots receiving “Good”, “Caution” and “Significant Concern” ratings for tree condition for each park sampled in 2010.	13
Figure 4. Average species richness per plot (A) and average quadrat percent cover (B) for native versus exotic vascular plant species for data collected from 2007 to 2010.....	19
Figure 5. Average native species richness per plot by plant guild (A) and average quadrat percent cover by native plant guild (B) for data collected from 2007 to 2010.....	20
Figure 6. Proportion of park forest in each patch size category.	27
Figure 7. Proportion of specified neighborhood buffer areas around forest plots in each percent anthropogenic land use category.....	29

Tables

	Page
Table 1. Northeast Temperate Network forest monitoring panel design.....	3
Table 2. Metrics and ratings for evaluating the ecological integrity of forest ecosystems.....	6
Table 3. Coarse woody debris (CWD) metric ratings, ratios, and volume calculations for NETN parks based on data collected from 2007 to 2010.	8
Table 4. Snag abundance ratings and calculations for NETN parks based on data collected from 2007 to 2010..	8
Table 5. Index of deer browse impacts assessed for each plot in national historical parks and sites (NHPs) and ACAD (adapted from Brose et al. 2008 and Perles et al. 2010).	10
Table 6. Mean stocking index and seedling ratio based on data collected from 2007- 2010. Mean deer browse index is based on 2010 data only.....	11
Table 7. Indicator invasive exotic plant species ratings for NETN parks.....	14
Table 8. Most frequent indicator invasive exotic species in NETN forest plots by park from 2007 to 2010.....	15
Table 9. Soil chemistry ratings for NETN parks from 2007 to 2010.....	16
Table 10. Jaccard Similarity Index scores for each park (includes data collected from 2007 to 2010).	18
Table 11. Earthworm detections in NETN parks, reported as number and % of plots with positive detections (includes data collected from 2007 to 2010).....	18
Table 12. Forest patch statistics for each park unit.	28
Table 13. Anthropogenic land use statistics and ratings for each park unit.....	29

Executive Summary

The 2010 field season marked the first year that the Northeast Temperate Network (NETN) Inventory and Monitoring Program resurveyed forest monitoring plots in Acadia National Park (ACAD), Marsh-Billings-Rockefeller National Historical Park (MABI), Minute Man National Historical Park (MIMA), Saint-Gaudens National Historic Site (SAGA), and Saratoga National Historical Park (SARA). One-fourth of the plots in ACAD were resurveyed and one-half of the plots in the other four parks were resurveyed. This report contains an ecological integrity scorecard for data collected from 2007 to 2010 in these five parks. Additional sections cover all 10 NETN parks where forest health is monitored, and include a baseline assessment of biotic homogenization and understory patterns, and an analysis of landscape context.

Results for Parks Sampled in 2010

Acadia National Park

Ecological integrity metrics suggest that forests in ACAD are approaching mature stages of forest succession, but late-successional structure, such as medium to large snags, is still lacking. ACAD continues to be the network park least affected by invasive species, including exotic plants and exotic earthworms. All management units in ACAD have little anthropogenic land use near forest plots. As long as impacts from stressors such as invasive species, forests pests and deer densities are kept in check by management or natural barriers, we expect forest structure metrics to improve with time.

Marsh-Billings-Rockefeller National Historical Park

Preliminary data, particularly the high abundance of ferns, suggest that deer browse pressure and exotic earthworms may be impacting forest understories in MABI. Quantifying deer densities in the park and characterizing the spring ephemeral component of the understory are both important next steps to determine if deer are impacting forests in MABI and if deer management is necessary.

Coarse woody debris and snag abundance continue to be lower than expected for late-successional hardwood stands, and medium to large snags are especially lacking in plantations. Forest patch size is sufficiently large to support native fauna, though plantations of exotic trees and open fields may negatively impact the landscape dynamics in this park.

Minute Man National Historical Park

Coarse woody debris and snag abundance continue to be low in MIMA. Soil chemistry data indicate potential impacts of atmospheric deposition, including soil acidification and excess soil nitrogen. Native species diversity and abundance are higher in MIMA forest understories than in most NETN parks (except SARA). However, invasive exotic species are also abundant, and exotic shrub thickets are likely impacting forest structure and composition.

Landscape context analyses revealed that MIMA is the network park with the highest percent of anthropogenic land use surrounding forest plots, and the forests in general are highly fragmented. The degrees of fragmentation and intensive land use in and around the park have likely contributed to the invasive exotic species problem in MIMA.

Saint-Gaudens National Historic Site

While coarse woody debris volume and snag abundance are higher in SAGA than most network parks, these levels are still lower than expected for late-successional hardwood stands. Invasive exotic species are present, but do not appear to be greatly impacting understory diversity or forest structure. Landscape context is good, with large buffers of intact forest surrounding most of the park boundary, and only minor anthropogenic land use near forest plots. Soil chemistry data indicate potential impacts of atmospheric deposition, including soil acidification and excess soil nitrogen. As long as park management efforts continue to control invasive exotic plants, and exotic pests (especially hemlock woolly adelgid) do not invade here, we expect ecological integrity structural metrics to improve with time.

Saratoga National Historical Park

Despite supporting the most diverse understory in the network, preliminary data suggest that invasive exotic species and possibly elevated deer densities and exotic earthworms are impacting forest condition. Exotic shrubs, particularly bush honeysuckle (*Lonicera* spp.), have invaded large areas of the park, and are suppressing forest succession of old-field habitats. Emerald ash borer poses a considerable threat to these early successional habitats, as white ash is one of the only tree species with seedlings capable of penetrating the thicket and forming a canopy.

Forest habitat is considerably fragmented by fields and roads inside the park boundary, and agricultural lands dominate the area outside of the park boundary. Habitat fragmentation may have contributed to the spread of invasive exotic species in SARA, and it appears that exotic shrub thickets are maintaining habitat fragmentation by inhibiting forest succession.

Landscape and Understory Composition Results for Other Parks

Morristown National Historical Park

At the scale of the park, landscape context in Morristown National Historical Park (MORR) is good. Much of MORR's boundary is buffered by other protected forest lands, and forest cover within the park is mostly intact. A larger view reveals MORR and the surrounding protected lands to be an undeveloped island in a sea of dense residential development. This landscape context may have played a role in the large numbers of deer in the park, as MORR and surrounding lands may represent some of the only natural habitat available to deer in the area.

Understory diversity and abundance have been drastically altered by prolonged deer herbivory and the presence of invasive exotic species. The forest understory in MORR is dominated by exotic plant species, and cover of deer-preferred forb species is very low. Along with regeneration metrics, these data serve as an important baseline to assess efficacy of any management actions (e.g., deer and exotic plant control) on restoring forest condition.

Roosevelt-Vanderbilt National Historic Sites

Landscape context varies considerably among the three park units in Roosevelt-Vanderbilt National Historic Sites (ROVA). Fragmentation and anthropogenic land use are highest in Vanderbilt Mansion National Historic Site (VAMA). The two management units of Home of Franklin D. Roosevelt National Historic Site (HOFR) are least fragmented and average less adjacent anthropogenic land use near forest plots. Despite the close proximity of both units of HOFR and Eleanor Roosevelt National Historic Site (ELRO), there is no patch connectivity

between units. ELRO and HOFR are, however, relatively well buffered by intact forest around most of their boundaries.

Weir Farm National Historic Site

Understory patterns in Weir Farm National Historic Site (WEFA) are similar to MIMA. Native forbs are well represented, but exotic species are also widespread. Fragmentation and anthropogenic land use are at moderate levels in WEFA, and may be contributing to the large numbers of deer and invasive exotic species in the park.

Conclusions

Forested systems in most NETN parks are relatively young, and are likely to fall short of desired levels of coarse woody debris (CWD) and snags for some time. As long as forests are left to mature and management activities don't reduce the potential for development of CWD and snags, we expect these metrics to improve with time. Results also suggest that forest conditions in most NETN parks could benefit from management actions such as reduction of white-tailed deer populations, and eradication and/or control of invasive species – especially exotic shrub species. Early detection of exotic forest pests and plants combined with rapid response control measures are important to maintaining forest condition. In addition, forest health in these parks may be negatively affected by soil chemistry problems stemming from atmospheric deposition.

Ecological Integrity Scorecard

Forest Condition

Park	CWD Ratio	Snag Abundance	Tree Condition/ Forest Pests	Invasive Exotic Plants	Soil Ca:AL	Soil C:N
ACAD	Good	Good	Caution	Good	Caution	Good
MABI	Caution	Caution	Caution	Caution	Good	Sign. Conc.
MIMA	Sign. Conc.	Caution	Caution	Sign. Conc.	Sign. Conc.	Sign. Conc.
SAGA	Caution	Caution	Good	Caution	Sign. Conc.	Sign. Conc.
SARA	Caution	Good	Good	Caution	Good	Sign. Conc.

Landscape Context

Park	Unit	Anthropogenic Land Use	Patch Size ¹
ACAD		Good	
MABI		Caution	
MIMA		Caution	
MORR		Good	
ROVA	ELRO/HOFR	Good	
	VAMA	Caution	
SAGA		Good	
SARA		Caution	
WEFA		Caution	

¹ The proportion of each color in the pie charts represents the proportion of forest patch area greater than 0.5 ha with a rating of good (green), caution (yellow), or significant concern (red).

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Introduction

The Northeast Temperate Network (NETN) of the National Park Service (NPS) Inventory and Monitoring Program developed a long-term monitoring program for forest resources in response to the identification of Forest Vegetation as a high-priority vital sign for the network (Mitchell et al. 2006). This program also provides data for three additional high-priority vital signs: Forest Soil Condition, White-Tailed Deer Herbivory, and Landscape Context. The overall goal of the forest monitoring program is to assess status and trends in the composition, structure, and function of NETN forested ecosystems.

Adapted from the U.S. Forest Service Forest Inventory and Analysis Program, the NETN forest protocol monitors a representative suite of site and vegetation measures in an extensive network of randomly located permanent plots (Tierney et al. 2010). Ten parks are monitored in this program: Acadia National Park (ACAD), Marsh-Billings-Rockefeller National Historical Park (MABI), Minute Man National Historical Park (MIMA), Morristown National Historical Park (MORR), Roosevelt-Vanderbilt National Historic Sites (ROVA), Saint-Gaudens National Historic Site (SAGA), Saratoga National Historical Park (SARA), and Weir Farm National Historic Site (WEFA). Roosevelt-Vanderbilt National Historic Sites includes Eleanor Roosevelt National Historic Site (ELRO), Home of Franklin D. Roosevelt National Historic Site (HOFR), and Vanderbilt Mansion National Historic Site (VAMA). Currently NETN has established a total of 350 plots, and completed the first round of plot resampling in ACAD, MABI, MIMA, SAGA and SARA.

To facilitate reporting and interpretation of forest condition in NETN parks, we use an Ecological Integrity Scorecard, which examines a suite of compositional, structural, and functional metrics in relation to their natural or historical range of variation (Tierney et al. 2009). NETN recognizes that “ecological integrity” may not be the primary goal of park resource management, particularly at historical parks and historic sites where cultural resource management may take precedence. Nevertheless, being able to compare the condition of park resources to ecological integrity benchmarks is valuable because it provides a deeper understanding of park condition, as well as a consistent baseline for assessment of management goals. NETN seeks to work with parks to develop scorecards that track progress towards park management goals that differ from ecological integrity benchmarks, in addition to reporting ecological integrity.

This report includes a section on ecological integrity calculated from data representing the most recent full cycle of plots (2007 to 2010) for ACAD, MABI, MIMA, SAGA and SARA. We also report a baseline assessment of biotic homogenization and understory patterns for these parks, and an analysis of landscape context for all ten parks. A power analysis and preliminary trend analyses will be performed in 2012 after data have been collected twice from plots in all ten parks and will be included in the next annual forest report. A full trend analysis will be performed on repeat data in 2013 after the entire second panel is completed.

Methods

Permanent forest plots have been installed and are being sampled every 4 years using a rotating panel design (Table 1). One panel is sampled each year at ACAD (four sampling panels) and in alternate years at the nine national historical parks and historic sites (two sampling panels per park). Plots were randomly located within each park using generalized random tessellation stratified sampling (GRTS; McDonald 2004). Because ELRO and HOFR are adjacent park units, the sampling design treats them as a single unit. It is not possible to report on these parks individually because there is not a sufficient sample size for ELRO to support a stand-alone analysis.

The permanent plot design is illustrated in Figure 1. Tree and stand measurements are made within fixed-area, square plots (15 x 15 m² at ACAD; 20 x 20 m² at the other parks). Tree regeneration is measured within three 2-m radius circular microplots embedded within each square plot. Coarse woody debris (CWD) is assessed using line intersect sampling along three 15-m transects originating at plot center. Understory diversity is monitored within eight 1-m² quadrats, and soil samples are obtained from a location adjacent to the plot. For a more detailed description of the forest protocol, including background information, field methods, and sample design, refer to Tierney et al. (2010).

To date, NETN has established 350 plots, and completed the first panel of resampling in ACAD, MABI, MIMA, SAGA and SARA. Several sampling methods were changed after the 2006 field season, and we are unable to compare some of the data collected in 2010 to the original sample. These methods include regeneration (only sampled one microplot in 2006), soil samples in ACAD (used corer in 2006 and not in subsequent years), and quadrat data (parks were sampled north to south in 2006, vs. south to north after). For a more detailed description of major protocol changes and data discrepancies, refer to the Deviations, Differences, and Summary of Major Changes Standard Operating Procedure in Tierney et al. (2010).

Table 1. Northeast Temperate Network forest monitoring panel design. Panel numbers are listed in the table. One-fourth of the plots in ACAD are sampled every year. One-half of the plots in MABI, MIMA, SAGA and SARA are sampled in panels 1 and 3. One-half of the plots in MORR, ROVA (HOFR, ELRO, VAMA), and WEFA are sampled in panels 2 and 4.

Park	Year								
	2006	2007	2008	2009	2010	2011	2012	2013	2014
ACAD	1	2	3	4	1	2	3	4	1
MABI	1		3		1		3		1
MIMA	1		3		1		3		1
MORR		2		4		2		4	
ROVA		2		4		2		4	
SAGA	1		3		1		3		1
SARA	1		3		1		3		1
WEFA		2		4		2		4	

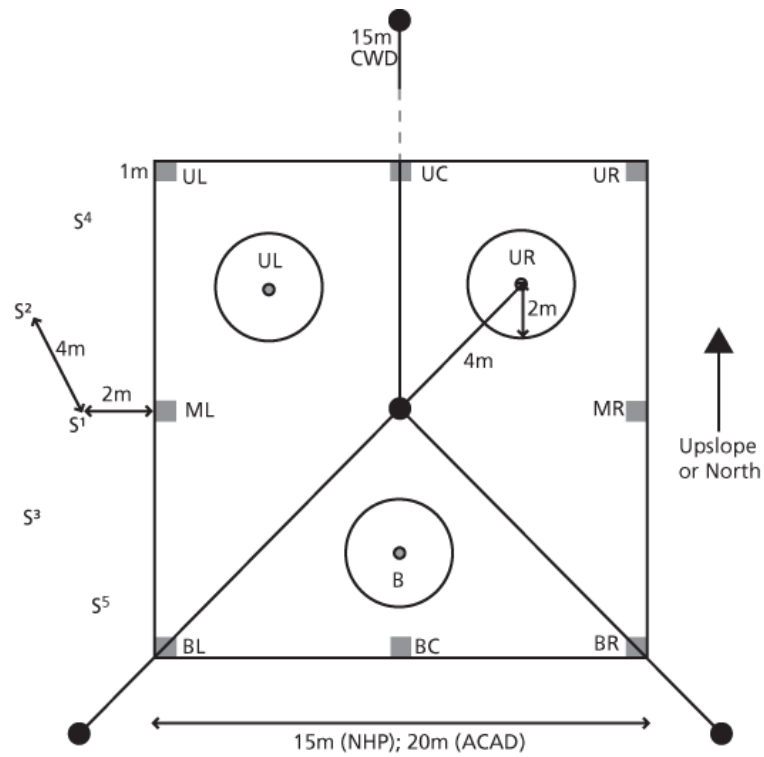


Figure 1. Plot layout showing square tree plot with three nested 2-m radius regeneration microplots, eight 1-m² vegetation quadrats, and three 15-m coarse woody debris (CWD) transects. S^x is location of soil sample.

Ecological Integrity Scorecard

The Ecological Integrity (EI) Scorecard uses the concept of “ecological integrity” to interpret the condition of forested ecosystems by assessing a suite of compositional, structural, and functional metrics in relation to their natural or historical range of variation (Tierney et al., 2009). For each metric, assessment points are defined that distinguish acceptable or expected conditions from undesired conditions based on current scientific understanding of their natural or historic range of variation (Bennetts et al. 2007). Integrity is interpreted for a broad audience using three categories: Good, Caution and Significant Concern. “Good” represents acceptable or expected conditions; “Caution” indicates a problem may exist; and “Significant Concern” indicates undesired conditions that may need management action. For some metrics, NETN does not define conditions that merit “Significant Concern” because current knowledge is insufficient to justify this rating. Ecological integrity assessment points are summarized in Table 2. For a more detailed discussion of metric justification, calculation and confidence, refer to the Ecological Integrity Reporting SOP in Tierney et al. (2010).

Metric calculations are based on the most recent full cycle (four panels) of data collected from all plots in each park (i.e., all plots were sampled once). Thus, metrics in ACAD include 4 years of plot data, and due to our alternating sampling schedule in the national historical parks (NHP) and national historic sites (NHS), calculations for those parks include 2 years of plot data. Tree condition is the only exception to this approach, as annual changes in tree condition may reflect a pest or disease outbreak. Therefore, the tree condition metric will consider both the 4-year average and the most recent year of plot data.

The following metrics are reported for parks sampled in 2010 (ACAD, MABI, MIMA, SAGA and SARA): coarse woody debris, snag abundance, tree condition and forest pests, tree regeneration, indicator invasive plants, and soil chemistry. Structural stage distribution was not included in the EI scorecard, as this is slow to change and has already been reported in Miller et al. (2008) for all plots in MABI, MIMA, SAGA and SARA, and in Miller et al. (2009) for all plots in ACAD, MORR, ROVA and WEFA. Deer browse indicator species metrics were not rated due to inconsistencies between 2006 and 2010 sampling methods, but will be included in future reports. Metrics for tree growth and mortality rates require comparisons with regional U.S. Forest Service Forest Inventory and Analysis (FIA) data. Database functions are currently under development to generate regional tree growth and mortality rates for each park based on FIA data, and will be included in future reports. Ecological Integrity ratings for these metrics are included in the Executive Summary.

Coarse Woody Debris and Snag Abundance

Dead wood, in the form of standing dead trees (snags) and fallen coarse woody debris (CWD), is an important structural feature of forests that provides habitat for many taxa. Silviculture, land management, and hazard tree removal can reduce the quantity or quality of these features. However, thoughtful land management can maintain or enhance snags and CWD (Keeton 2006).

Density of snags and volume of CWD in mature and late-successional stands vary substantially across ecosystems and with site conditions (Tyrrell et al. 1998). However, positive relationships

Table 2. Metrics and ratings for evaluating the ecological integrity of forest ecosystems.

Metric type	Metric	Metric Rating		
		Good	Caution	Significant Concern
Landscape structure	Forest patch size	> 50 ha	10-50 ha	0.5 to < 10 ha
	Anthropogenic land use	< 10%	10 - 40%	> 40%
Structure	Structural stage	≥ 70% (MABI, SAGA), ≥ 50% (ACAD), and ≥ 25% (MIMA, MORR, ROVA, SARA and WEFA) late-successional structure	< 70% (MABI, SAGA), < 50% (ACAD), and < 25% (MIMA, MORR, ROVA, SARA and WEFA) late-successional structure	< 70% (MABI, SAGA), < 50% (ACAD), and < 25% (MIMA, MORR, ROVA, SARA and WEFA) combined mature <i>and</i> late-successional structure
	Snag abundance	> = 10% standing trees are snags and > = 10% med-lg trees are snags ¹	< 10% standing trees are snags or < 10% med-lg trees are snags	< 5 med-lg snags/ha
	Coarse woody debris ratio	> 15% live tree volume	5 - 15% live tree volume	< 5% live tree volume
Composition	Tree regeneration	Seedling ratio > = 0	Seedling ratio < 0	Stocking index outside acceptable range ²
	Tree condition and forest pests	Foliage problem < 10% <i>and</i> no priority 1 or 2 pests ³ <i>and</i> BBD ³ ≤ 2	Foliage problem 10 - 50% <i>or</i> priority 2 pest present <i>or</i> BBD > 2	Foliage problem > 50% <i>or</i> priority 1 pest present
	Biotic homogenization	No change	Increasing homogenization ⁴	
	Indicator species: invasive exotic plants	< 0.5 key species per plot	0.5 to < 3.5 key species per plot	3.5 or more key species per plot
	Indicator species: deer browse	No decrease in frequency of most browse-sensitive species	Decrease in frequency of most browsed species <i>or</i> increase in frequency of browse-avoided species	Decrease in frequency of most browsed species <i>and</i> increase in frequency of browse-avoided species
Function	Tree growth and mortality rates	Growth ≥ 60% mean <i>and</i> Mort ≤ 1.6%	Growth < 60% mean <i>or</i> Mort > 1.6% ⁴	
	Soil chemistry: acid stress	Soil Ca:Al ratio > 4	Soil Ca:Al ratio 1 - 4	Soil Ca:Al ratio < 1
	Soil chemistry: nitrogen saturation	Soil C:N ratio > 25	Soil C:N ratio 20 - 25	Soil C:N ratio < 20

¹ Med-lg trees are ≥ 30 cm diameter-at-breast-height.

² Tree regeneration stocking index is only applicable to MORR, ROVA and WEFA.

³ Priority 1 pests are Asian longhorned beetle, emerald ash borer, hemlock woolly adelgid, and sudden oak death. Priority 2 pests are balsam woolly adelgid, butternut canker, elongate hemlock scale, and beech bark disease (BBD).

