



Forest Health Monitoring in the Northeast Temperate Network

2012 Summary Report

Natural Resource Report NPS/NETN/NRR—2013/678



ON THE COVER

Evan Heck and Camilla Seirup sampling a forest plot in a Saratoga National Historical Park
Photograph by: Kate Miller, NPS

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Contents

	Page
Figures.....	v
Tables.....	vii
Apendices.....	ix
Executive Summary.....	xi
Ecological Integrity	xi
Acadia National Park	xi
Marsh-Billings-Rockefeller National Historical Park	xi
Minute Man National Historical Park.....	xi
Saint-Gaudens National Historic Site	xii
Saratoga National Historical Park.....	xii
Ecological Integrity Scorecard	xii
Forest Inventory and Analysis Comparisons	xiii
Conclusions.....	xiii
Acknowledgements.....	xiv
Introduction.....	1
Methods.....	3
Ecological Integrity Scorecard.....	5
Background	7
Results and Discussion	8
Coarse Woody Debris and Snag Abundance.....	8
Background	8
Results and Discussion	10
Tree Regeneration.....	14
Background	14
Results and Discussion	16
Tree Condition and Forest Pests	18
Background	18
Results and Discussion	19
Invasive Exotic Plant Indicator Species	20
Background	20

Contents (continued)

	Page
Results and Discussion	21
Deer Browse Indicator Species.....	22
Background	22
Results and Discussion	24
Tree Growth and Mortality Rates	24
Background	24
Results and Discussion	25
Soil Chemistry	28
Background	28
Results and Discussion	29
Management Implications	30
Acadia National Park	30
Marsh-Billings-Rockefeller National Historical Park	30
Minute Man National Historical Park.....	30
Saint-Gaudens National Historic Site	31
Saratoga National Historical Park.....	31
Forest Inventory and Analysis Comparisons	33
Introduction.....	33
Methods	33
Results.....	33
Land Cover.....	33
Structural Stage Distribution.....	36
Coarse Woody Debris and Snag Abundance	36
Discussion.....	39
Literature Cited	41

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. S ^x is location of soil sample.	4
Figure 2. Proportion of plots in each structural stage (Late Succession, Mature, and Pole) and field stand structure class (Early Succession, Mosaic and Woodland), based on data collected between 2009 and 2012..	9
Figure 3. Proportion of plots in NHPs receiving Good (green), and Caution (yellow) ratings for tree regeneration.	16
Figure 4. Mean seedling and sapling density (stems/ha) based on data collected from 2009-2012..	17
Figure 5. Proportion of plots receiving Good (green), Caution (yellow), and Significant Concern (red) ratings for tree condition for each park sampled in 2011..	19
Figure 6. Map of Ecological Subsections used for comparisons between FIA data with NETN parks.	34
Figure 7. Percent of forestland and reserved forestland, based on area in FIA plots summed across the Ecological Subsection containing each park.	35
Figure 8. Percent of forestland by ownership group, based on area of forest in FIA plots summed across the Ecological Subsection containing each park.	35
Figure 9. Percent of forest plots by structural stage in NETN parks and FIA plots within the same Ecological Subsection of each park.	36
Figure 10. Average density of live trees per hectare that are A) ≥ 30 cm DBH and B) ≥ 60 cm DBH for NETN parks and FIA plots located in the same Ecological subsection as each park.	37

Tables

	Page
Table 1. Northeast Temperate Network forest monitoring panel design.	4
Table 2. Metrics and ratings for evaluating the ecological integrity of forest ecosystems.	6
Table 3. Structural stage distribution of plots in NETN parks.	9
Table 4. Coarse woody debris (CWD) metric ratings, ratios, and volume calculations for NETN parks based on data collected from 2009 to 2012.	12
Table 5. Snag abundance ratings and calculations for NETN parks based on data collected from 2009 to 2012.	13
Table 6. Tree cavity summary statistics for each park.	13
Table 7. Index of deer browse impacts assessed for each plot in national historical parks and historic sites (NHPs) and ACAD.	15
Table 8. Mean stocking index and seedling ratio averaged over three 2-m radius microplots, and based on data collected from 2009-2012 for the NHPs.	17
Table 9. Regeneration metric summaries for ACAD.	18
Table 10. Indicator invasive exotic plant species ratings for NETN parks.	21
Table 11. Most frequent indicator invasive exotic species in NETN forest plots by park from 2009 to 2012.	23
Table 12. Deer browse indicator species ratings for plots resampled in 2012.	24
Table 13. Average growth rates (% basal area / year) overall, and by tree species in each park.	26
Table 14. Average annual percent mortality rate by tree species in each park.	27
Table 15. Chemistry variables available for NETN soil samples.	29
Table 16. Soil chemistry ratings for NETN parks from 2009 to 2012.	30
Table 17. Coarse woody debris metrics for NETN parks and FIA plots within the same Ecological Subsection of each park, and based on the most recent full survey cycle from both datasets.	38
Table 18. Snag abundance metrics for NETN parks and FIA plots within the same Ecological Subsection of each park, and based on the most recent full survey cycle from both datasets.	39