⁴ Significant Concern rating has not been defined for this metric.

between live and dead tree density can be used to indicate expected snag levels, and positive relationships between live tree volume and volume of CWD can be used to indicate expected CWD levels (Tierney et al. 2010). These metrics assess the density of snags and volume of CWD in relation to live tree density and volume. CWD metric ratings are based on CWD ratio, which is the ratio of CWD volume to live tree volume and is expressed as a percent. The CWD metric calculation requires a stand height measurement for each plot to calculate live tree volume. Therefore, early successional plots, which do not have a stand height measurement, and plots missing stand height measurements are excluded from this metric calculation. Snag abundance metric ratings are based on the percent of standing trees that are snags and are calculated on all plots. Since NETN plots are not large enough to accurately estimate rare features such as snags, snag abundance is evaluated at the scale of the park or park subunit, and requires at least 10 plots to be adequately estimated. To facilitate comparisons of our CWD metric calculations with other studies, we report volume of CWD using both metric and English units.

There are several data issues that had to be resolved for the CWD metric. The first sampling error occurred in 2010 in SAGA (plots 01, 05, 06 and 08) where super canopy white pines were misclassified as the co-dominant canopy layer instead of the dominant layer. This led to over-estimation of stand height and live tree volume, and under-estimation of the CWD ratio. This error was detected during plot resampling for QA/QC in plots 05 and 06, and further inspection of the data collected in SAGA revealed the same issue in plots 01 and 08. To ensure the CWD metric was not underestimated for SAGA, we replaced the 2010 stand height and crown classes with the QA/QC data for SAGA 05 and 06, and the 2006 data for SAGA 01 and 08. These data issues were also documented and changed in the database. The other data issue occurred on MABI plot 014 in 2008. Stand height was mistakenly not recorded by the crew. By chance this plot was sampled by QA/QC in 2008, and we used the stand height from QA/QC to calculate the CWD metric for this plot, and replaced the missing value with the QA/QC stand height in the database. These issues and other concerns related to the 2010 field season are discussed in more detail in Appendix A.

ACAD was the only park that rated “Good” for CWD, and MABI, SAGA, and SARA were rated “Caution” (Table 3). MIMA was rated “Significant Concern” for both CWD and snag abundance, indicating that dead wood is considerably lacking in this park (Table 4). ACAD, SAGA and SARA were rated “Caution” for snag abundance, due to the low abundance of medium to large snags (Table 4).

MABI was also rated “Significant Concern” for snag abundance. While CWD volume was slightly higher in plots located in plantations than those in naturally regenerated stands, the CWD ratio was slightly lower in plantations due to the higher levels of live tree volume and abundance in plantations than in the natural regenerating stands in the park. Overall snag abundance was slightly higher in plantations, but medium to large snags were less abundant. The differences in CWD volume and overall snag abundance may be partially due to park managers' efforts to increase CWD in park plantations, which tend to be managed more intensively than the natural stands in the park. A long term goal is to integrate vital signs monitoring data with the silvicultural inventory data collected by MABI staff to allow us a better understanding of how live tree volume, snag abundance, and CWD volume vary across the park. Despite the differences in CWD volume and snag abundance between plantations and naturally regenerated

Table 3. Coarse woody debris (CWD) metric ratings, ratios, and volume calculations for NETN parks based on data collected from 2007 to 2010. Metric ratings are based on CWD ratio, which is the ratio of coarse woody debris volume to live tree volume and are expressed as a percent. Only plots with complete stand height data are included in the analysis. SE refers to 1 standard error around the mean.

Park	Group	# Plots	Rating	CWD Ratio (%)		Metric CWD Volume (m ³ /ha)		English CWD Volume (ft ³ /acre)	
				Mean	SE	Mean	SE	Mean	SE
ACAD		161	Good	15.30%	3.59%	22.45	2.46	320.88	35.09
MABI	Overall	24	Caution	7.74%	1.99%	33.40	7.48	477.34	106.91
	Natural	13	Caution	7.93%	3.12%	29.28	11.82	418.44	168.89
	Plantation	11	Caution	7.48%	2.30%	38.27	8.85	546.95	126.51
MIMA		19	Sign. Conc.	2.55%	0.72%	7.09	2.53	101.40	36.10
SAGA		21	Caution	8.25%	2.72%	37.34	9.38	533.59	134.11
SARA		25	Caution	11.36%	2.99%	22.33	5.25	319.18	75.00

∞

Table 4. Snag abundance ratings and calculations for NETN parks based on data collected from 2007 to 2010. Metric ratings are based on the percent of standing trees (i.e., ≥ 10 cm diameter at breast height) that are snags. M-L Snags refers to medium to large (≥ 30 cm diameter at breast height) diameter snags. SE refers to 1 standard error around the mean.

Park	Group	# Plots	Rating	# of Snags / ha		# of M-L Snags / ha		% of Trees as Snags	
				Mean	SE	Mean	SE	All Sizes	M-L Snags
ACAD		175	Caution	180.57	12.34	7.11	1.38	17.09%	9.15%
MABI	Overall	24	Sign. Conc.	41.67	9.11	2.08	1.44	8.33%	1.23%
	Natural	13	Sign. Conc.	38.46	13.76	3.85	2.60	7.52%	2.78%
	Plantation	11	Sign. Conc.	45.45	12.07	0.00	0.00	9.35%	0.00%
MIMA		20	Sign. Conc.	52.50	9.23	3.75	2.05	10.71%	3.06%
SAGA		21	Caution	83.75	13.96	12.50	4.25	13.03%	6.10%
SARA		31	Caution	87.90	19.36	8.06	3.15	19.71%	7.94%

stands, both forest types received a “Caution” rating for CWD and a “Significant Concern” rating for snag abundance. The significant concern rating is primarily due to the lack of snags over 30 cm diameter at breast height (DBH).

Forested systems in most NETN parks are relatively young, and are likely to fall short of desired levels of late-successional CWD and snags for some time. As long as forests are left to mature and management activities do not reduce the potential for development of CWD and snags, we expect these metrics to improve with time.

Tree Regeneration

This metric assesses the quantity and composition of advance tree regeneration in the forest understory, which will impact future canopy structure and composition. Regeneration can be affected by a variety of stressors, including invasive species and climate change. Most notably, sustained, selective browsing by a historically high population of white-tailed deer is currently impacting seedling establishment, growth, and composition in parts of the Midwest and Northeast U.S. (Cote et al. 2004). Significant impacts on forest tree regeneration are associated with deer densities ≥ 8.5 per km², well above pre-settlement estimates of 3-4 deer per km² in the northeastern U.S. (Russell et al. 2001, Augustine and deCalesta 2003).

For this rotation of parks (ACAD, MABI, MIMA, SAGA and SARA) we will interpret multiple indicators, including a seedling ratio, stocking index, deer browse index, and seedling/sapling distributions, to assess overall tree regeneration. However, we will not assign a metric rating until these indicators have been further tested and refined for northern hardwood and boreal spruce-fir forest systems. NETN is in the process of developing a tree regeneration metric for ACAD using data collected in late-successional forests and deer exclosures in the park. As data become available, we also plan to examine how deer densities in network parks relate to these indicators to further refine the tree regeneration metric.

The first indicator considers preferential browse of deer on particular seedling species and size classes (Cornett et al. 2000), and uses a ratio developed by Sweetapple and Nugent (2004) that calculates the ratio of seedling species richness in browsed versus unbrowsed size classes of preferred species (Appendix B). While this ratio is useful in detecting moderate impacts of deer browse, it is less effective in systems that lack browse preferred species for reasons other than deer browse (e.g., spruce-fir forests in ACAD), and may be less effective in systems with relatively low tree diversity (e.g., northern hardwood forests in MABI, MIMA, SAGA and SARA).

The stocking index developed by McWilliams et al. (2005) quantifies whether current seedling numbers are sufficient to restock a mid-Atlantic hardwood forest stand. This index awards and sums points for native tree seedlings by size class within 2-m radius circular microplots as follows: one point for each seedling 15-30 cm, two points for each seedling 30-100 cm, 20 points for each seedling 100-150 cm, and 50 points for each seedling or sapling > 150 cm tall but less than 10 cm DBH. A stocking index less than 25 is considered inadequate for mid-Atlantic hardwood stands, and is the assessment point that distinguishes “Caution” from “Significant Concern” for MORR, ELRO/HOFR, VAMA and WEFA. While this stocking index is a useful

baseline for the remaining parks, it may need to be refined for northern hardwood and boreal spruce-fir forest systems.

The final and newest indicator is a qualitative assessment of deer browse impact at each plot based on the presence of browse-preferred and non-preferred woody and herbaceous species (Table 5). This method was adapted from Brose et al. (2008), and Perles et al. (2010), and was initially implemented in 2009. Starting in 2010, the browse index was modified for ACAD to account for the absence of browse-preferred species for reasons other than deer browse, and relies more on signs of deer (e.g., scat, deer trails, browse, etc.) than presence of browse-preferred species. The deer browse index in this report only includes 2010 data, and has not been incorporated into regeneration metric calculations. As more data are collected and deer density data are available, we will assess if the deer browse index is appropriate to incorporate the tree regeneration metric.

Currently tree regeneration appears to be adequate in ACAD, MABI, MIMA and SAGA, as all seedling size classes are represented (Figure 2), the mean stocking index is over 40 in all four parks, and the average deer browse index is below 3 (Table 6). For MIMA and SAGA, seedling densities are a bit lower than expected. Considering the average deer browse index is < 3 , browse pressure may be moderately impacting regeneration in MIMA and SAGA, or other factors such as stand development and invasive species may be involved. It will be important to track regeneration in these parks to see how these patterns change over time.

Table 5. Index of deer browse impacts assessed for each plot in national historical parks and sites (NHPs) and ACAD (adapted from Brose et al. 2008 and Perles et al. 2010).

Parks	Level	Browse Impact	Description
NHPs	1	None	Plot located inside deer enclosure, and no browse.
	2	Low	No observed browse; browse preferred species present.
	3	Moderate	Evidence of browse; browse preferred regeneration present but with little height variability; non-preferred and browse resistant species common.
	4	High	Browse evidence common; browse preferred species rare to absent; non-preferred or browse resistant vegetation limited in height by browsing.
	5	Very High	Browse evidence omnipresent; browse preferred species absent; browse resistant plants show signs of heavy browsing and browse line evident.
ACAD	1	None	Plot located inside deer enclosure, and no browse.
	2	Low	No observed browse or sign of deer activity on plot
	3	Moderate	Evidence of browse and signs of deer activity on the plot
	4	High	Browse evidence common; and non-preferred species show signs of browse
	5	Very High	Browse evidence omnipresent; browse resistant and non-preferred species show signs of heavy browsing and browse line evident.

Seedlings less than 30 cm tall are abundant in SARA. However, seedlings in height classes over 1 m are less common, sapling density is low, and the mean deer browse index is over 3. SARA also has the lowest seedling ratio. These indicators all suggest that deer browse pressure may be impacting forest regeneration in SARA. Competition from invasive exotic species, such as exotic bush honeysuckle (*Lonicera* spp.), may also be limiting tree regeneration (see section on Invasive Plant Indicator Species). An important next step will be to quantify deer densities in the park using the distance sampling data that are collected annually. If densities are above 8.5 per km², the park may want to consider developing a deer management plan.

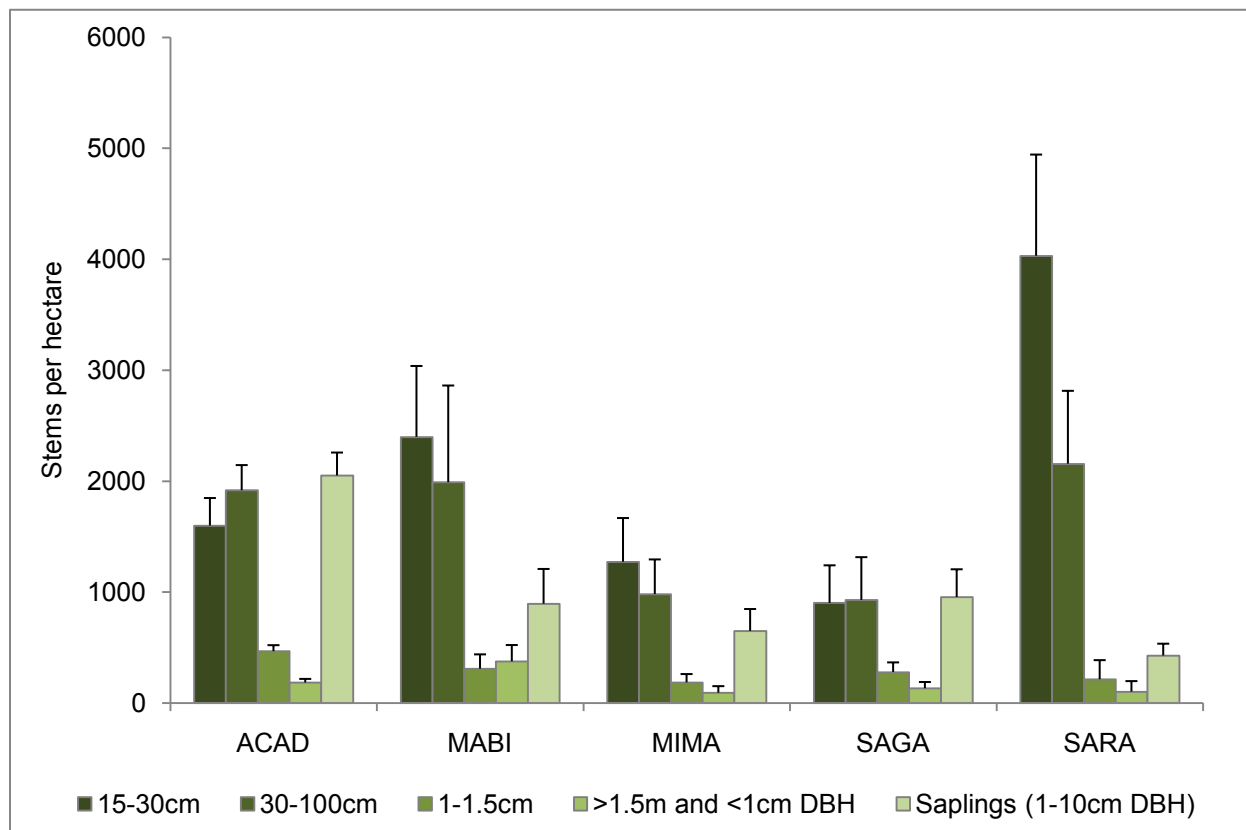


Figure 2. Mean seedling and sapling density (stems/ha) based on data collected from 2007-2010. Error bars denote +1 SE about the mean.

Table 6. Mean stocking index and seedling ratio based on data collected from 2007-2010. Mean deer browse index is based on 2010 data only.

	Stocking Index		Seedling Ratio		Deer Browse Index	
	Mean	SE	Mean	SE	Mean	SE
ACAD	142.79	14.02	-0.10	0.06	2.80	0.07
MABI	75.83	25.34	-0.14	0.13	2.67	0.14
MIMA	47.19	13.91	-0.11	0.18	2.80	0.13
SAGA	75.79	18.88	-0.38	0.10	2.55	0.16
SARA	43.54	12.61	-0.32	0.10	3.07	0.12

Tree Condition and Forest Pests

Qualitative observations of specific tree health problems and canopy foliage condition can provide an early warning of problems or decline in canopy trees of a particular species or region. As the season progresses, most trees develop minor foliage problems. However, more extensive damage to canopy foliage may be indicative of tree health problems within a species or across a region, and could be related to soil chemistry, climate stress, pathogens, or other stressors. In particular, exotic pests and pathogens have the potential to severely impact forest tree composition as well as structure and function. A number of exotic pest species pose serious threats to northeastern forests if they advance into the region, including Asian longhorned beetle (ALB), emerald ash borer (EAB), hemlock woolly adelgid (HWA), and sudden oak death (SOD); these are NETN “Priority 1” forest pests. Other forest pests can cause problems that are not quite as severe. These NETN “Priority 2” pests include balsam woolly adelgid (BWA), beech bark disease (BBD), butternut canker (BC), and elongate hemlock scale (EHS).

To calculate this metric, specific tree health problems are tallied per plot, and average percent foliage condition is calculated for the plot and for each tree species represented by two or more individuals. Good condition is defined as minor foliage problems averaged across a plot and within individual species, minor damage from BBD, and no evidence of damage by the other specific invasive exotic pests and pathogens noted. More extensive foliage problems (10-50%), or BBD damage, or evidence of damage by one of several invasive exotic pests and pathogens already widespread in the NETN region (BWA, BC, and EHS) indicate cause for concern. Foliage damage above 50% averaged across a stand or within an individual species (represented by at least two individuals) indicates a more serious problem. Likewise, evidence that certain invasive exotic pests and pathogens of high concern for extensive mortality to trees (ALB, EAB, HWA and SOD) have reached NETN forests indicates a significant concern which might still be controlled by management action.

Tree condition in 2010 was slightly better than or similar to the 2007-2010 tree condition. Most plots in SARA were rated “Good”. Roughly half of the plots in the remaining parks were rated “Good” and no plots rated “Significant Concern” in 2010 (Figure 3). MIMA had the greatest proportion of plots receiving a “Caution” rating due to moderate foliage problems, and the foliage condition that was the most often reported was holes in leaves. Holes in leaves and chlorosis of the foliage were the most common reported conditions in ACAD, MABI, and SAGA. Other than beech bark disease, no priority pests or pathogens were detected in a plot during the 2010 field season.

Hemlock woolly adelgid was detected by the crew while working in MIMA, but it was not found on a monitoring plot. HWA has been suspected within MIMA for a while, but this may be the first positive identification of the pest. HWA was detected on a hemlock about halfway between North Great Road and Virginia Road on Bedford Lane (approximate UTM coordinates: 311420 East and 4702561 North). The crew should have reported this as an early detection, but it was mistakenly overlooked during the field season and a note about the detection was found in early 2011. In the future the crew will be trained on the importance of early detection reporting to ensure speedier reporting.

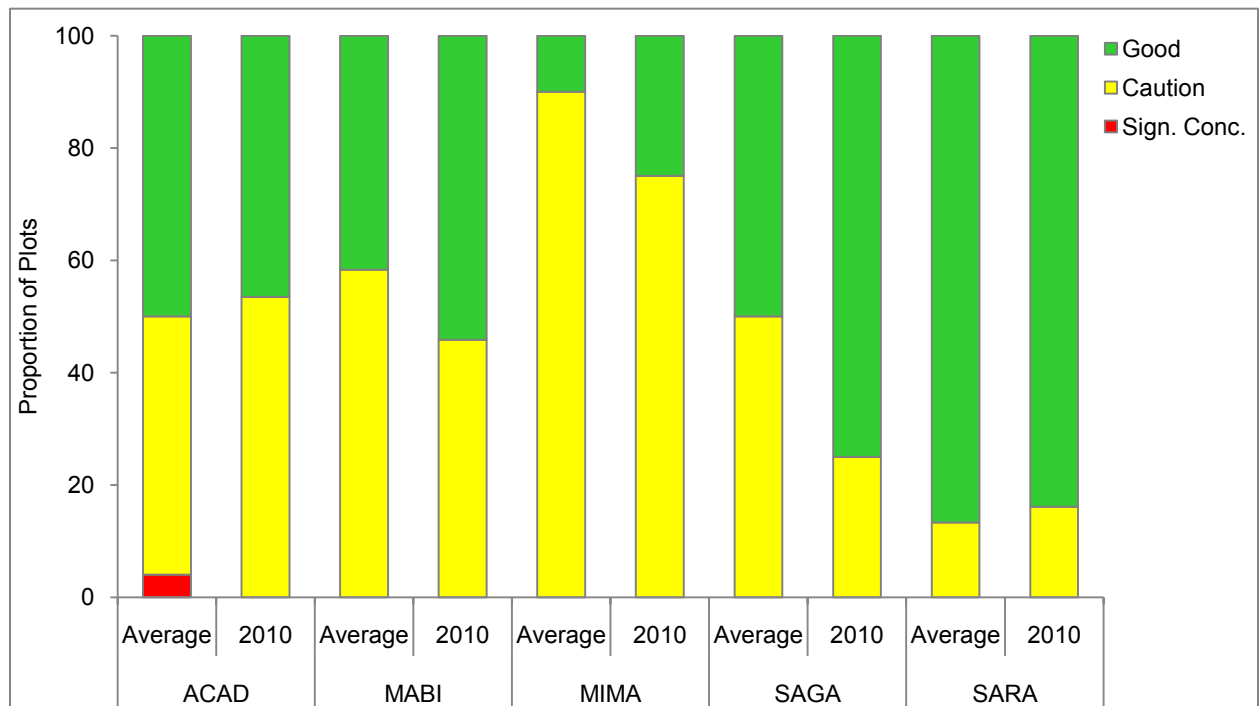


Figure 3. Proportion of plots receiving “Good”, “Caution” and “Significant Concern” ratings for tree condition for each park sampled in 2010. Average bars include 4 years (2007 – 2010) of data for ACAD, and 2008 and 2010 data for remaining parks. 2010 bars only include data collected in 2010.

HWA is one of several pests that are of particular concern in NETN parks, and that have been recently detected or are expanding within the geographic region of our network. Emerald ash borer and Asian longhorned beetle are also expanding into NETN (Appendix C). Early detection and rapid response efforts are vital to minimize impacts of these pests in NETN parks.

Invasive Exotic Plant Indicator Species

Invasive exotic species have the potential to impact structure, composition, and function of forested ecosystems, and are one of the leading threats to biodiversity and ecological integrity of ecosystems worldwide (Mooney et al. 2005). Early detection of invasive exotic plants is an important NETN vital sign that has been incorporated into several long-term monitoring protocols. Status and trends of invasive species are monitored on NETN forest plots, and the Eastern Rivers and Mountains Network (ERMN) and NETN are implementing a separate protocol for early detection of invasive species and forest pests.

To better understand the threat posed by invasive plants, we developed a list of indicator plant species that are highly invasive in northeastern forest, woodland, and successional habitats (Appendix D). Included species are those that may dominate and/or persist under shaded conditions (i.e., in forest or woodland), or that may disrupt succession to forest or woodland. Several exotic species such as knapweeds (*Centaurea* spp.) and celandine (*Chelidonium majus*) were not used as indicator species, despite being present in several parks, because they are not capable of suppressing forest succession and/or do not dominate under a shaded canopy.

Therefore, total abundance of exotic species may be higher than reported here for indicator species. Diversity and abundance of all exotic species are examined in the later section on biotic homogenization and understory diversity.

Averaging over 3.5 indicator invasive species per plot, MIMA received a “Significant Concern” rating for this metric (Table 7). SARA narrowly missed the “Significant Concern” rating by averaging 3.3 indicator invasives per plot. The five most common indicator invasives in MIMA and three most common in SARA are woody shrub or vine species (Table 8). These woody species are all capable of forming dense thickets that can reduce understory diversity, depress forest regeneration, and are of particular concern where old fields are left to succeed to forest (Woods 1993, Hutchinson and Vankat 1997, Webster et al. 2006). In SARA, we detected exotic bush honeysuckle (*Lonicera* spp.) in every plot sampled in 2010, and several large areas in the park are dominated by dense honeysuckle thickets. Exotic bush honeysuckle was detected in 70% of the plots in MIMA in 2010, and extensive areas of exotic shrub thickets also occur in this park. Efforts to eradicate exotic shrub thickets will be costly and labor intensive, but without management these thickets are likely to persist, spread, and continue to impact forest structure and understory diversity (Woods 1993).

Perhaps the greatest concern about the exotic shrub thickets in SARA relates to forest pests. In SARA, white ash (*Fraxinus americana*) and American elm (*Ulmus americana*) appear to be the only tree species capable of penetrating the shrub thicket to form a sparse canopy. The shade created by the sparse canopy may reduce shrub density enough for other tree species to become established and eventually form a continuous canopy. American elm mortality due to Dutch elm disease typically occurs by the time elms reach 15-20 cm diameter at breast height, and we have already observed elm mortality that was likely due to Dutch elm disease in half of the elms that were measured and alive in 2006. If emerald ash borer becomes established in SARA, it is unclear if there are remaining tree species capable of penetrating the exotic shrub thicket and that can persist long enough to form a canopy.

Table 7. Indicator invasive exotic plant species ratings for NETN parks. Metric ratings are based on the mean number of indicator species found per plot from 2007 to 2010.

Park	Group	# Plots	Rating	Mean #/ Plot	SE
ACAD		175	Good	0.02	0.02
MABI	Overall	24	Caution	0.63	0.16
	Natural	13	Good	0.46	0.18
	Plantation	11	Caution	0.82	0.26
MIMA		20	Significant Concern	4.30	0.45
SAGA		20	Caution	0.65	0.20
SARA		31	Caution	3.26	0.22

Table 8. Most frequent indicator invasive exotic species in NETN forest plots by park from 2007 to 2010.

Park	Latin name	Common Name	# Plot Occurrences	% Frequency
ACAD	<i>Berberis thunbergii</i>	Japanese barberry	1	0.6
	<i>Frangula alnus</i>	glossy buckthorn	1	0.6
	<i>Lonicera</i> spp.	exotic bush honeysuckle	1	0.6
	<i>Rosa multiflora</i>	multiflora rose	1	0.6
MABI	<i>Berberis thunbergii</i>	Japanese barberry	1	4.2
	<i>Berberis vulgaris</i>	common barberry	6	25.0
	<i>Lonicera</i> spp.	exotic bush honeysuckle	4	16.7
	<i>Rhamnus cathartica</i>	common buckthorn	4	16.7
MIMA	<i>Acer platanoides</i>	Norway maple	10	50.0
	<i>Celastrus orbiculata</i>	oriental bittersweet	13	65.0
	<i>Frangula alnus</i>	glossy buckthorn	18	90.0
	<i>Lonicera</i> spp.	exotic bush honeysuckle	10	50.0
	<i>Rosa multiflora</i>	multiflora rose	14	70.0
SAGA	<i>Berberis thunbergii</i>	Japanese barberry	5	23.8
	<i>Ligustrum</i>	privet	1	4.8
	<i>Lonicera</i> spp.	exotic bush honeysuckle	6	28.6
	<i>Rhamnus cathartica</i>	common buckthorn	1	4.8
SARA	<i>Alliaria petiolata</i>	garlic mustard	9	29.0
	<i>Lonicera</i> spp.	exotic bush honeysuckle	29	93.5
	<i>Rhamnus cathartica</i>	common buckthorn	28	90.3
	<i>Rosa multiflora</i>	multiflora rose	20	64.5

Soil Chemistry

NETN monitors soil chemistry to understand the effects of atmospheric deposition on the health of forest vegetation. Atmospheric deposition is a special concern for forests in the northeast and on thin soils where soil buffering capacity is generally low. Atmospheric deposition alters forest soil chemistry by depleting soil nutrients such as calcium (Ca), magnesium (Mg), and potassium (K) through leaching, and can result in increased availability of toxic aluminum (Al). Moreover, atmospheric deposition has dramatically increased inputs of nitrogen (N) in the northeast.

Concern has arisen that excess N may “saturate” forested ecosystems, causing excess nitrification and N leaching, which in turn could exacerbate the effects of acidification (Aber et al. 1998). All these changes can reduce plant growth and increase susceptibility of trees to other stresses (Bullen and Bailey 2005).

At each plot, NETN collects a composite of up to three soil samples from each O and A horizon. If no soil horizons are apparent, NETN collects a composite of the upper soil containing fine roots to a maximum depth of 10 cm. The upper soil layers (O and A) are where the bulk of fine roots are located and nutrient uptake occurs. We currently rate soil chemistry based on the ratio of exchangeable Ca to Al, which has been used as an indicator of acid stress on forest soils (Cronan and Grigal 1995), and the ratio of total C to total N, a primary indicator of N status (Aber et al. 2003, MacDonald et al. 2002). Soil metrics are rated on median values for all park samples (i.e., samples collected for each plot), rather than means, due to the non-normal distribution of values typical in soil chemistry samples.

Feedback from several soil scientists in the northeast has led us to realize that these metrics are insufficient to understand the complexity of acid deposition and stress in forest soils. We plan to revise this metric to improve accuracy and interpretability. For now, we tentatively report the Ca:Al and C:N ratios, and interpret their condition collectively.

Soil chemistry results vary across the network (Table 9). All parks but ACAD were rated “Significant Concern” for the C:N ratio, indicating that excess nitrogen may be an issue in these parks. Soil acidification may be an issue in MIMA, SAGA, and potentially ACAD.

Table 9. Soil chemistry ratings for NETN parks from 2007 to 2010.

Park	Median Ca:Al	Ca:Al Rating	Median C:N	C:N Rating
ACAD	2.60	Caution	32.15	Good
MABI	7.42	Good	14.78	Significant Concern
MIMA	0.91	Significant Concern	14.55	Significant Concern
SAGA	0.73	Significant Concern	19.10	Significant Concern
SARA	31.52	Good	13.22	Significant Concern

Biotic Homogenization and Understory Dynamics

Background

Biotic homogenization is the process by which regional biodiversity declines over time, and is often due in part to the addition of widespread exotic species and the loss of native species (Olden & Rooney 2006). This process can be driven by the spread of invasive exotic species associated with human activity, by physical and environmental habitat modification by humans, including land use and climate change, and by natural causes.

A recurring trend that has been observed throughout eastern U.S. forests is a compositional shift in forest understories in response to high deer densities (Horsley et al. 2003, Rooney et al. 2004, Wiegmann and Waller 2006, Thiemann et al. 2009, Mudrak et al. 2009). This shift is characterized by losses in deer-preferred species such as native perennial forbs and increases in browse-resistant or non-preferred species such as grasses and sedges, ferns, and exotic species (Rooney 2009). Rooney et al. (2004) found this compositional shift to be most pronounced in protected areas where deer hunting was prohibited.

Invasion of exotic earthworms (Family: Lumbricidae) has also been shown to have synergistic effects with deer overabundance on forest understories, further shifting the understory away from diverse perennial forb communities to a more simple sedge-dominated community (Frelich et al. 2006). Earthworms are not native to parks in our network (MORR may be an exception), and their invasion has the potential to drastically alter forest soils and understory communities.

Methods

Biotic homogenization was examined using Jaccard's Similarity Index to compare plant species composition between plots (Olden and Poff 2003). The index ranges from 0 to 1, and the more species in common between two plots, the closer their index score is to 1. Averaging the similarity values across all plot pairs gives a park-level similarity index. While we do not have repeat data to rate this metric, which evaluates change over time, we have adequate data to present baseline similarity scores, and examine patterns in species diversity and abundance.

Species diversity was calculated at the plot level, and includes all species detected on a plot. Average quadrat percent cover was calculated from percent cover class data collected in quadrats, and is an estimate of abundance. Using the midpoints of each cover class, percent cover was averaged over the eight quadrats per plot, and then averaged at the park level. The exotic species category includes all species that are not native to the eastern U.S., and includes more species than the invasive plant indicator species metric. Forbs are defined as herbaceous flowering plants, but do not include grasses and sedges. The fern category contains vascular plants that reproduce by spores and includes ferns and fern allies (e.g., club moss [*Lycopodium* spp.]). The graminoids group includes grasses (Family: Poaceae), sedges (Family: Cyperaceae) and rushes (Family: Juncaceae). Shrubs are all woody plants that are not tree species (i.e., species that do not have a central vertical trunk).

Presence of exotic earthworms was assessed by performing a visual inspection for earthworm evidence while collecting soil samples in each plot. While our methods aren't comprehensive

and not likely to detect earthworms at low densities, we have detected earthworms in all NETN parks and present the preliminary data below.

Results and Discussion

Jaccard similarity scores are similar across the network, and range from 0.19 in MIMA to 0.27 in ACAD and SARA (Table 10). These values indicate that on average, pairs of plots share about 20% of the same species within a park. There is no available research that we can use to judge whether a particular similarity score is appropriate for a given habitat type or park. Rather, we will use this index to detect park-level changes in understory diversity over time, as well as to examine patterns in species diversity and abundance.

Averaging nearly 60 native species per plot, SARA has the highest understory diversity overall, and in forbs, graminoids and shrubs (Figures 4A and 5A). SARA also has the highest average quadrat percent cover of native forbs, ferns, and graminoids, and is tied with MIMA for the highest average cover (approx. 44%) of native species overall (Figures 4B and 5B). Considering the high average percent cover of ferns and graminoids in SARA, it is possible that deer browse pressure has already influenced the composition of the understory. It will be helpful to quantify deer density in the park to see how close the density is to 8.5 deer/ km², the threshold where deer impacts are typically observed in the understory (Russell et al. 2001, Horsley et al. 2003).

MIMA, MORR, and SARA all average over five exotic species per plot, and exotic species occupy on average 10% or more cover in quadrats (Figure 4b). MORR is particularly invaded by exotic species, and is the only park where average cover of exotic species is considerably greater than cover of native species. High deer browse pressure has likely been an important driver in the understory patterns observed in MORR, and earthworms may also be a contributing factor (Table 11).

Table 10. Jaccard Similarity Index scores for each park (includes data collected from 2007 to 2010).

	ACAD	MABI	MIMA	MORR	ROVA	SAGA	SARA	WEFA
Similarity	0.27	0.22	0.19	0.24	0.21	0.25	0.27	0.23

Table 11. Earthworm detections in NETN parks, reported as number and % of plots with positive detections (includes data collected from 2007 to 2010).

	# of Plots	% of Plots
ACAD	7	4.0
MABI	8	33.3
MIMA	4	20.0
MORR	23	82.1
ROVA	25	62.5
SAGA	8	40.0
SARA	19	52.8
WEFA	8	80.0

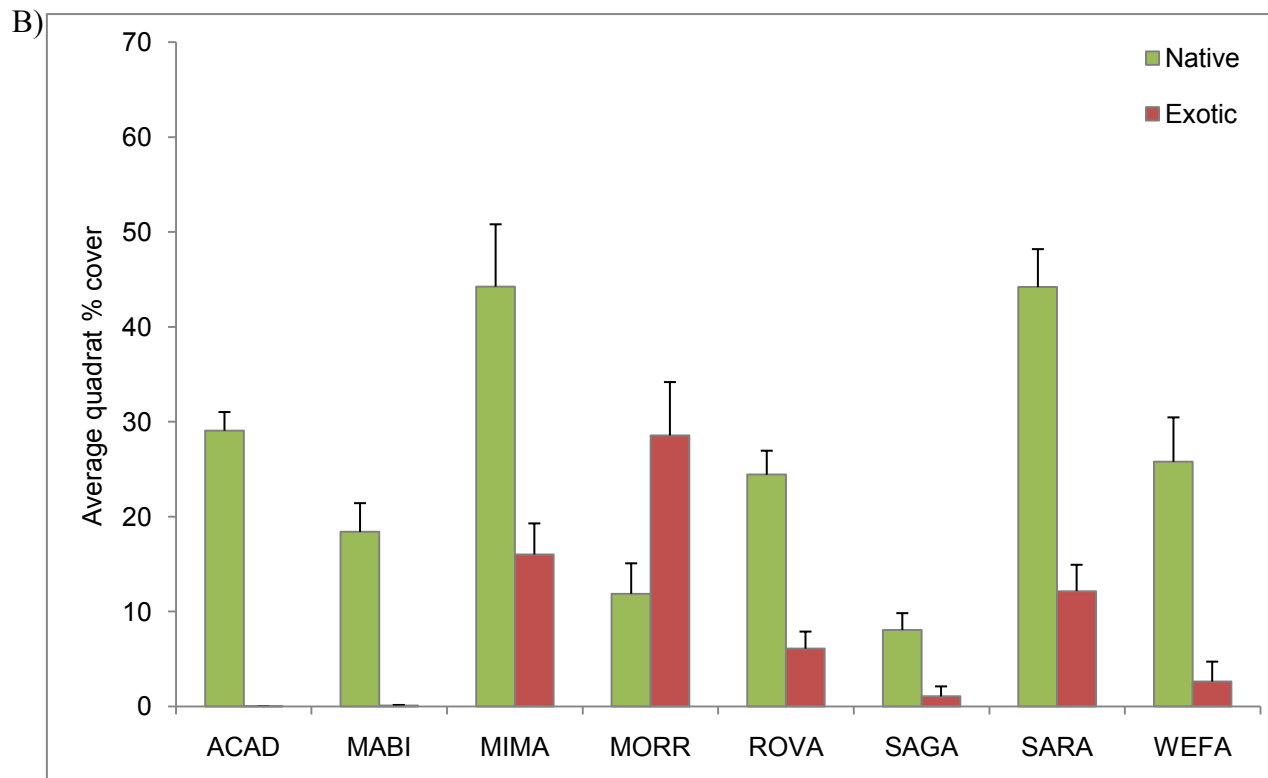
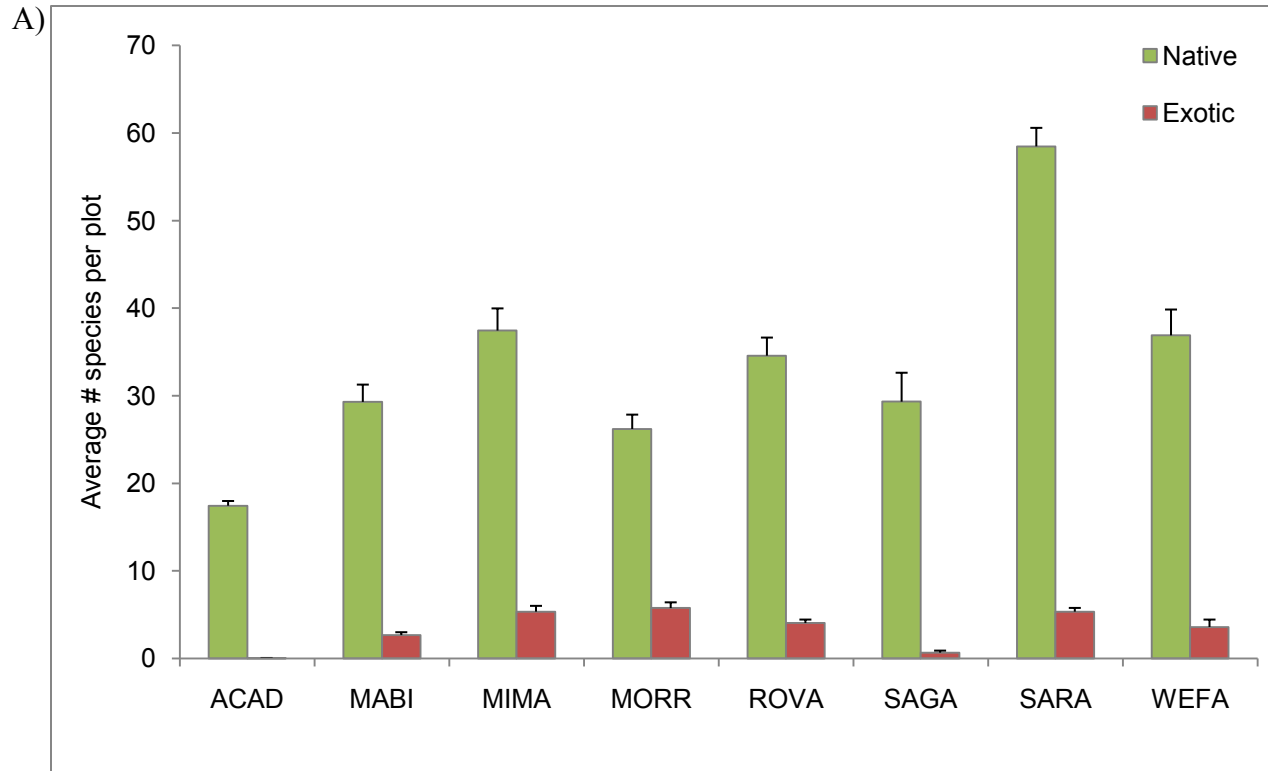


Figure 4. Average species richness per plot (A) and average quadrat percent cover (B) for native versus exotic vascular plant species for data collected from 2007 to 2010. Error bars represent +1 SE about the mean.

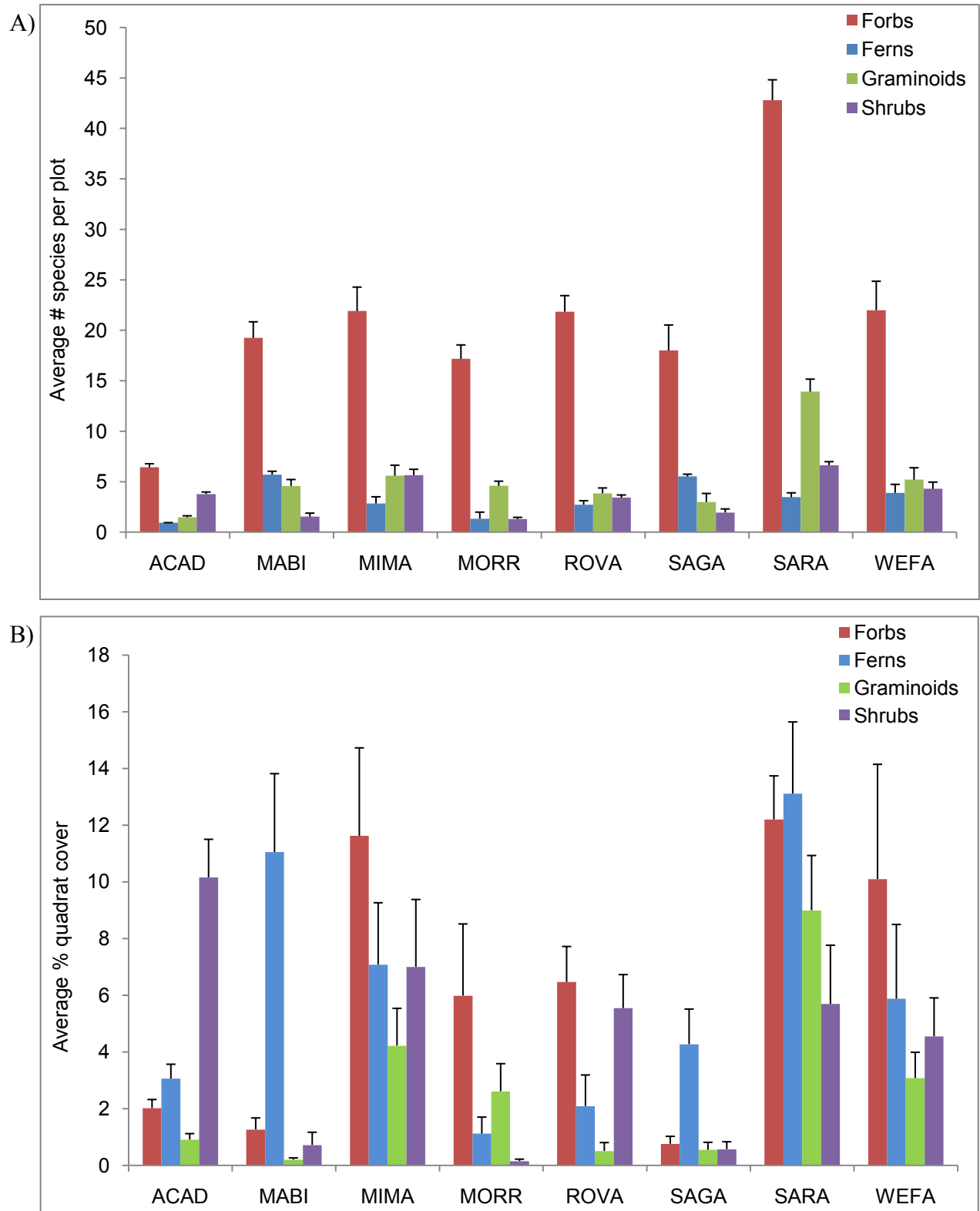


Figure 5. Average native species richness per plot by plant guild (A) and average quadrat percent cover by native plant guild (B) for data collected from 2007 to 2010. Error bars represent +1 SE about the mean.

MABI, MIMA, MORR, ROVA, SAGA and WEFA all show similar patterns in diversity by guild, with the greatest diversity of species in the forb guild (Figure 5A). Average percent cover by guild is much more variable (Figure 5B). MIMA and WEFA have very similar diversity and percent cover patterns, although percent cover is generally higher in MIMA. Low average percent cover for SAGA is likely due to the dominant forest types (i.e., hemlock and beech forests), which typically do not support rich understories.