Appendices

	Page
Appendix A. Protocol implementation for the 2012 field season.....	48
Appendix B. Indicator species used for seedling ratio.....	50
Appendix C. Key indicator invasive exotic plant species of forest, woodland and successional ecosystems in the northeastern U.S.that were used in the NETN Ecological Integrity Scorecard.....	52
Appendix D. Herbaceous indicator species of deer browse pressure in northeastern U.S. forests.....	53
Appendix E. Scientific and common names of tree species mentioned in the Tree Growth and Mortality metric.	55
Appendix F. Soil Chemistry boxplots for samples collected between 2009 and 2012.....	57

Executive Summary

The 2012 field season marked the Northeast Temperate Network (NETN) Inventory and Monitoring Program's third year of repeat sampling in forest monitoring plots, and now three quarters of all forest plots have been sampled twice. This report contains an ecological integrity scorecard for the following parks that were sampled in 2012: 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). A second section compares forest metrics for all of the NETN parks with U.S. Forest Service Forest Inventory and Analysis (FIA) plots located in the same ecological subsection of each park.

Ecological Integrity

Acadia National Park

Ecological integrity metrics related to forest structure suggest that forests in ACAD are beginning to reach mature stages, but lack late successional structure such as medium to large snags. Tree regeneration in ACAD was rated Good for abundance, and impacts from deer browse were minimal. Patterns of regeneration were indicative of early successional and mature spruce-fir forest, and ACAD was rated Caution for regeneration patterns due to a high sapling;small seedling ratio. As long as forest composition metrics remain stable (e.g., no new invasive species, stable tree condition/forest pests, and continued regeneration), late successional structure is expected to develop over time. Tree growth rates were slightly lower than regional averages, and may be due to a higher proportion of mature and late successional plots than the regional FIA dataset. Poor site quality (e.g., thin acidic soils and rocky substrates) may also explain the lower growth rates in ACAD. Soil chemistry metrics suggest that forest soils may be stressed by acid deposition, but are robust to N saturation. ACAD continues to be the least invaded NETN park, with only three out of 176 plots containing indicator invasive exotic plant species. Damage from beech bark disease and balsam woolly adelgid (*Adelges piceae*) were the only major tree condition issues reported in 2012.

Marsh-Billings-Rockefeller National Historical Park

Ecological integrity metrics indicate that while over half of the plots in MABI are classified as late successional, MABI forests lack late successional structure such as medium to large snags and coarse woody debris. Medium to large snags were especially lacking in plantations. Tree growth rates were slightly lower than regional averages, and may be due to a higher proportion of mature and late successional plots than the regional FIA dataset. Invasive exotic species are a threat to forest health in MABI, and are of particular concern in plantations, which had higher diversity and abundance of indicator invasive exotic species than other stands. Beech bark disease was the only reported pest/pathogen in 2012. Soil chemistry metrics suggested that forest soils in MABI may be vulnerable to N saturation.

Minute Man National Historical Park

Metrics of ecological integrity indicate that a number of stressors are impacting forest health in MIMA. Forest plots in MIMA had the lowest coarse woody debris volume and ratio of all NETN parks, and medium to large snags were also lacking. Soil chemistry data indicate potential impacts of atmospheric deposition, including soil acidification and excess soil nitrogen.

Invasive exotic species were abundant, and exotic shrub thickets are likely impacting forest structure and composition. Elevated levels of insect herbivory were detected on a number of red maple trees in 2012. If this pattern continues, it may indicate a forest pest issue. Tree growth and mortality rates were within expected ranges.

Saint-Gaudens National Historic Site

While coarse woody debris volume and snag abundance were higher in SAGA than most network parks, these levels were still lower than that expected for late successional hardwood stands. As long as park management efforts continue to control invasive exotic plants, and exotic pests (especially hemlock woolly adelgid) do not invade, we expect ecological integrity structural metrics to improve with time. Tree growth rates were slightly lower than regional averages, and may be due to a higher proportion of mature and late successional plots than the regional FIA dataset. Invasive exotic plant species were present, but do not appear to be greatly impacting understory diversity or forest structure. Beech bark disease was the only reported pest/pathogen in 2012. Soil chemistry data indicated potential impacts of atmospheric deposition, including soil acidification and excess soil nitrogen.