The understory in MABI is dominated by ferns, and has relatively low cover of forbs, graminoids and shrubs. Ferns are not palatable to deer, and it is possible that the high abundance of ferns may be a result of deer browse pressure on preferred species. However, we are missing an important component of the forb group in MABI, as our field schedule does not allow us to sample for spring ephemerals. Spring ephemerals are sensitive to deer browse (Thiemann et al. 2009), and more information on abundance and diversity of spring ephemerals and deer densities will be necessary to determine if deer are impacting forest condition in MABI. Another potential factor affecting the abundance of forbs is invasion of earthworms, as exotic earthworms have been detected on more than a third of the forest plots in MABI (Table 11).

Exotic species diversity and cover, and earthworm invasion rates were lowest in ACAD. Native species diversity and abundance were also relatively low in ACAD. This is to be expected, as the thin, acidic soils and boreal climate in ACAD do not support the vascular plant diversity that the northern hardwood forests dominating most NETN parks typically support.

These preliminary results suggest that deer browse pressure may be influencing forest understories in SARA and MABI and deer are very likely impacting the understory in MORR. However, these results are preliminary for MABI and SARA, and we need repeat data and information on deer density trends before cause-effect relationships can be investigated. Exotic earthworms may also be impacting forest understories in all parks but ACAD, and we plan to examine this issue further in next year's annual report.

Landscape Context

Prior to European settlement, the northeastern U.S. was primarily forested and dominated in large part by climax forest (Lorimer and White 2003). Over the last 350 or so years, large shifts in land use in the northeastern U.S. have caused radical changes in forest habitat starting with widespread logging and land clearing and later reforestation following agricultural abandonment (Foster et al. 1998). Currently the northeastern U.S. is primarily forested, but the forests typically are highly fragmented and impacted by anthropogenic land use and human disturbance. Negative impacts from fragmentation and human land use on forest condition include reduction in interior forest habitat, increased risk of exotic species invasion, loss of biodiversity, and altered forest structure and composition (Austen et al. 2001, Boulinier et al. 2001, Fahrig 2003, Lundgren et al. 2004, Harper et al. 2005, Honnay et al. 2005). In this section we characterize forest patch size and adjacent anthropogenic land use to examine the extent that surrounding landscape may be influencing forest condition in NETN parks.

Landscape context was examined by delineating forest patch size at the park level, and adjacent land-use analyses were performed at the level of the forest plot. All spatial analyses were performed using recent leaf-on orthophotography, were delineated at the 1:6,000 scale or finer, and incorporated vegetation map delineations where appropriate. For more detail on the justification and methods for generating forest patch size and anthropogenic land use data, refer to the Landscape Context SOP in Tierney et al. (2010).

Forest patch size was defined as an area of continuous medium to high-canopy (≥ 8 m height) forest vegetation or plantation with at least 60% overall canopy closure and at least 0.5 ha. Roads wide enough to register as a break in the canopy on an orthophoto cannot be contained by a forest patch. Woodlands, though naturally occurring in ACAD, were not included in forest patch delineations. This definition of a forest patch is very similar to that used by the U.S. Forest Service Forest Inventory and Analysis (FIA) program, with the exception that FIA's minimum patch size is 0.4 ha and uses a minimum stocking percent instead of a minimum stand height and density (Riemann and Tillman 1999). To be included in the analysis, forest patches had to contain area within one of the major park units currently being monitored with forest plots (e.g., small islands in ACAD were not included in the analysis). However, where there was no visible break in the canopy, forest patches extended beyond the park boundary.

Forest patch size ratings were derived from Kennedy et al. (2003), which reviewed the literature to determine the minimum patch area required by a variety of taxa. Minimum patch sizes ranged from 1 ha for invertebrates, 10 ha for small mammals, up to 50 ha for most bird species, and over 200,000 ha for large mammals. Considering their relatively small size, NETN parks are not capable of independently supporting large mammal populations, and thus our ratings are based on the needs of birds, which thus also meets the needs of small mammals and invertebrates.

Currently, forest patch size at ACAD is calculated but not rated because naturally-occurring woodlands and forests historically co-exist at this site as a patchwork and naturally limit forest patch size. For all other parks, each patch is rated based on size, and the area of forest in each size category is reported at the park level. Ratings for patch sizes are as follows:

Good Patch is ≥ 50 ha

Caution: Patch is 10 to less than 50 ha

Significant Concern: Patch is 0.5 to less than 10 ha.

Adjacent anthropogenic land use (ALU) was delineated at the plot level, and was calculated as the percentage of anthropogenic land use within the local or immediate neighborhood surrounding each plot. Because parks vary substantially in size, the “neighborhood” considered around each plot was adjusted for park size. Plantations of exotic tree species, maintained open fields, active farmlands, roads, and residential sites were all considered anthropogenic land use. Native tree plantations, abandoned fields, woodlands, and early successional forests were considered natural land use. Neighborhoods (i.e., plot buffers) of different plots commonly overlapped in parks. While the mean % ALU was unbiased, the lack of independence between plots did not allow for straight-forward standard error estimates.

Adjacent anthropogenic land use ratings were derived from theoretical models that examined the combined impacts of habitat loss and fragmentation. Simulations examining connectivity and proportion of natural habitat found 60% natural habitat to be an important threshold; likelihood of a continuous landscape sharply declined below 60% natural habitat (McIntyre and Hobbs 1999, O'Neill et al. 1997). Therefore, we use $> 40\%$ anthropogenic land use to define a “Significant Concern” rating for this metric. Ratings for this metric are as follows:

Good: Less than 10% anthropogenic land use.

Caution: 10-40% anthropogenic land use.

Significant Concern: More than 40% anthropogenic land use.

Acadia National Park

Forest patch size varied across the four management units in ACAD, but over 80% of the forest area across all units occurred in patches that were more than 50 ha in size (Figure 6). The largest patch was on western Mount Desert Island (MDI) and was 940 ha (Table 12). We currently do not rate this metric for ACAD because naturally occurring woodlands and forests historically co-exist at this site as a patchwork that naturally limits forest patch size. Woodlands were most common on eastern MDI and Schoodic Peninsula, resulting in smaller forest patch sizes within these units. Forest patches were most fragmented by roads on the eastern side of MDI, where road density in and adjacent to the park was highest and clearly visible on orthophotos (Appendix E: Figures 1-4). Over 20% of the area delineated as forest patch extended outside the boundary of the park, and several of the largest patches on eastern MDI and Isle au Haut extended well beyond the park boundary and were not protected by easements.

Despite having the largest plot buffer (400 m radius), ACAD had the lowest anthropogenic land use (ALU) score in the network (Figure 7 and Table 13), and received a “Good” rating for all park units. Plots in the eastern section of MDI and on Schoodic Peninsula had the highest proportion of neighborhood ALU, but plot neighborhood areas still averaged over 95% natural

habitat. Roads and parking areas were the most common features delineated as anthropogenic land use.

Marsh-Billings-Rockefeller National Historical Park

Forest patch area in MABI was rated “Good” and delineated as one large, 455 ha patch (Table 12). Over half of this patch extended beyond the park boundary, and included the town-owned Billings Park, portions of King Farm, and privately-owned land north of MABI (Appendix E: Figure 5).

Averaging 11% anthropogenic land use (ALU), MABI narrowly received a “Caution” rating for this metric (Figure 7 and Table 13). The two most common types of ALU were forest plantations composed of exotic tree species, and open fields (Appendix E: Figure 6). Over half of the plots had no ALU within a 200 m radius. Increased development or clearing north of the park boundary and east of Prosper Road have the greatest potential to impact forest patch size and increase anthropogenic land use near forest plots.

Minute Man National Historical Park

Forest patches in MIMA were highly dissected by roads, residential development, and maintained open fields (Appendix E: Figure 7). Over 60% of the forest patch area in the park was rated “Caution” for the metric (i.e., were part of patches between 10 and < 50 ha), and another 25% of forest patch area was rated “Significant Concern” (were part of patches between 0.5 and less than 10 ha; Figure 6 and Table 12). The largest forest patch started in MIMA near Folly Pond and extended past Hobbs Brook to Cambridge Turnpike. This was the only forest patch in the park that was rated “Good”, and only about 10% of this large patch occurred within the park boundary.

MIMA was rated “Caution” for adjacent anthropogenic land use (ALU; Figure 7 and Table 13). ALU was most abundant and closest to the boundary northeast of the park where the Hanscom Air Force Base is located (Appendix E: Figure 8).

The high abundance and diversity of invasive species in MIMA are at least partially a result of the high fragmentation and intense development surrounding MIMA. Land use history and past disturbance are also likely factors in the spread of invasive species. Faccio and Mitchell (2010) also suggest that fragmentation and intense land use have impacted avian communities in the park. Minimizing further fragmentation of the larger patches is advisable.

Morristown National Historical Park

MORR was rated “Good” for both forest patch size and anthropogenic land use (Figures 6 and 7). Forests in MORR consisted of two large patches, both of which extended well beyond the park boundary and into Lewis Morris County Park and the Scherbarn-Hoffman Audubon Sanctuary (Appendix E: Figures 9-10). Because MORR is primarily forested, and most of the boundary is buffered by forest, most plots had no neighborhood anthropogenic land use (ALU).

Residential development existed at the margins of many of the forest patches and the overall patch size may be a bit misleading. Other than the adjacent county park and Audubon sanctuary, the land surrounding MORR is heavily developed. It is possible that the lack of suitable natural

habitat outside of the park and adjacent protected areas, along with lack of predators, is contributing to the deer overabundance problem.

Roosevelt-Vanderbilt National Historic Sites

Forest patch size was rated separately for each unit of ROVA, and HOFR was split into two management units (separated by Route 9). ELRO and HOFR were combined in the anthropogenic land use (ALU) metric because there is not a sufficient sample size in ELRO to support a stand-alone analysis.

Forest patch sizes varied considerably by park unit, and there was no forest patch connectivity between any of the four units (Appendix E: Figure 11). Over 98% of forest area in HOFR-East and HOFR-West was rated “Good” for patch size (Figure 6). In contrast, 60% of the forest patch area in VAMA was rated “Caution” for patch size and 40% was rated “Significant Concern”. Patch size ratings in ELRO forests were mixed, with 60% of forest patch area rated “Good” and occurring in one large, 170 ha patch. The remaining 40% of forests in ELRO were split between patches rated “Caution” and “Significant Concern”.

Both units of HOFR and ELRO have a decent forest buffer around portions of the park boundary. Increased development or land clearing in these areas could impact forest health in ROVA in a variety of ways, including an increased risk of exotic species invasion, or an increase in deer densities due to habitat loss elsewhere.

VAMA is the smallest of the ROVA park units, and thus the ALU calculation was down-scaled to a 100m buffer. Despite the smaller buffer (100 m versus 200 m at ELRO/ HOFR), VAMA forest plots had a high percentage of neighborhood ALU and VAMA was rated “Caution” for this metric. In contrast, ELRO/HOFR averaged a little over 5% neighborhood ALU, and was rated “Good”. Plots in the east section of HOFR had the least amount of neighborhood ALU (Figure 7 and Table 13).

Saint-Gaudens National Historic Site

SAGA was rated “Good” for both forest patch size and neighborhood anthropogenic land use (Figure 6 and Figure 7). Forest patch habitat consisted of two large patches, the largest of which started east of Saint-Gaudens Road, and continued nearly 2 km east and south to include most of Dingleton Hill (Appendix E: Figure 14). Considering that over 90% of area of both forest patches occurred outside of the park, most of SAGA had a good buffer of natural habitat around the boundary.

Roughly half of the plots in SAGA had over 10% neighborhood ALU (100 m buffer radius), but seven plots had no ALU (Figure 7). Neighborhood ALU was highest in plots located near the buildings and gardens in the park, and close to the northeastern border (Appendix E: Figure 14). Development to the east of SAGA may have the greatest potential to impact the condition of park forests and fauna dependent on interior forest habitat.

Saratoga National Historical Park

Forest habitat was considerably fragmented by fields and roads inside the park boundary, and agricultural lands dominated the area outside of the park boundary (Appendix E: Figure 15). While 56% of forest patch area in SARA occurred in patches that were rated “Good”, 32% of

forest patch area was rated “Caution” and 12 % was rated “Significant Concern” (Figure 6). Neighborhood ALU (200 m buffer radius) was also fairly high, was rated “Caution”, and averaged 11% per forest plot (Table 13). Neighborhood ALU consisted primarily of open fields (Appendix E: Figure 16).

Habitat fragmentation may have contributed to spread of invasive species in SARA, and it appears that aggressive invaders, such as exotic bush honeysuckles (*Lonicera* spp.), are maintaining habitat fragmentation by inhibiting forest succession.

Weir Farm National Historic Site

While over 80% of forest area in WEFA was rated “Good” for forest patch size (Figure 7), the buffer surrounding the park was significantly fragmented by residential development (Appendix E: Figure 17). As a result, most forest patches had a Swiss cheese pattern. Considering the patchwork of houses surrounding WEFA, it was not a surprise that ALU was high enough to warrant a “Caution” rating (Appendix E: Figure 18).

A broader view of the area shows that the forest patches extending from WEFA and just outside of the park are surrounded by dense residential development. WEFA and the forest patches nearby are likely important wildlife habitat, which may be contributing to deer overabundance in the park.

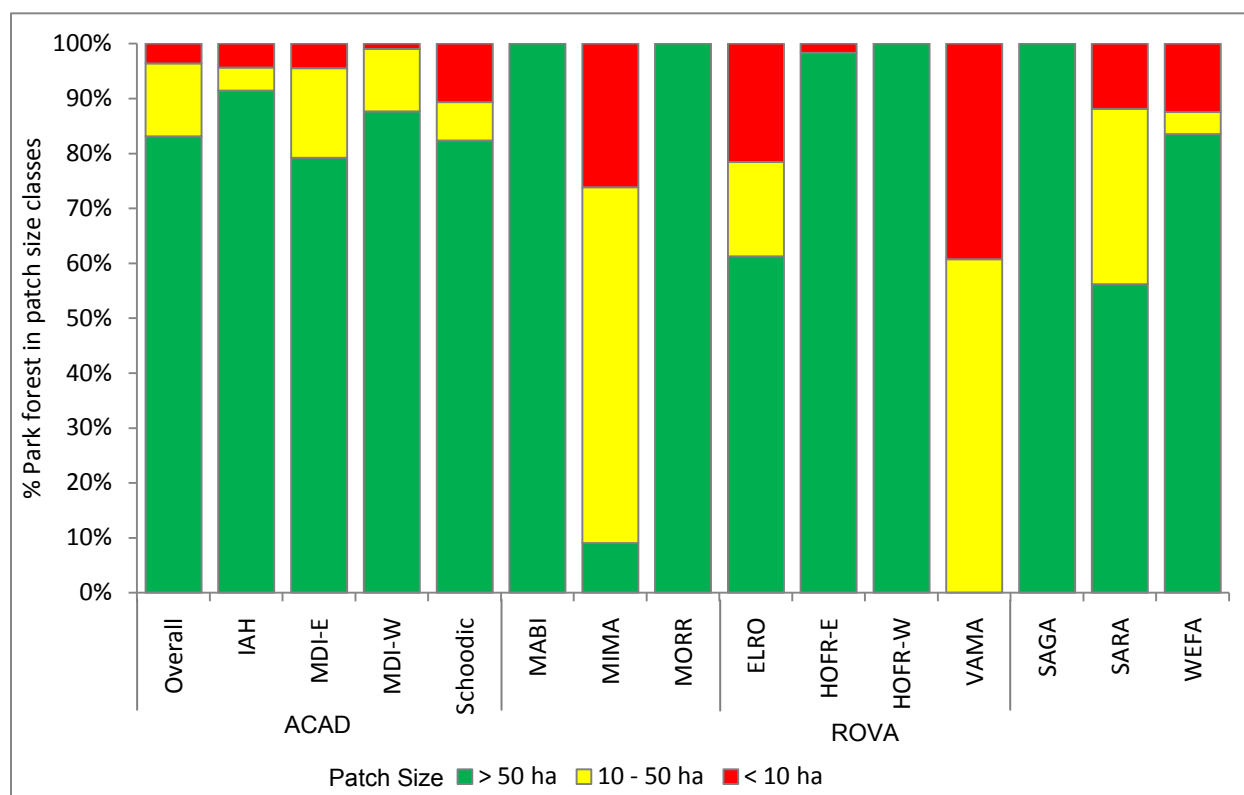


Figure 6. Proportion of park forest in each patch size category. Bar colors reflect the Ecological Integrity rating where green is “Good”, yellow is “Caution”, and red is “Significant Concern”. ACAD is not rated for this metric.

Table 12. Forest patch statistics for each park unit. Parks with one forest patch have patch size listed only in the Maximum column. Parks with two forest patches have patch sizes listed only in the Minimum and Maximum columns. % of Patches Outside of Park is the average percentage of forest patch area that is outside the park boundary. NAIP Imagery was produced by the USDA National Agriculture Imagery Program.

Park	Unit	Patch Size (ha)					# Patches	% of Patches Outside Park	NAIP Imagery
		Minimum	25% Quartile	Median	75% Quartile	Maximum			
ACAD	Overall	0.54	2.28	7.73	32.46	939.88	247	23.69	2009
	IAH	0.55	1.42	2.55	13.30	850.30	19	30.09	2009
	MDI-E	0.60	2.27	7.49	29.10	734.95	151	25.23	2009
	MDI-W	0.54	4.87	13.76	60.17	939.88	55	22.84	2009
	Schoodic	0.55	0.88	3.75	8.50	197.70	22	6.95	2009
MABI		---	---	---	---	455.09	1	57.42	2009
MIMA		0.53	1.91	4.77	20.27	161.59	44	60.50	2010
MORR		609.62	---	---	---	818.37	2	56.77	2008
ROVA	ELRO	1.28	2.91	3.88	7.58	172.42	7	71.16	2009
	HOFR-E	2.01	6.11	72.74	146.80	173.22	4	61.06	2009
	HOFR-W	---	---	---	---	175.06	1	50.24	2009
	VAMA	0.76	2.42	3.67	4.41	33.37	6	24.32	2009
SAGA		67.93	---	---	---	395.24	2	91.49	2009
SARA		0.50	2.02	5.13	35.85	168.91	38	36.04	2009
WEFA		9.97	17.46	41.92	66.45	74.13	4	89.06	2010

Table 13. Anthropogenic land use statistics and ratings for each park unit. Anthropogenic Land Use Percent is the percent of anthropogenic land use within the specified buffer surrounding each forest plot. SE is standard error. Plot Maximum and Minimum report the maximum and minimum individual plot values.

Park	Unit	Buffer radius (m)	Number of plots	Anthropogenic Land Use Percent			Rating
				Plot Average	Plot Maximum	Plot Minimum	
ACAD	Overall	400	175	2.9%	31.7%	0%	Good
	IAH	400	19	0.9%	2.6%	0%	Good
	MDI-E	400	82	4.1%	31.7%	0%	Good
	MDI-W	400	65	1.8%	13.6%	0%	Good
	Schoodic	400	9	3.8%	17.4%	1.1%	Good
MABI		200	24	11.0%	48.7%	0%	Caution
MIMA		200	20	28.3%	52.0%	9.4%	Caution
MORR		200	28	5.3%	20.3%	0%	Good
ROVA	ELRO/HOFR	200	24	5.2%	26.4%	0%	Good
	VAMA	100	16	23.2%	47.7%	0.5%	Caution
SAGA		100	21	9.3%	38.8%	0%	Good
SARA		200	32	11.7%	48.8%	0%	Caution
WEFA		100	10	10.5%	29.9%	0%	Caution

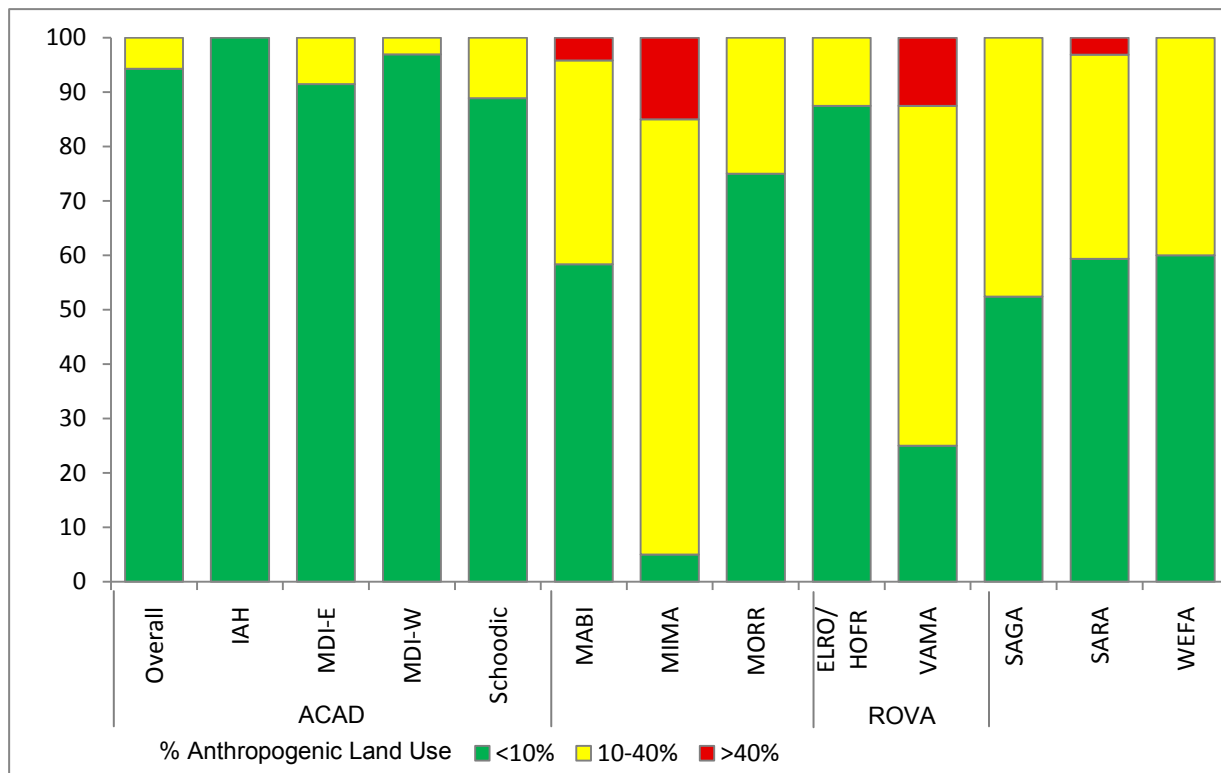


Figure 7. Proportion of specified neighborhood buffer areas around forest plots in each percent anthropogenic land use category. Bar colors reflect the Ecological Integrity rating where green is “Good”, yellow is “Caution”, and red is “Significant Concern”.

Management Implications

Acadia National Park

Ecological integrity metrics related to forest structure (e.g., coarse woody debris and snag abundance) suggest that forests in ACAD are beginning to reach mature stages, but still lack late-successional structure such as medium to large snags. As long as forest composition metrics remain stable (e.g., invasive species, tree condition/forest pests and regeneration), we expect late-successional structure to develop over time. Our only suggestion is for the park to continue exotic plant management and early detection efforts.

Marsh-Billings-Rockefeller National Historical Park

Coarse woody debris and snag abundance continue to be lower than expected for late-successional hardwood stands. As long as forest pests and invasive species are kept at a minimum, and management activities do not reduce the potential for formation of dead wood, these metrics are expected to improve as the stands mature and develop more structure. Alternatively, increased use of management techniques designed to maintain or enhance snags and CWD in this working forest may enhance desired structural features sooner.

Eradication of exotic shrub species in MABI is especially important. Exotic shrubs, such as bush honeysuckle (*Lonicera* spp.) and Japanese barberry (*Berberis thunbergii*) have caused significant impacts to forest condition in other network parks, and once established eradication is costly and labor intensive.

Regeneration and understory data are beginning to show potential deer impacts. Quantifying deer densities in the park will be a helpful step to determine if deer densities are high enough to impact forest condition in MABI.

Minute Man National Historical Park

Invasive species, particularly thickets of exotic shrubs, are negatively impacting forest condition in MIMA. Without management efforts, these exotic shrub thickets are expected to persist and spread into new areas.

An emerging threat to forest health in MIMA is the Asian longhorned beetle (ALB). With a range of hardwood host species and high fecundity, the ALB is a huge threat to the northern hardwood forest. An extensive infestation of ALB was discovered in 2008 not far from MIMA in Worcester, MA (Appendix D). The quarantine area continues to expand as ALB is detected by search teams further from the original infestation. Early detection and rapid response of ALB is important not just for the health of forests in MIMA forests, but for the entire northern hardwood forest.

Saint-Gaudens National Historic Site

While invasive species are present in SAGA, they do not appear to be greatly impacting forest condition. Management should continue its efforts to eradicate invasive species, especially exotic shrub species. Hemlock woolly adelgid (HWA) may pose the greatest threat to forests and cultural landscapes in SAGA. Early detection efforts should focus on surveillance for HWA in and around the park.

Saratoga National Historical Park

The combined impacts of invasive species and deer herbivory appear to be altering forest condition in SARA. While we encourage the continued eradication efforts by park staff, reduction in deer densities may be an important part of the solution. Deer are known to spread exotic species through excrement (Williams and Ward 2006) and to promote non-palatable species, including many exotic species, ferns and graminoids (Rooney 2009). Exotic earthworms may also be impacting forest understories in SARA. An important next step will be to quantify deer densities in the park using the distance sampling data that are collected annually.

Emerald ash borer (EAB) poses a significant threat to forests in SARA. White ash is a common forest species in SARA, and it appears to be the only tree species capable of penetrating and persisting in the exotic shrub thickets in the park. Ash are also the most abundant seedlings in the 15-30 and 30-100 cm height classes (Miller et al. 2010). Loss of ash in SARA would cause extreme changes in forest composition and structure. Early detection and outreach efforts to prevent spread of EAB into SARA are extremely important, especially considering the recent detection of EAB in southern NY.

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Appendix A. Protocol implementation for the 2010 field season

Sampling Inconsistencies and Data Issues

Overall data quality for the 2010 field season was very good. The crew members had more field experience coming in to the season than in previous years, and were quick to pick up sampling techniques. Using PowerPoint presentations to introduce each standard operating procedure and demonstrate unusual sampling situations also improved crew training.

The new user friendly database for field data entry contributed to data quality. The crew made good use of data collected from plots in 2006, and their experience supported the idea that the crew should be provided with as much data from previous sample events as possible.

The greatest challenge for the 2010 crew was organization and data management. Photopoints were not regularly downloaded from field cameras and saved in the proper locations, and as a result several plots are missing photopoints for this round of sampling. All microplot data for SAGA plot 008 were lost, and this plot had to be removed from regeneration calculations in this report. The entire set of datasheets for ACAD plot 029 also went missing, and those data were not replaceable. Data associated with ACAD plot 029 were not included in analyses in this report.

Quality Control and Quality Assurance (QA/QC)

In general, comparisons between the crew data and QA/QC collected data were good. In some cases, diameter at breast height (DBH) could have been more accurate. This is especially the case for leaning trees and very large diameter trees where locating DBH can be tricky. We therefore are requiring that all leaning trees and trees over 40cm be paint-marked at DBH.

During QA/QC in SAGA we found that the crew occasionally misclassified super-canopy white pine trees as the co-dominant layer instead of the dominant canopy layer on a plot. This misclassification resulted in a stand height being overestimated for at least one plot. Both stand height and crown classes are used to calculate live tree volume for the coarse woody debris metric. To make sure we did not over-estimate live tree volume, and therefore underestimate the CWD ecological integrity metric, we changed the crown classes and stand height to the 2010 QA/QC values (where available) or back to the original values from 2006.

Resampling and Protocol Revision

In general, plots were easy to relocate, and most of the plot markers were still present. However, it was common for one or several stakes per plot to be missing, out of the ground, or off from the expected location. The upper-right stake was most frequently off, and had to be relocated often. This was an artifact of our original plot establishment method, which started at the upper center position and went counter clockwise to end at the upper-right corner. We expect the plots that were set up in 2007 to have similar issues as the 2006 plots, and these will be sampled next year. Plots established in 2008 and later were set up from plot center using laser rangefinders, which are much more accurate than compasses and tapes and do not have issues of compounding errors like the original method.

Appendix A. Protocol implementation for the 2010 field season (continued)

In previous study years, tree tags were most often attached using cable ties and a staple gun. Although this method is faster than using nails and allows the tree to grow larger before the tag has to be replaced, the field crew found that many tree tags were no longer attached in the plots that were resampled this year. There were several plots in SARA where at least half of the tags were missing, and the crew spent considerable time figuring out which tree was which. As such, all future tags will be attached to trees with nails. It also helps that we are now mapping the distance and bearing to each tree from plot center.

The final issue that surfaced during resampling related to plot disturbance. There were two plots in MIMA that received moderate understory disturbance since their establishment in 2006. Had these disturbances been present during plot establishment, we would have rejected both sites and established plots in a different location. However, we decided that once plots were established, they will only be rejected if part of the plot is permanently converted to non-forest habitat. One-time impingement of mowing or brush removal will not be grounds for plot rejection.

Two plots in SARA were also disturbed since establishment in 2006. An array of amphibian coverboards intersected with SARA plot 07, and one coverboard was in one of the quadrats in the plot. While we encourage other researchers to co-locate their sampling sites near NETN forest plots, we recommend these sites be 50 m from the forest plot center to make sure NETN forest plots are not disturbed by other research projects. The second plot (SARA 14) was located in the Hudson River floodplain, and all permanent plot markers had been buried or washed away. We will reestablish a plot at this site in 2012 for sampling in 2014 using more permanent and taller plot markers. Data associated with SARA plot 14 were not included in the analyses for this report.

Appendix B. Indicator species used for seedling ratio.

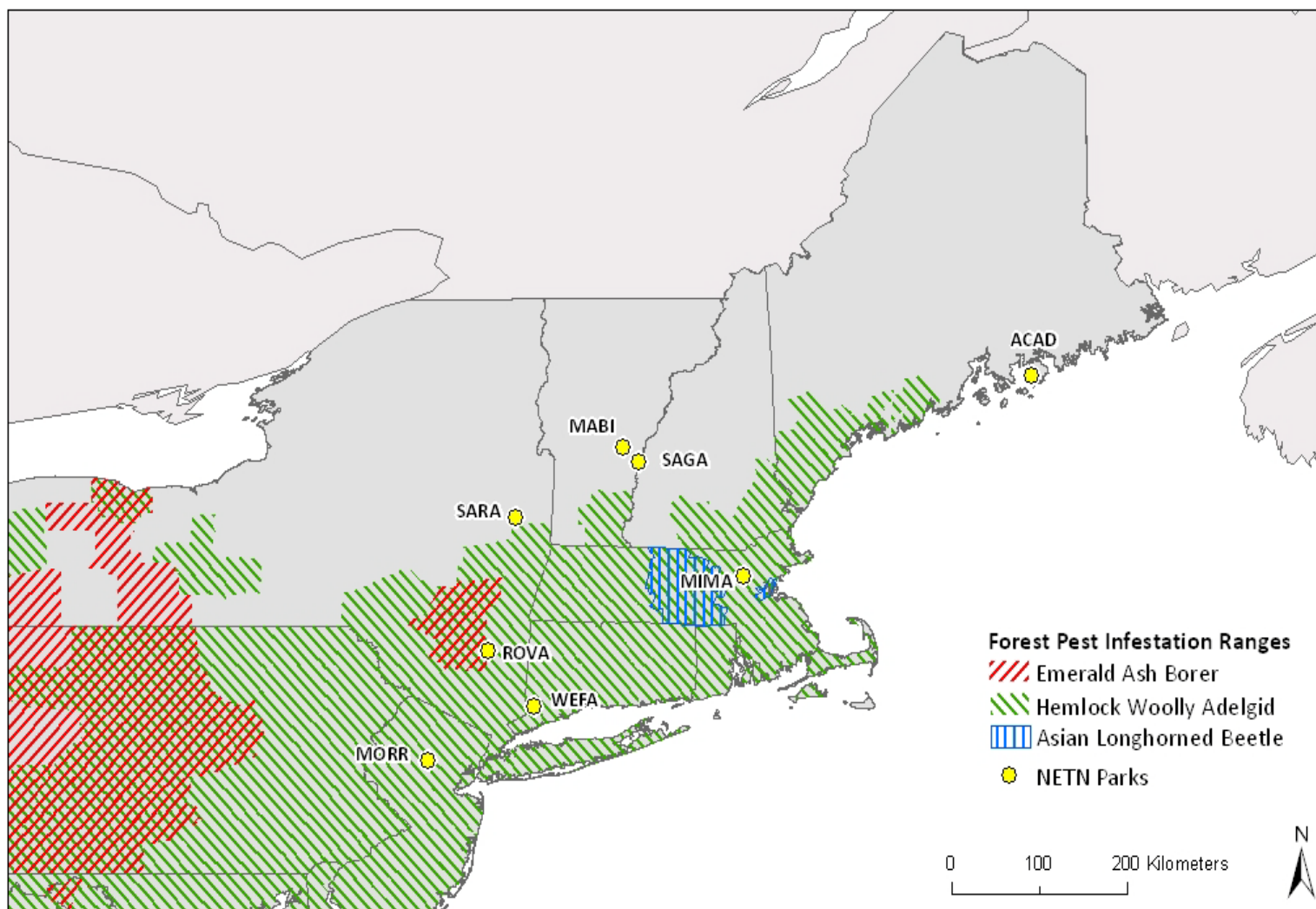
Species	Common Name	Potential Deer Impact	Cite ¹	Note
<i>Acer rubrum</i>	red maple	High	2	
<i>Acer saccharum</i>	sugar maple	High	2	
<i>Cornus florida</i>	flowering dogwood	High	1	
<i>Liriodendron tulipifera</i>	tulip poplar	High	2	
<i>Magnolia acuminata</i>	cucumber tree	High	2	
<i>Prunus pensylvanica</i>	pin cherry	High	2	
<i>Sassafras albidum</i>	sassafras	High	1	
<i>Sorbus americana</i>	mountain ash	High	1	
<i>Thuja occidentalis</i>	northern white cedar	High	1	
<i>Tilia americana</i>	basswood	High	1	
<i>Tsuga canadensis</i>	eastern hemlock	High	2	
<i>Betula alleghaniensis</i>	yellow birch	Medium	2	High preference but medium browse tolerance
<i>Betula lenta</i>	black birch	Medium	2	High preference but medium browse tolerance
<i>Carya</i> spp.	hickories	Medium	2	High preference but medium browse tolerance
<i>Fraxinus</i> spp.	ashes	Medium	2	High preference but medium browse tolerance
<i>Hamamelis virginiana</i>	witch hazel	Medium	1	
<i>Juglans cinerea</i>	butternut	Medium	1	
<i>Juglans nigra</i>	black walnut	Medium	1	
<i>Nyssa sylvatica</i>	black gum	Medium	3	Sprouts have medium to high palatability
<i>Quercus</i> spp.	oaks	Medium	2	High preference but medium browse tolerance
<i>Ulmus</i> spp.	elm	Medium	1	
<i>Abies balsamea</i>	balsam fir	Medium/Low	1	Low choice but heavily browsed if needed
<i>Acer pensylvanicum</i>	striped maple	Medium/Low	2	Medium preference but high browse tolerance
<i>Fagus grandifolia</i>	American beech	Medium/Low	2	Medium preference but high browse tolerance
<i>Pinus resinosa</i>	red pine	Medium/Low	1	Low choice but heavily browsed if needed
<i>Pinus rigida</i>	pitch pine	Medium/Low	1	Low choice but heavily browsed if needed
<i>Pinus strobus</i>	white pine	Medium/Low	1	Low choice but heavily browsed if needed
<i>Pinus sylvestris</i>	Scotch pine	Medium/Low	1	Low choice but heavily browsed if needed
<i>Alnus</i> spp.	alder	Low	1	
<i>Betula papyrifera</i>	paper birch	Low	1	
<i>Betula populifolia</i>	gray birch	Low	1	
<i>Carpinus caroliniana</i>	musclewood	Low	1	
<i>Crataegus</i> spp.	hawthorn	Low	1	
<i>Juniperus virginiana</i>	red cedar	Low	1	

Appendix B. Indicator species used for seedling ratio (continued).

Species	Common Name	Potential Deer Impact	Cite ¹	Note
<i>Larix laricina</i>	tamarack	Low	1	
<i>Ostrya virginiana</i>	hop hornbeam	Low	1	
<i>Picea</i> spp.	spruces	Low	1	
<i>Populus</i> spp.	aspens	Low	1	
<i>Prunus serotina</i>	black cherry	Low	2	
<i>Rhamnus cathartica</i>	buckthorn	Low	1	
<i>Robinia pseudoacacia</i>	black locust	Low	1	

¹1 — New York State Department of Environmental Conservation (NYS DEC). A Preference List of Winter Deer Foods (www.dec.state.ny.us/website/dfwmr/wildlife/deer/foodlist.html); 2 — USFS 2003. Forest Inventory and Analysis. Northeast Field Guide, Version 1.7, App. 12; 3 — USFS Fire Effects Information System tree description. (www.fs.fed.us/database/feis/plants/index.html).

Appendix C. Exotic forest pest detections near NETN parks. Pest ranges were mapped at the county level and were downloaded from the Alien Forest Pest Explorer (<http://www.nrs.fs.fed.us/tools/afpe/maps/>). Asian Longhorned Beetle range only reflects the most recent detections that have not yet been eradicated.



Appendix D. Key invasive exotic plant indicator species of forest, woodland and successional ecosystems in the northeastern U.S. that were used in the NETN Ecological Integrity Scorecard.

Latin name	Common name	Habitat
<i>Acer platanoides</i>	Norway maple	Open & forest habitats
<i>Ailanthus altissima</i>	Tree-of-heaven	Edges & successional habitats
<i>Alliaria petiolata</i>	Garlic mustard	Open & forest habitats
<i>Berberis thunbergii</i>	Japanese barberry	Open & forest habitats
<i>Berberis vulgaris</i>	European barberry	Open & wooded habitats
<i>Cardamine impatiens</i>	Narrowleaf bittercress	Open & wooded habitats
<i>Celastrus orbiculatus</i>	Oriental bittersweet	Edges & successional habitats
<i>Cynanchum louiseae</i>	Black swallow-wort	Open, successional & wooded habitats
<i>Cynanchum rossicum</i>	European swallow-wort	Open, successional & wooded habitats
<i>Euonymus alata</i>	Winged burning bush	Open, successional & wooded habitats
<i>Frangula alnus</i>	Glossy buckthorn	Wetland & successional habitats
<i>Ligustrum</i> spp. (<i>obtusifolium</i> , <i>vulgare</i>)	Privet	Successional & forest habitats
<i>Lonicera japonica</i>	Japanese honeysuckle	Edges & successional habitats
<i>Lonicera</i> spp. (<i>morrowii</i> , <i>tatarica</i> , x <i>bella</i>)	Exotic honeysuckles	Open & successional habitats
<i>Luzula luzuloides</i>	Forest woodrush	Open & wooded habitats
<i>Microstegium vimineum</i>	Japanese stiltgrass	Open & forest habitats
<i>Polygonum caespitosum</i>	Oriental ladythumb	Open & successional habitats
<i>Polygonum cuspidatum</i>	Japanese knotweed	Riparian, open & successional habitats
<i>Rhamnus cathartica</i>	Common buckthorn	Riparian, open & successional habitats
<i>Rhodotypos scandens</i>	Black jetbead	Open, successional & wooded habitats
<i>Rosa multiflora</i>	Multiflora rose	Open & successional habitats
<i>Rubus phoenicolasius</i>	Wineberry	Open, successional & wooded habitats

Appendix E. Landscape Context maps for NETN parks.

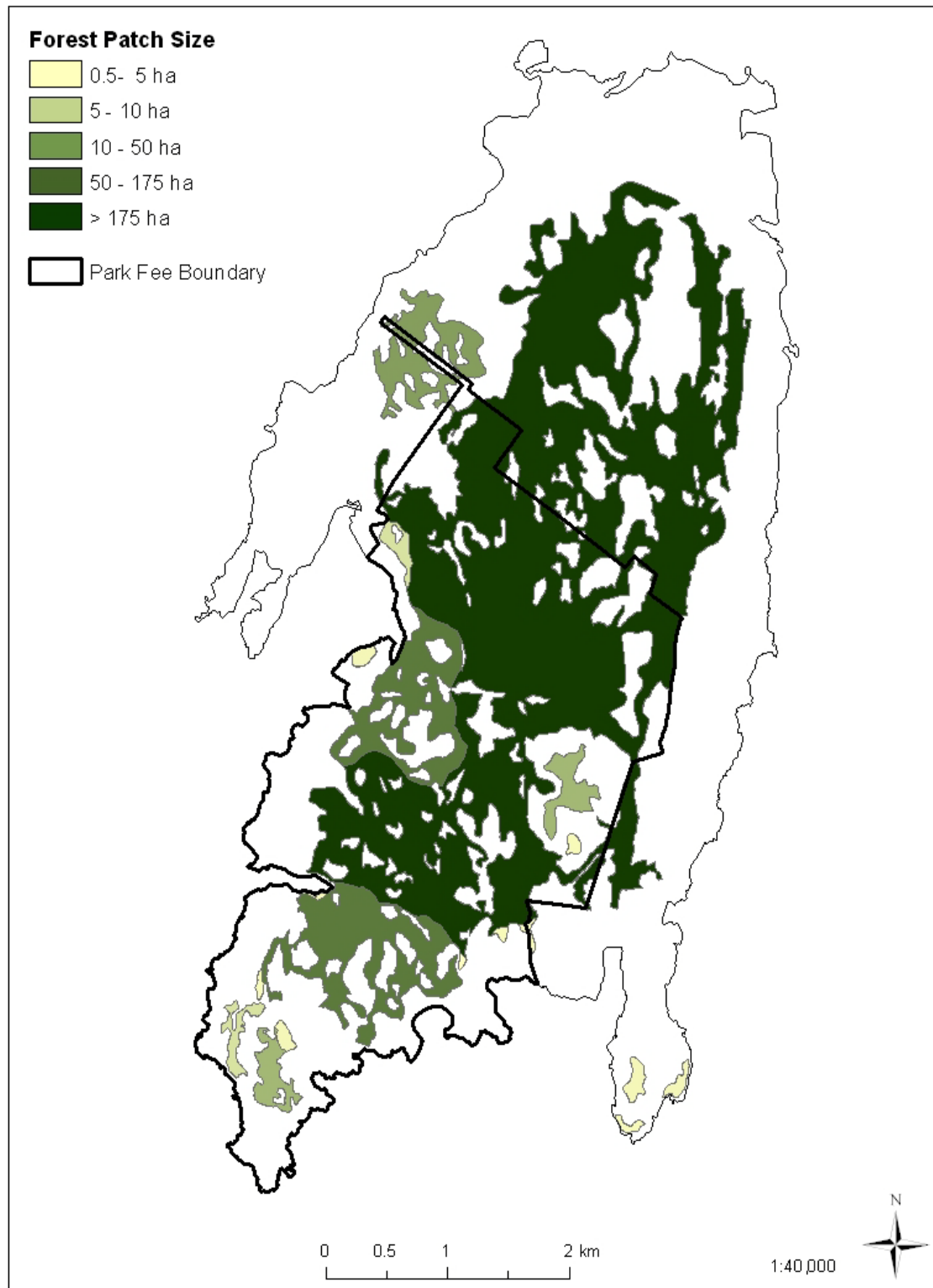


Figure E-1. Forest patches delineated on Isle au Haut in Acadia National Park.

Appendix E. Landscape Context maps for NETN parks (continued).

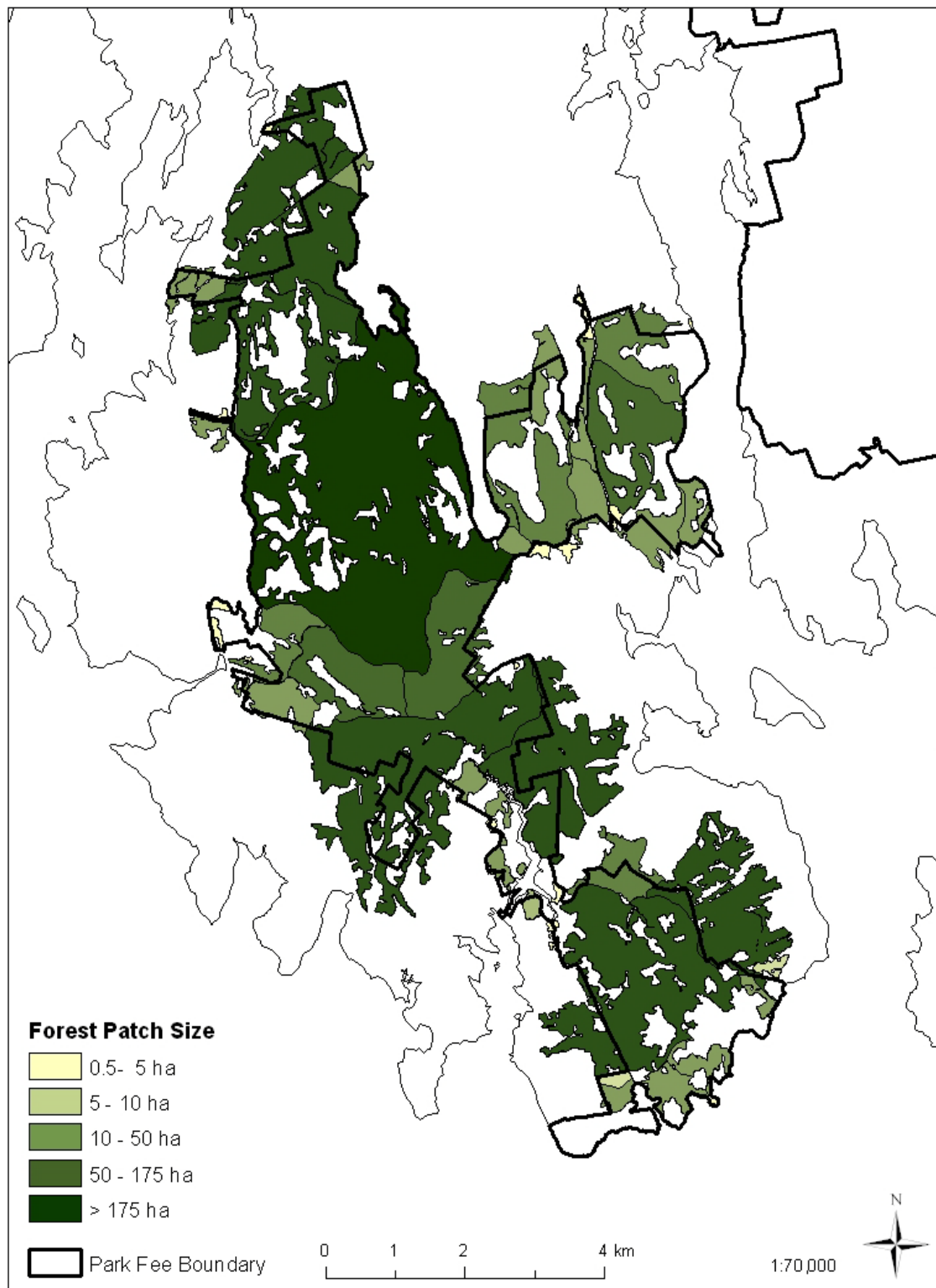


Figure E-2. Forest patches delineated for the western section of Mount Desert Island in Acadia National Park.

Appendix E. Landscape Context maps for NETN parks (continued).

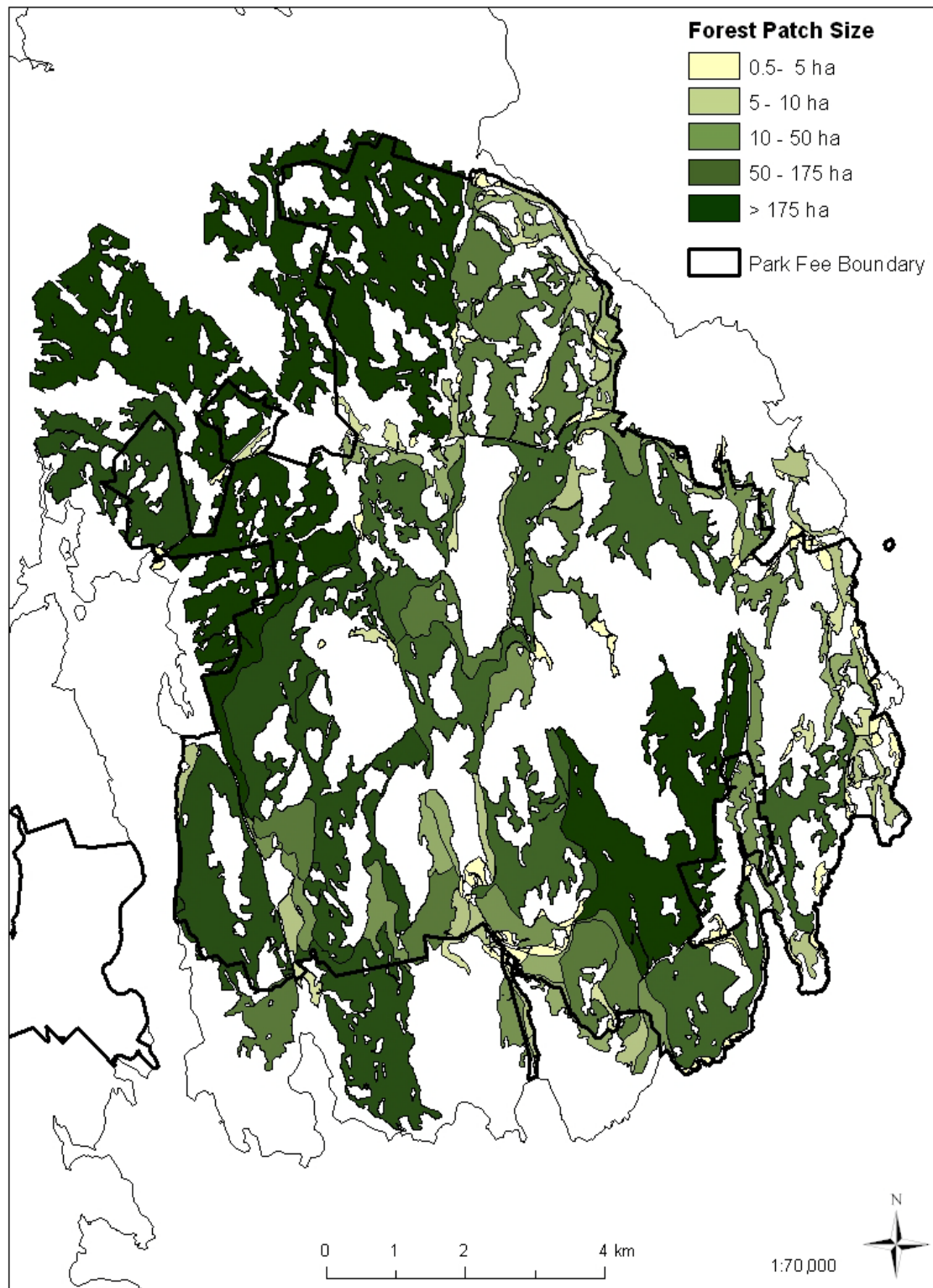


Figure E-3. Forest patches delineated for the eastern section of Mount Desert Island in Acadia National Park.

Appendix E. Landscape Context maps for NETN parks (continued).

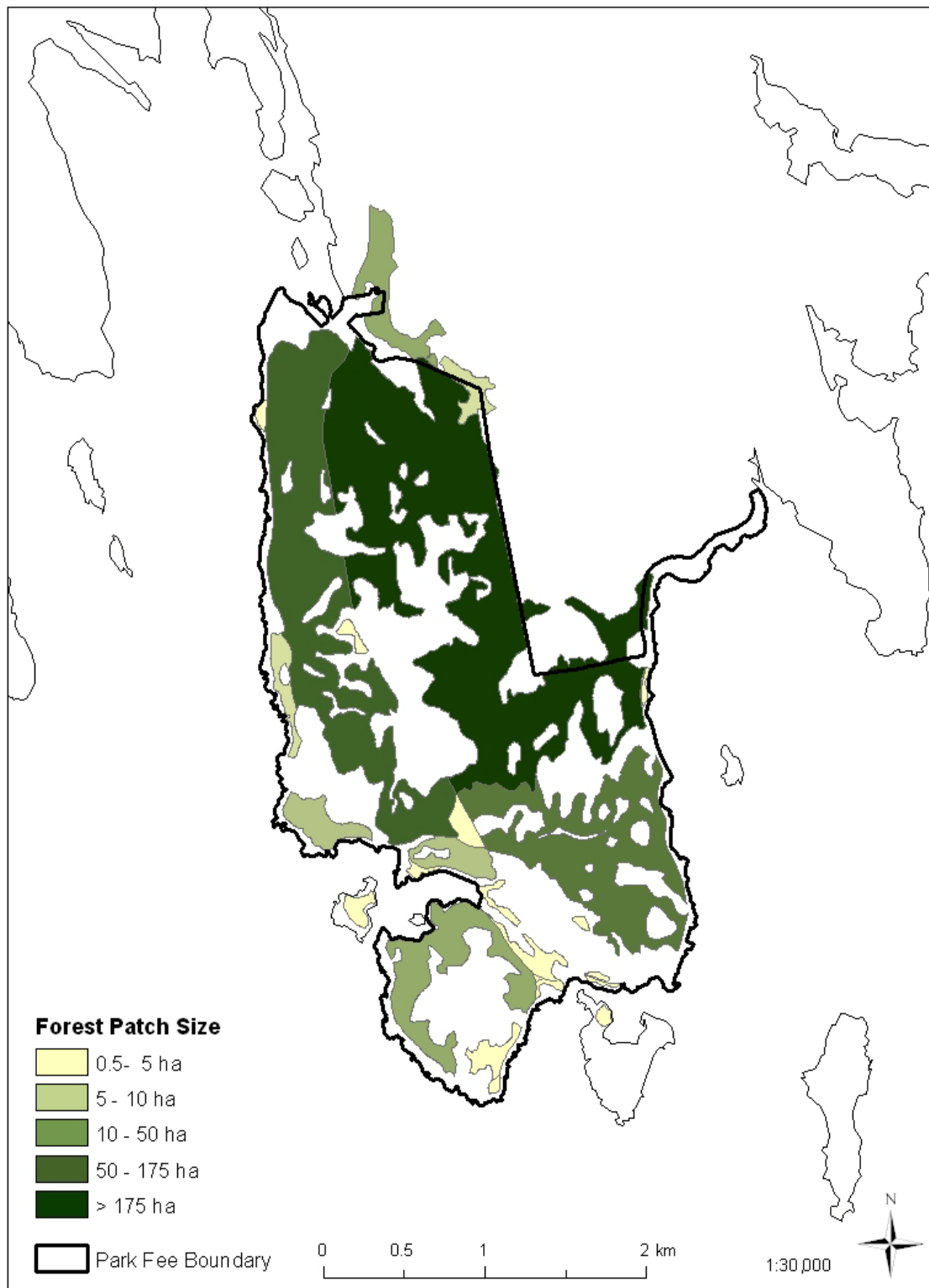


Figure E-4. Forest patches delineated for Schoodic Peninsula in Acadia National Park.

Appendix E. Landscape Context maps for NETN parks (continued).

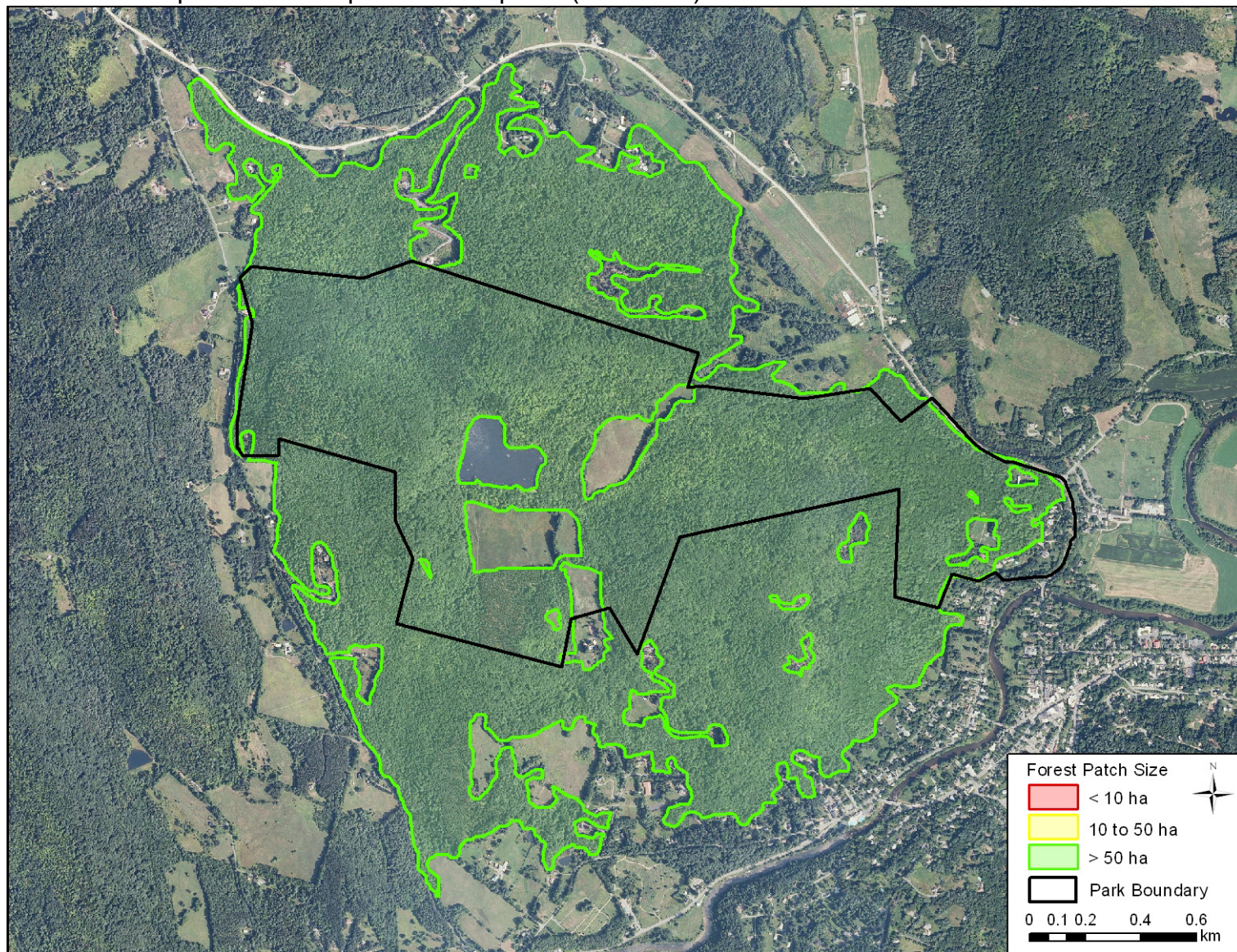


Figure E-5. Forest patch delineations for Marsh-Billings-Rockefeller National Historical Park.

Appendix E. Landscape Context maps for NETN parks (continued).

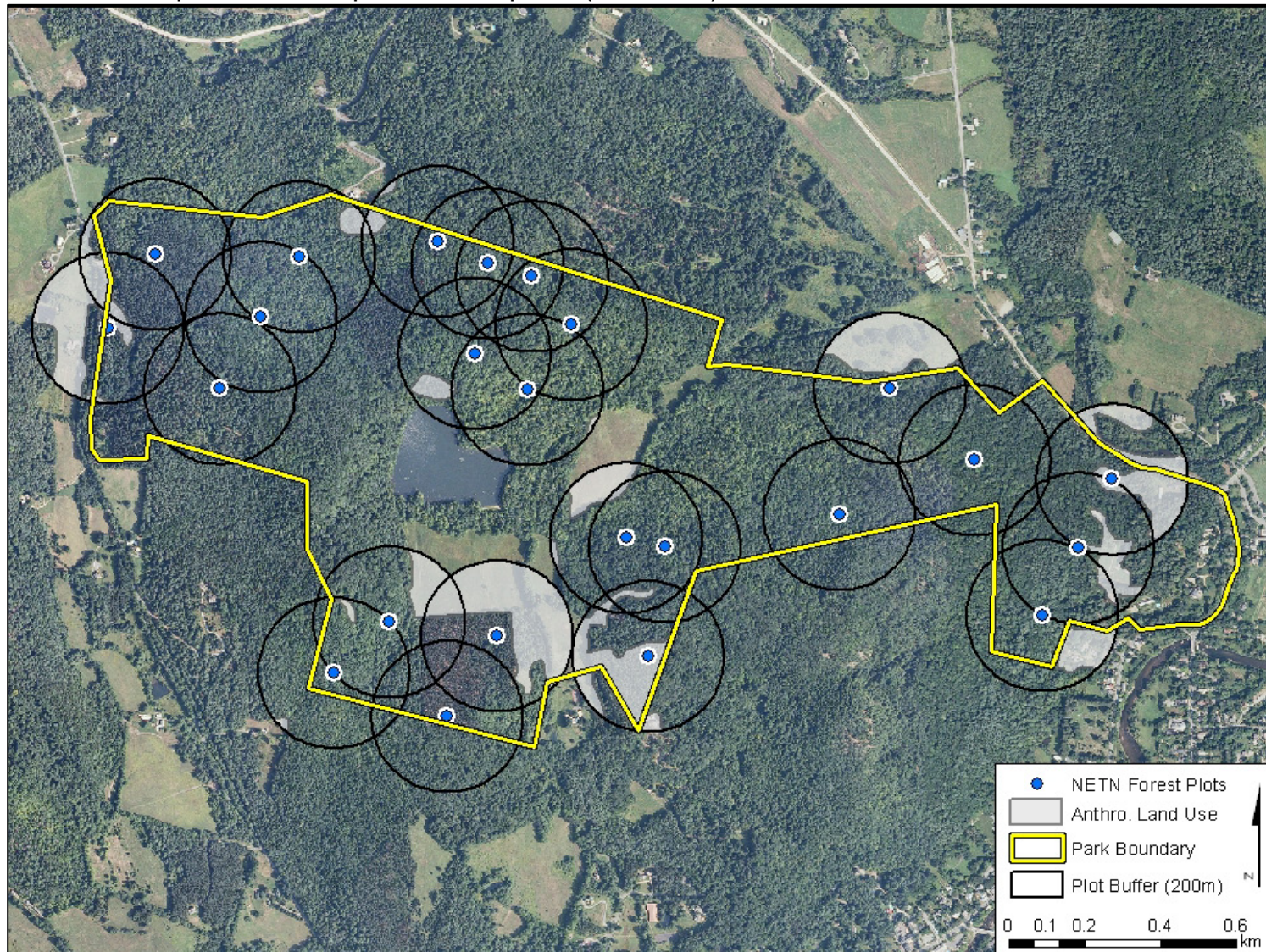


Figure E-6. Anthropogenic land use delineations for Marsh-Billings-Rockefeller National Historical Park.

Appendix E. Landscape Context maps for NETN parks (continued).

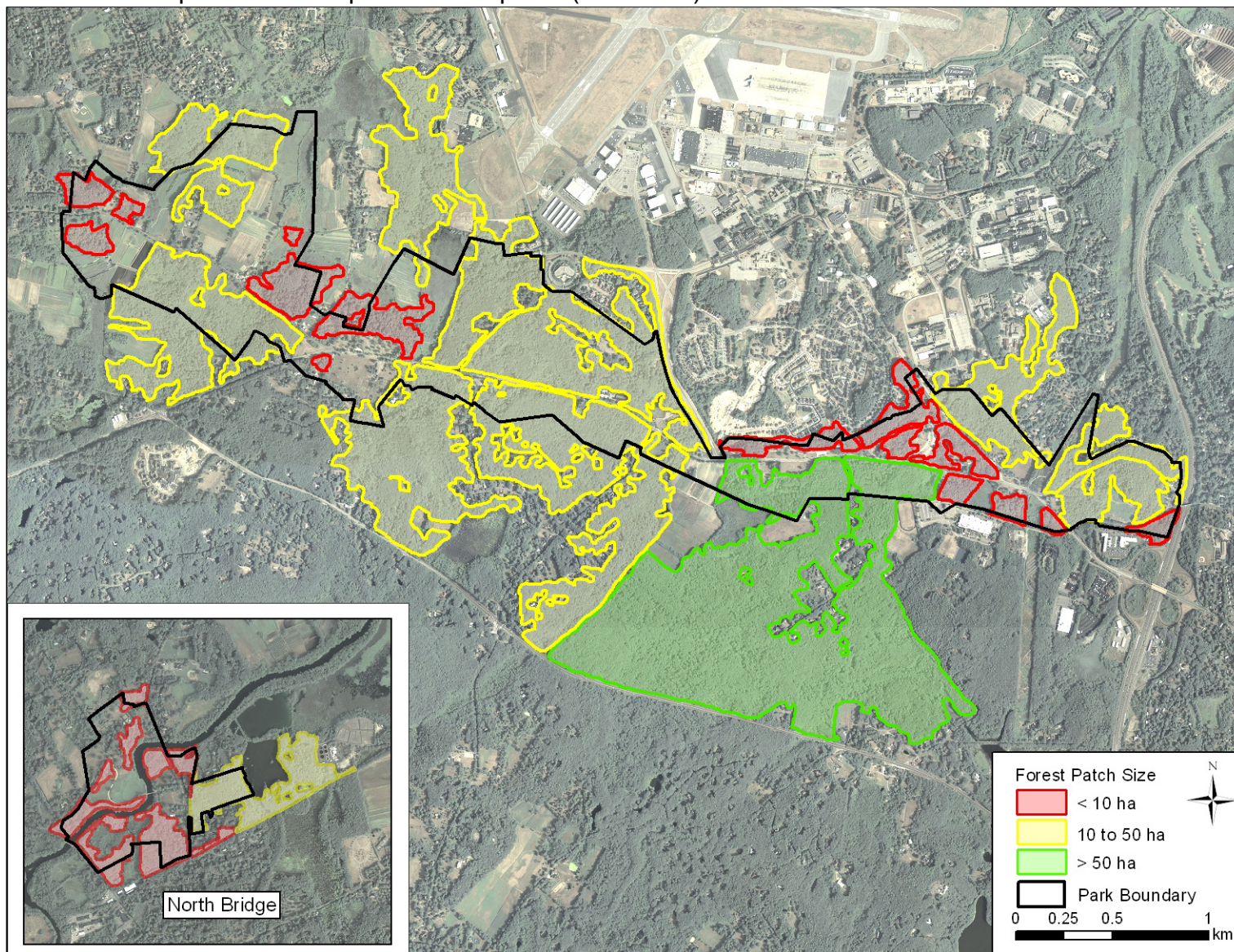


Figure E-7. Forest patch delineations for Minute Man National Historical Park.

Appendix E. Landscape Context maps for NETN parks (continued).

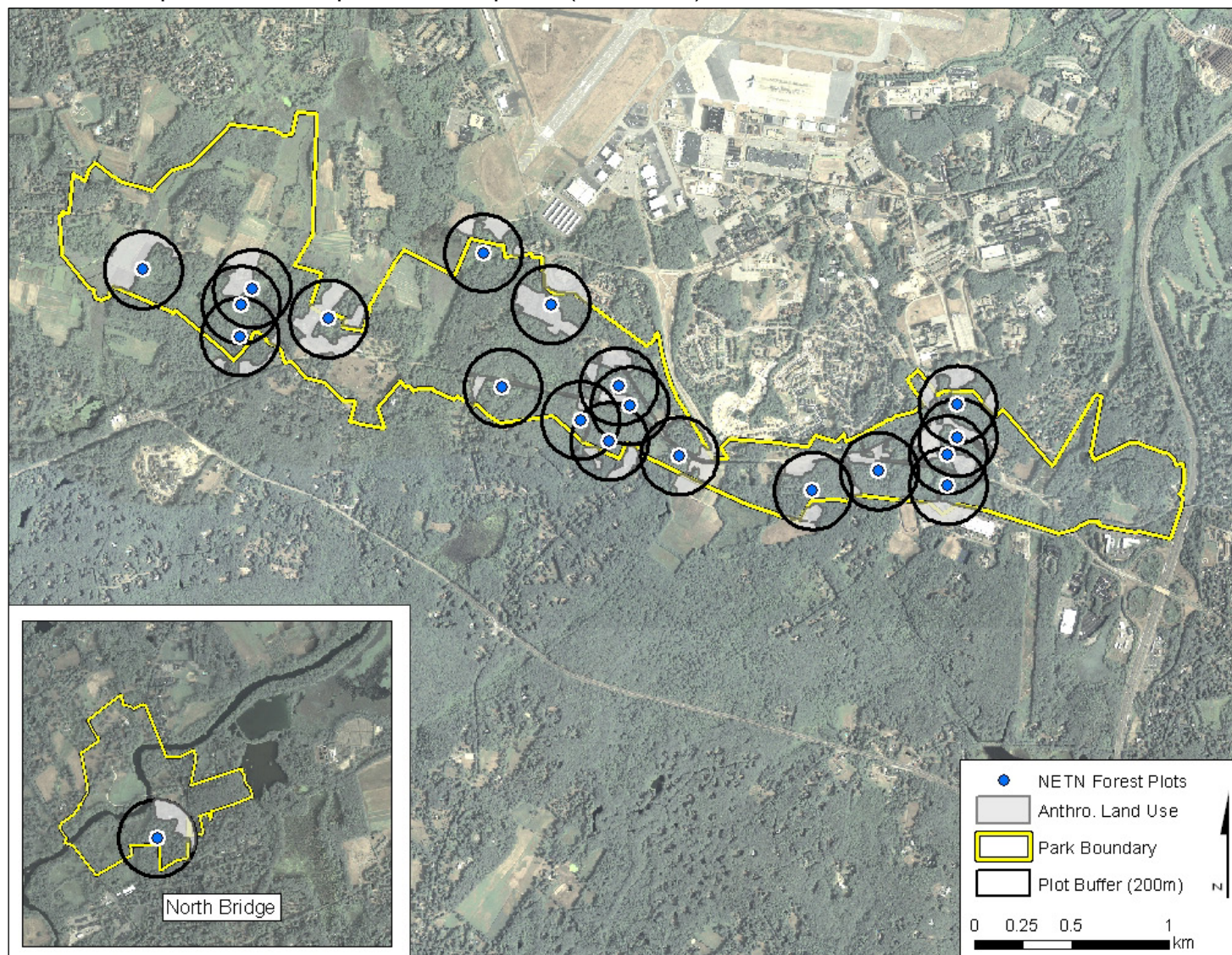


Figure E-8. Anthropogenic land use delineations for Minute Man National Historical Park.

Appendix E. Landscape Context maps for NETN parks (continued).

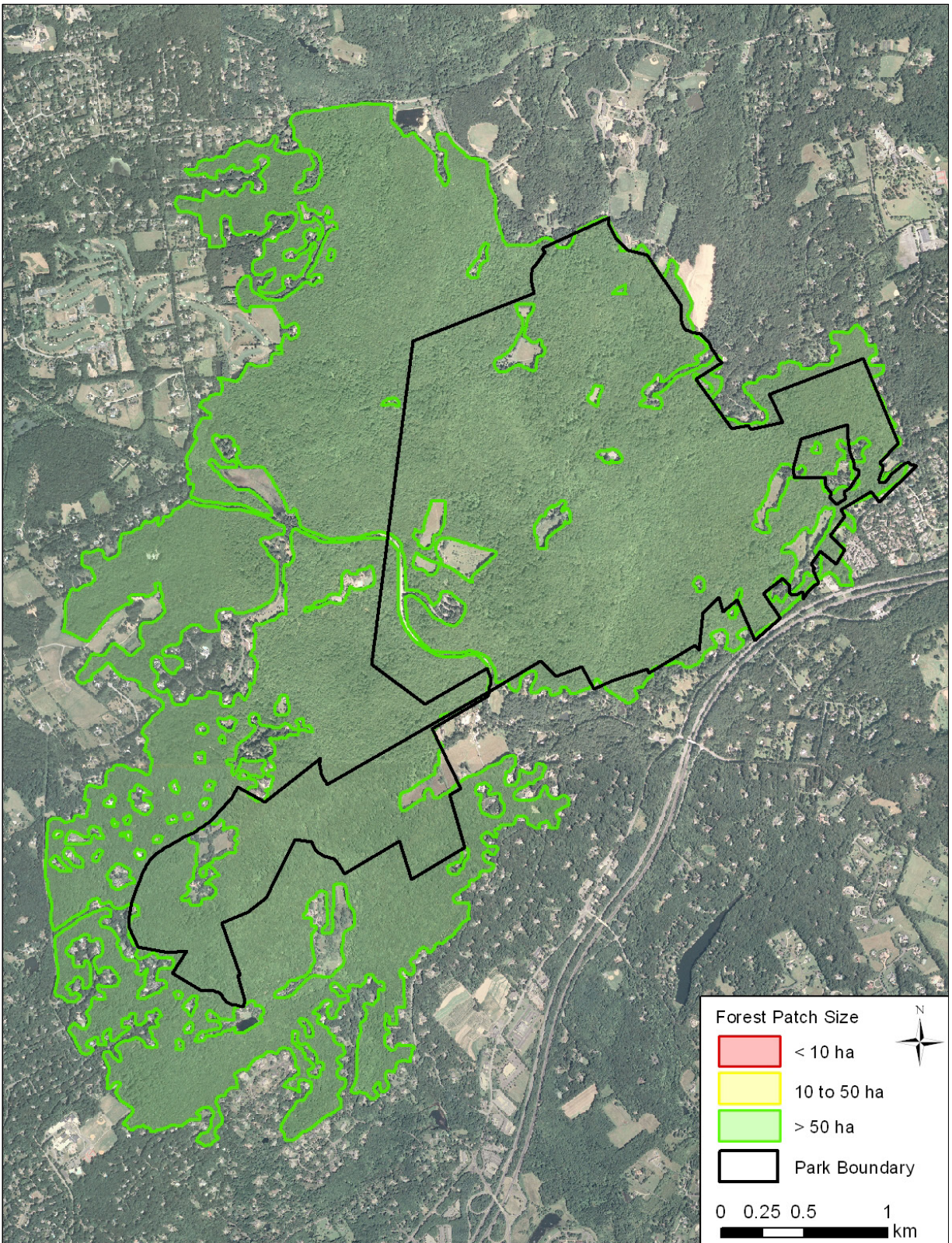


Figure E-9. Forest Patch delineations for Morristown National Historical Park.

Appendix E. Landscape Context maps for NETN parks (continued).

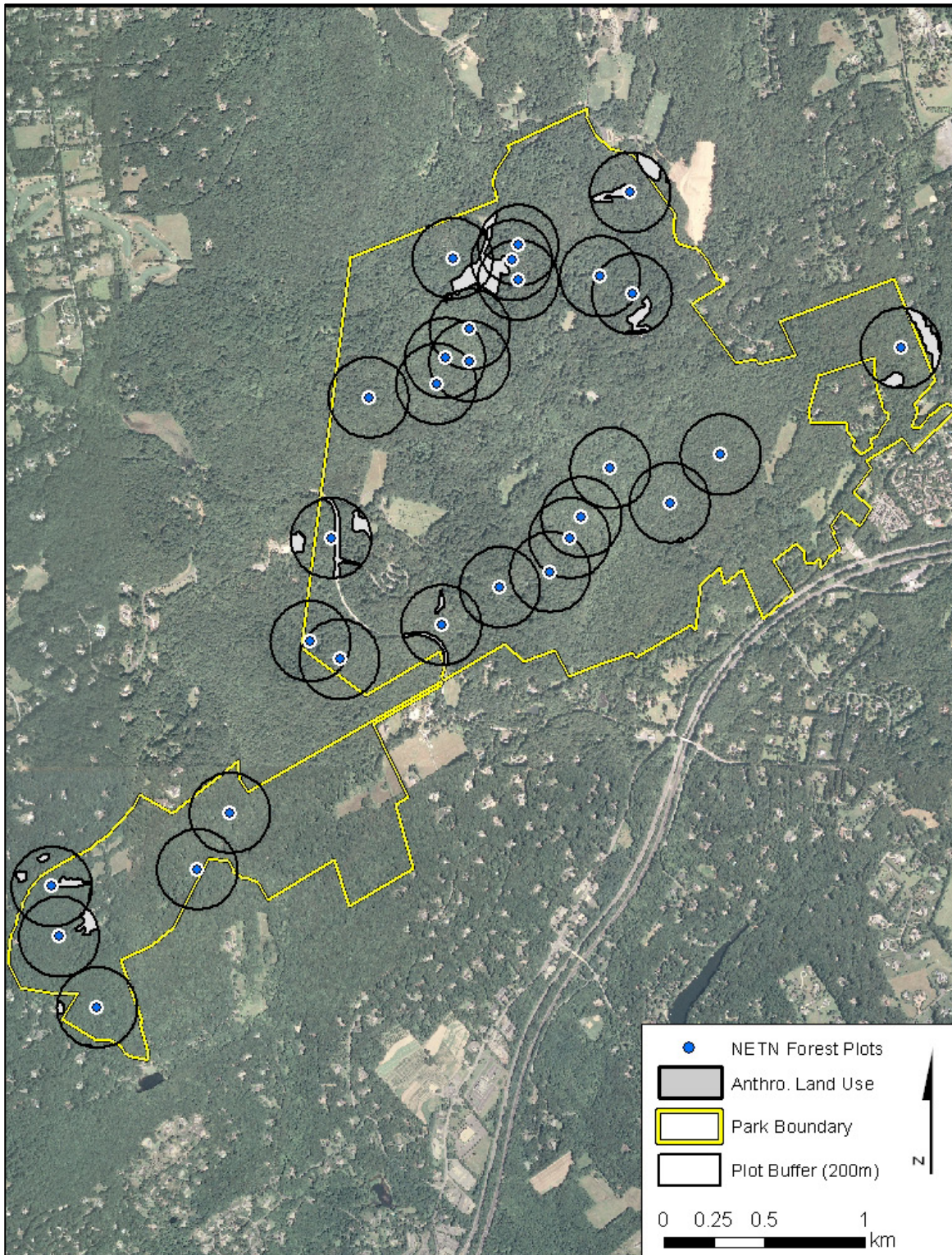


Figure E-10. Anthropogenic land use delineations for Morristown National Historical Park.

Appendix E. Landscape Context maps for NETN parks (continued).

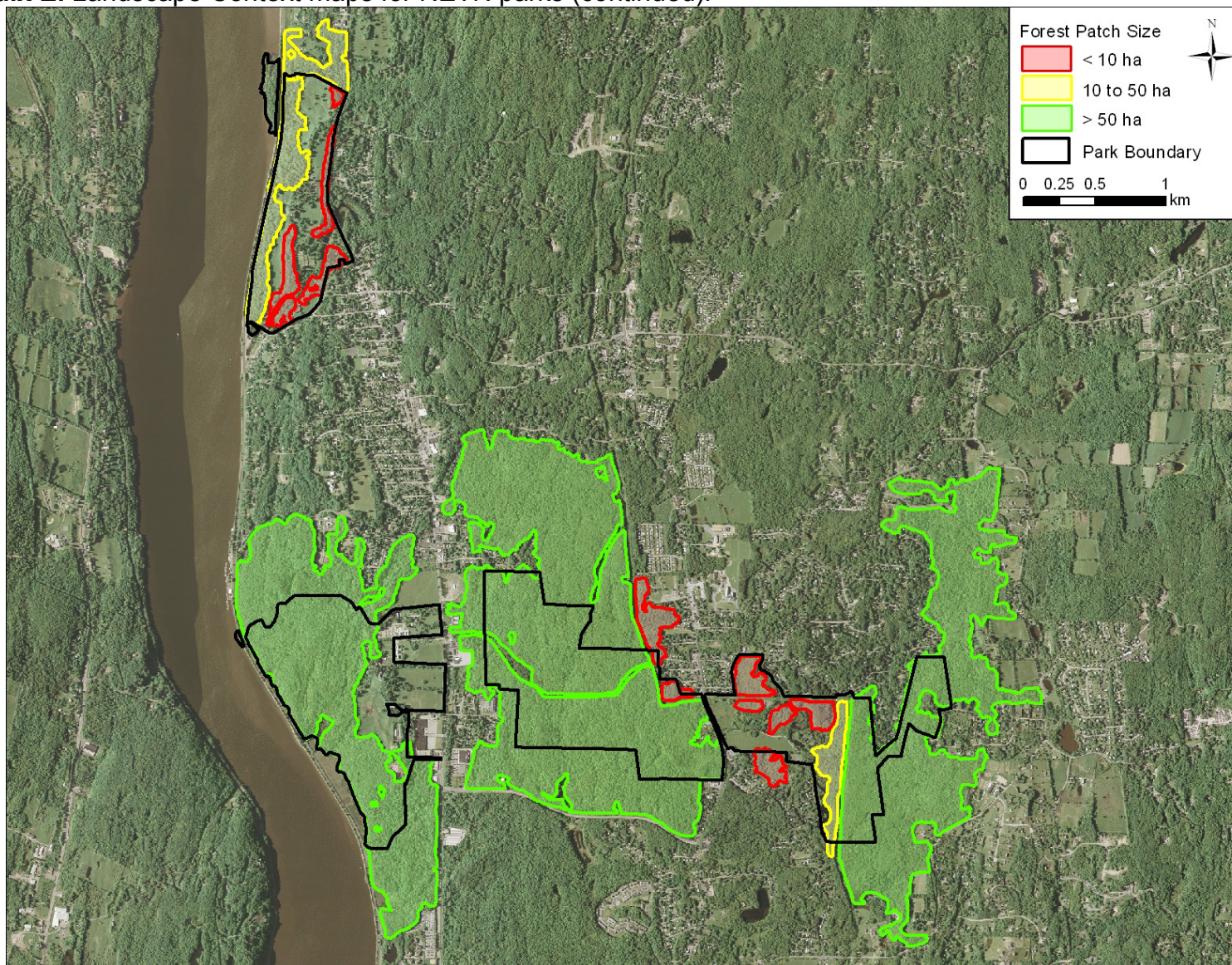


Figure E-11. Forest patch delineations for Roosevelt-Vanderbilt National Historic Sites.

Appendix E. Landscape Context maps for NETN parks (continued).

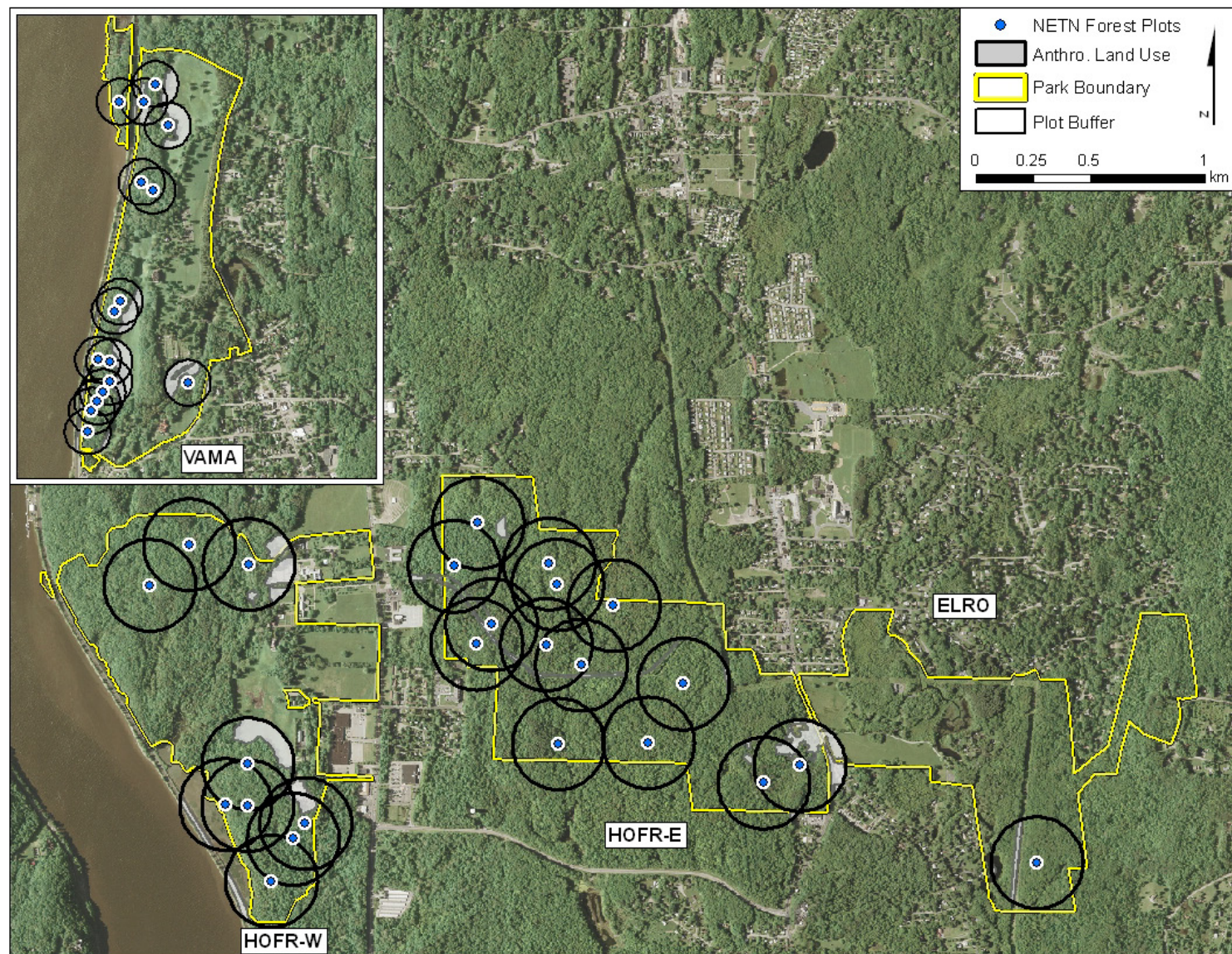


Figure E-12. Anthropogenic land use delineations for Roosevelt-Vanderbilt National Historic Sites.

Appendix E. Landscape Context maps for NETN parks (continued).

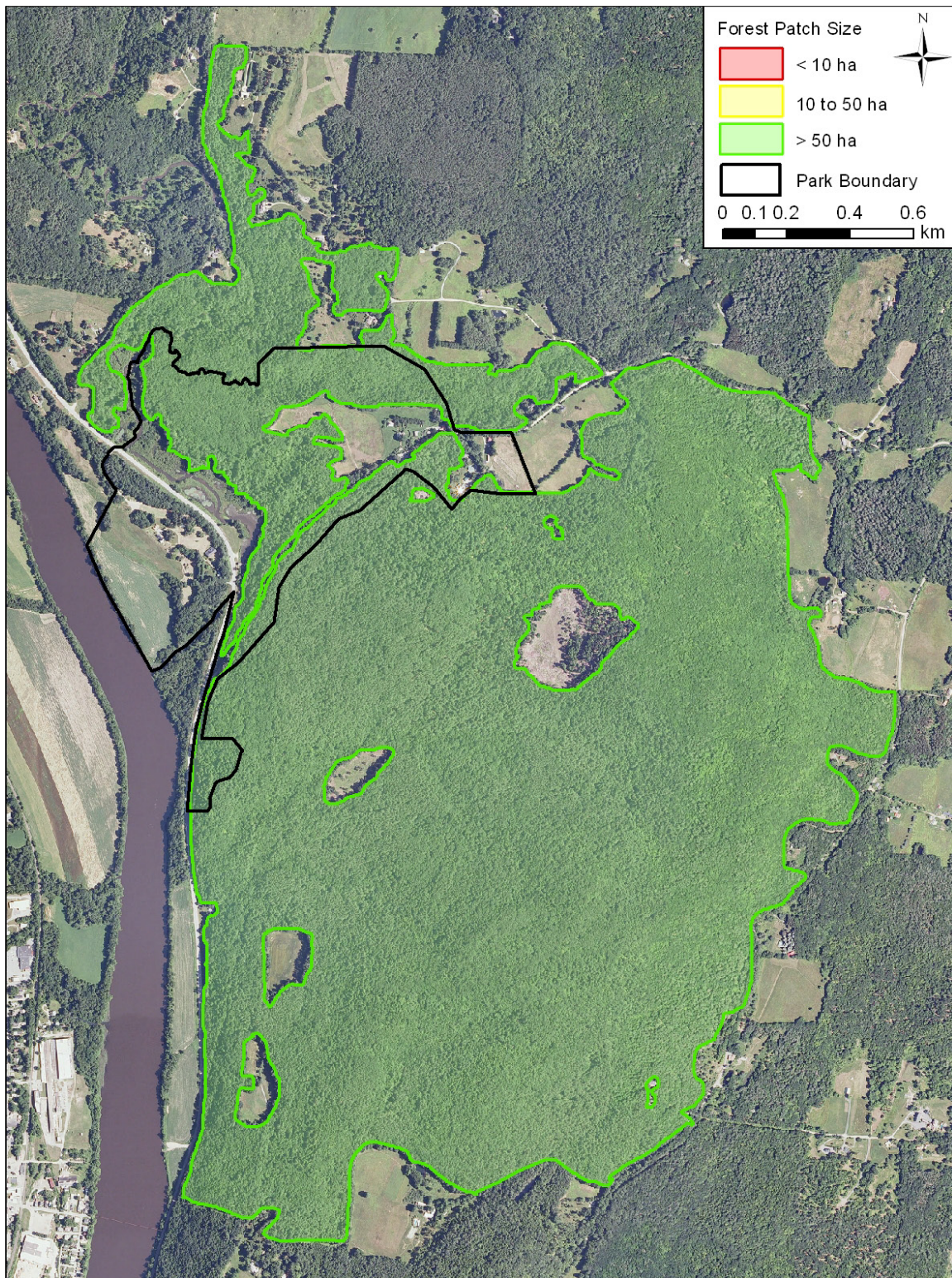


Figure E-13. Forest patch delineations for Saint-Gaudens National Historic Site.

Appendix E. Landscape Context maps for NETN parks (continued).

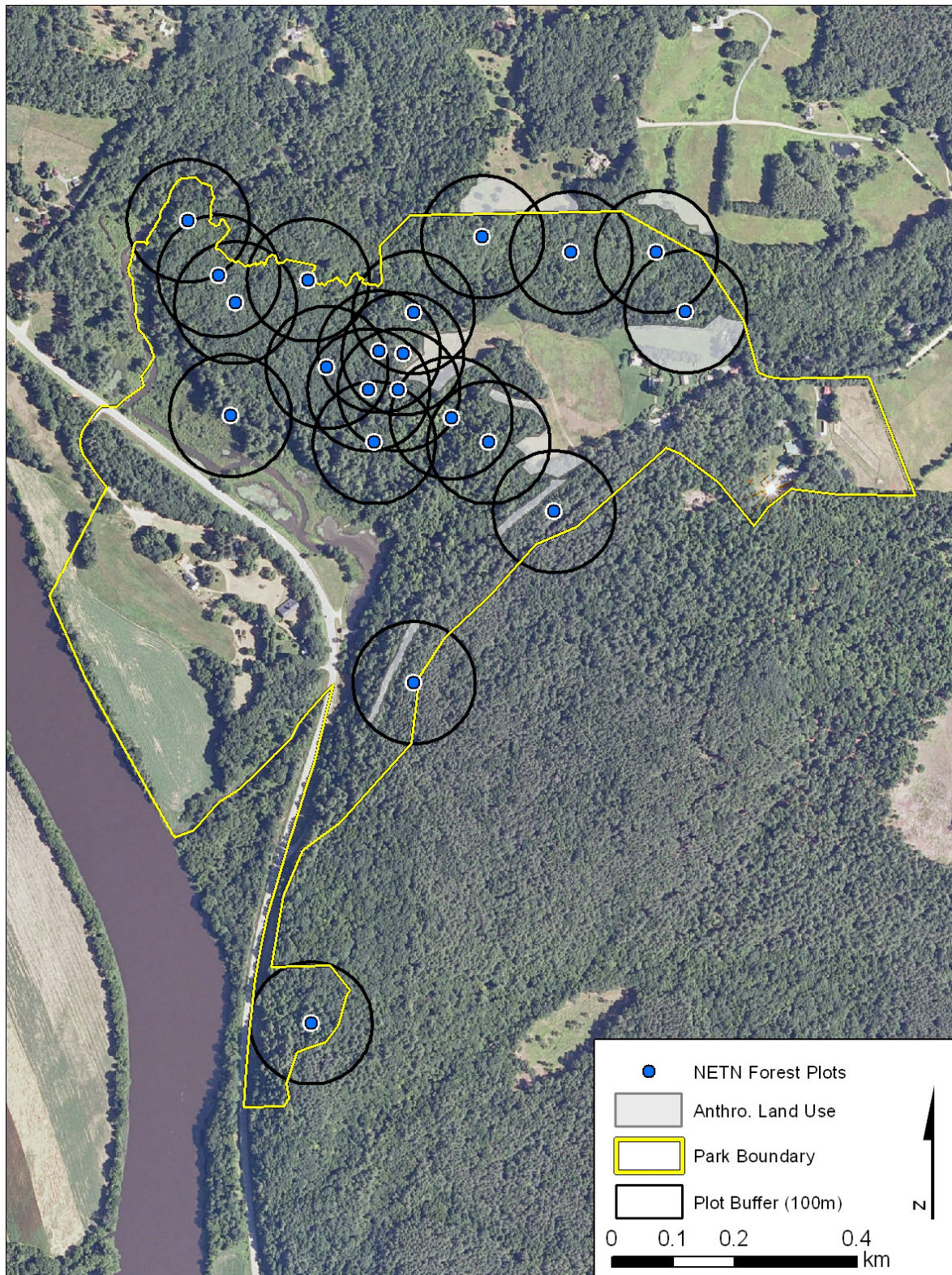


Figure E-14. Anthropogenic land use delineations for Saint-Gaudens National Historic Site.

Appendix E. Landscape Context maps for NETN parks (continued).

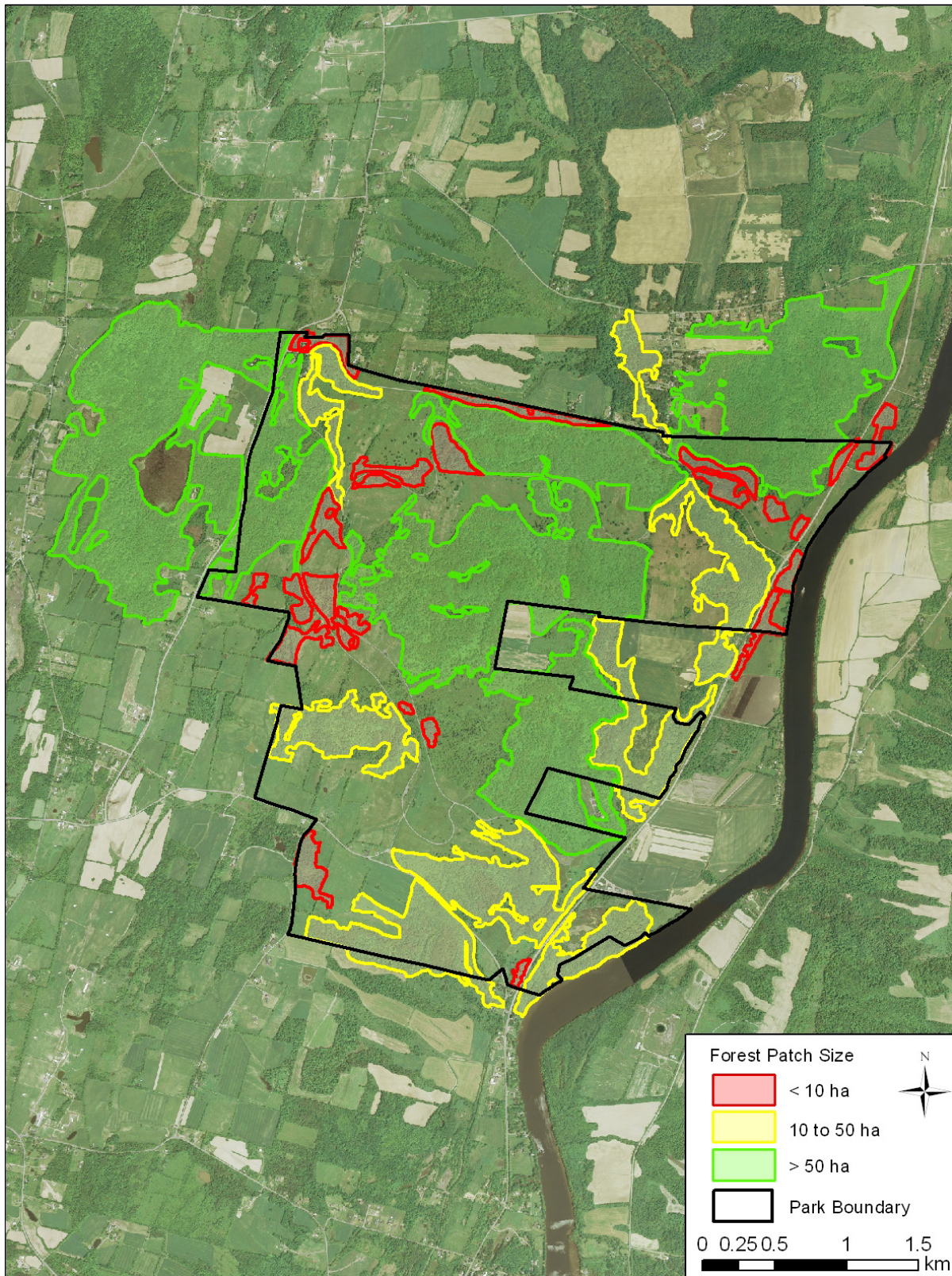


Figure E-15. Forest patch delineations for Saratoga National Historical Park.

Appendix E. Landscape Context maps for NETN parks (continued).

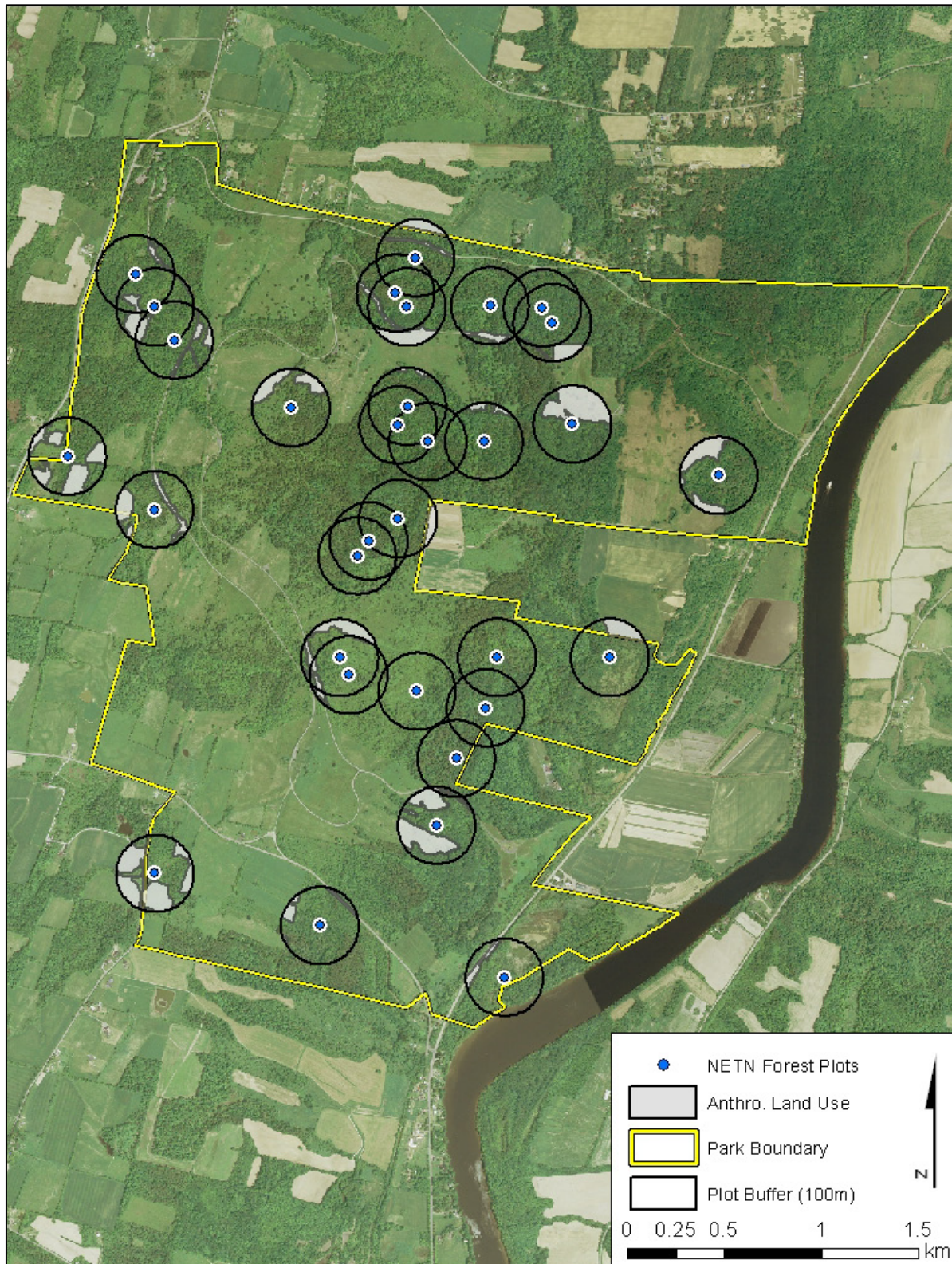


Figure E-16. Anthropogenic land use delineations for Saratoga National Historical Park.

Appendix E. Landscape Context maps for NETN parks (continued).

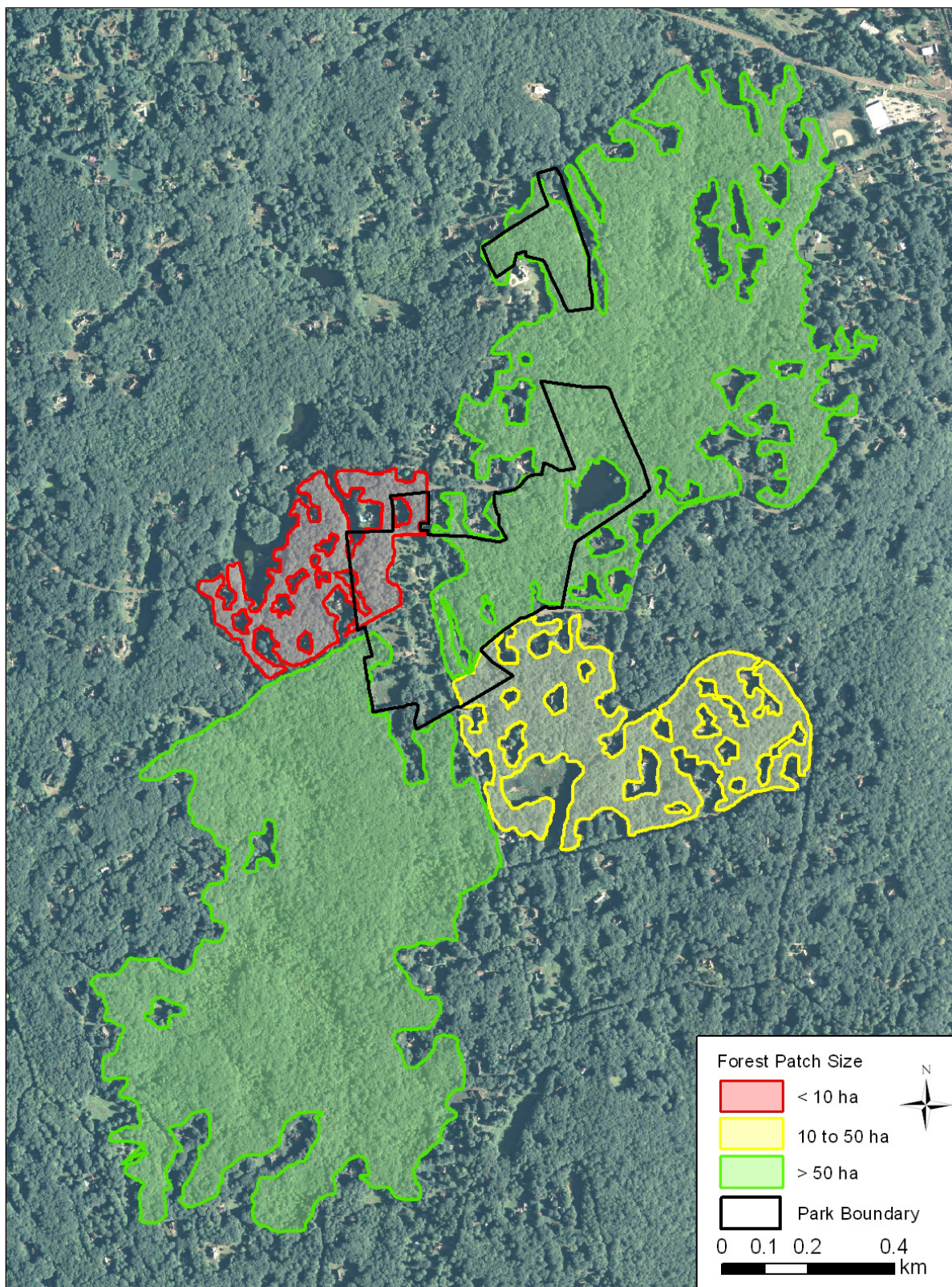


Figure E-17. Forest patch delineations for Weir Farm National Historic Site.

Appendix E. Landscape Context maps for NETN parks (continued).

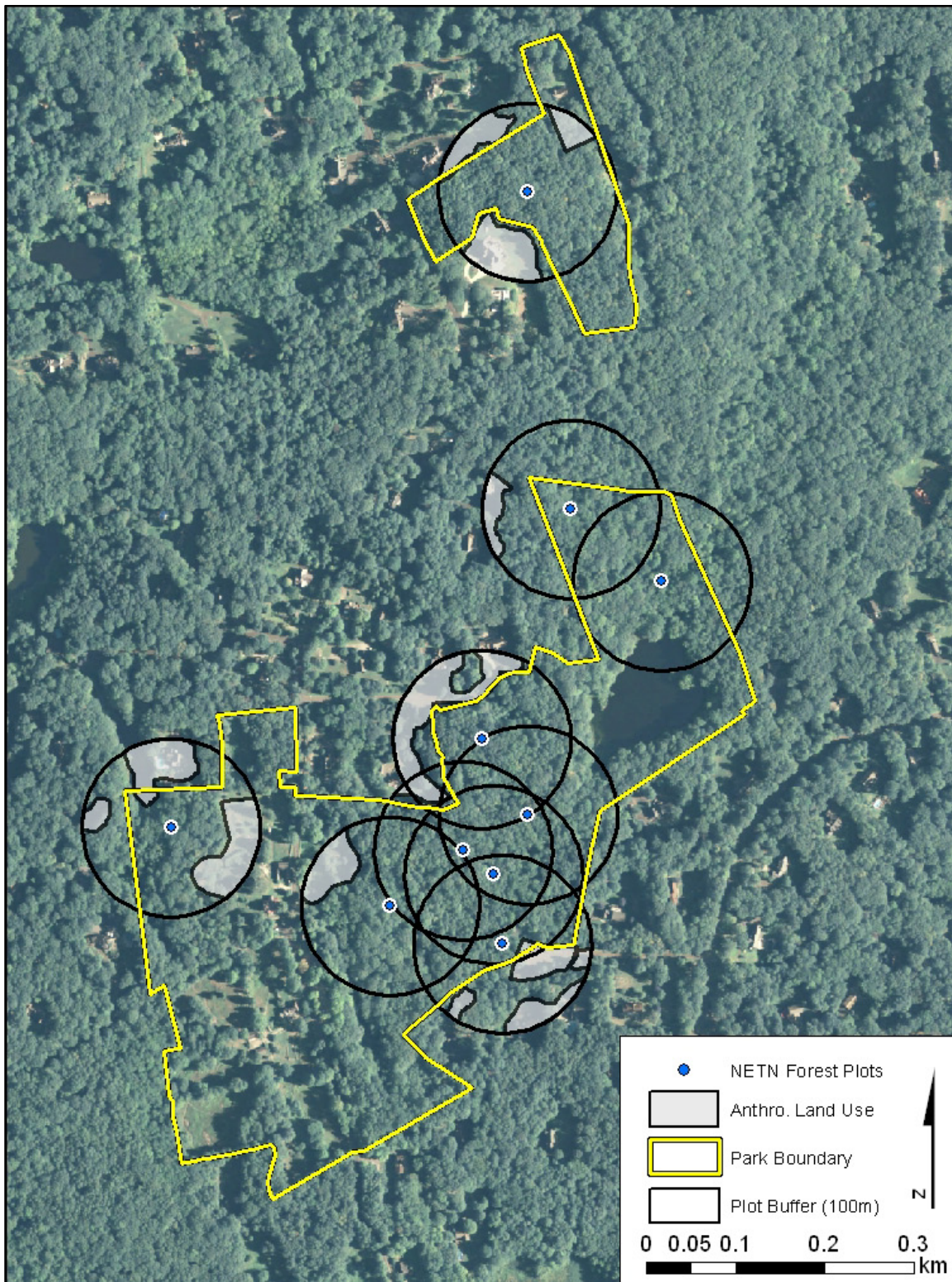


Figure E-18. Anthropogenic land use delineations for Weir Farm National Historic Site.

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 962/107729, May 2011

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U.S. Department of the Interior



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