Saratoga National Historical Park

A number of factors are impacting forest health in SARA, including forest pests, invasive exotic species, and, potentially, excess deer browse. Exotic shrubs, particularly bush honeysuckles (*Lonicera* spp.), have invaded large areas of the park, and are suppressing forest succession of old-field habitats. Invasive exotic plant species are especially abundant in stands that have succeeded to forest from old-field since 1927. Emerald ash borer (*Agrilus planipennis*) poses a considerable threat to these early successional habitats, as white ash (*Fraxinus americana*) is one of the only tree species with seedlings capable of penetrating the thicket and forming a canopy. Soil chemistry data indicated that soils in SARA are vulnerable to N saturation, and robust to acidification. Deer browse may be impacting forest regeneration, particularly in early successional stands. While growth rates were comparable with regional patterns, tree mortality rates were higher than regional rates, and may indicate an issue if this pattern continues. American elm (*Ulmus americana*) had the highest mortality rate, and this was likely the result of Dutch elm disease (*Ophiostoma ulmi*).

Ecological Integrity Scorecard

Park	Structural Stage Distribution	CWD Ratio	Snag Abundance	Invasive Exotic Plants	Tree Condition/ Forest Pests	Tree Regen	Tree Growth and Mortality	Soil Ca:Al	Soil C:N
ACAD	Caution	Caution	Caution	Good			Caution	Caution	Good
MABI	Caution	Caution	Sign. Conc.	Caution			Caution	Good	Sign. Conc.
MIMA	Good	Sign. Conc.	Caution	Sign. Conc.			Good	Caution	Sign. Conc.
SAGA	Caution	Caution	Caution	Caution			Caution	Sign. Conc.	Sign. Conc.
SARA	Good	Caution	Caution	Caution			Caution	Good	Sign. Conc.

¹Pie charts represent the proportion of plots in each ecological integrity rating category.

²ACAD regen is rated overall for abundance (Good) and pattern compared to late successional forests (Caution).

³Significant Concern is abbreviated as Sign. Conc.

Forest Inventory and Analysis Comparisons

Parks varied in the extent of forest in surrounding lands, with the highest proportion of forest around parks in New England. Forestlands surrounding NETN parks are largely under private ownership and in timber production, whereas forests in NETN parks are primarily reserved from timber production. The difference in management regimes has resulted in forests in NETN parks that are distinct from the surrounding matrix of forestlands. The proportion of plots in late successional forest is higher in every park, and the proportion of plots in mature forest is also higher in ACAD than surrounding forestlands. Indicators of older forest structure, such as coarse woody debris, large snags, and large live trees are more abundant in many NETN parks than the surrounding matrix of more intensively managed forests. These results suggest that, despite their relatively small size, forests in NETN parks may represent islands of regionally significant, older forest habitat.

Conclusions

Forest condition in NETN parks is threatened by a range of stressors, including invasive exotic plants, exotic pests and pathogens, high deer densities, acid deposition, and lack of late successional structure. Current indicators suggest that most parks could benefit from heightened invasive species control. Early detection of exotic forest pests and plants combined with rapid response control measures are also important to maintaining forest condition. While NETN parks lack late successional structure compared with benchmark conditions, NETN parks have proportionately more late successional forest and structure than surrounding forestlands. As long as forests are left to mature and management activities do not reduce the potential for development of late successional structure (e.g., cutting and/or removing coarse woody debris), we expect these metrics to improve in NETN parks with time.

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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. 2012). The following 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 resurveyed three-quarters of the plots that have been established throughout the network.

An Ecological Integrity Scorecard is used to facilitate reporting and interpreting forest condition in NETN parks. The Ecological Integrity Scorecard 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 to assess management goals. NETN staff have started working with managers at several parks to develop scorecards that track progress towards park resource management goals, and is open to working with managers at other parks.

This report includes a section on ecological integrity calculated from data representing the most recent full cycle of plot sampling (2009 to 2012) for ACAD, MABI, MIMA, SAGA and SARA. The second section compares forest metrics in NETN parks with U.S. Forest Service Forest Inventory and Analysis plots in the same ecological subsection as each park. Quality Assurance/Quality Control results and issues related to the 2012 field season are summarized in Appendix A.

Methods

Permanent forest plots have been installed and are sampled every 4 years using a rotating four-panel design (Table 1). One panel is sampled each year at ACAD (one-fourth of the plots during each of the four sampling panels) and in alternate years at the nine national historical parks and historic sites (one-half of the plots during each of two sampling panels per park). 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 at ELRO to support a stand-alone analysis.

Plots were randomly located within each park using generalized random tessellation stratified sampling (GRTS; Stevens and Olsen 2004). GRTS points which were located in areas that were primarily forested or succeeding to forest were established as forest plots, as long as they were ≥ 15 m from a road (including a carriage road), a perennial stream or water body large enough to create a canopy opening, a mowed area, or the park boundary. Plots in areas receiving management, such as logging and invasive species removal, are included in the target population as long as plots are not being specifically targeted for the management. That is, NETN forest plots should be representative of park forests, and not receive preferential treatment. In one case, a GRTS point was located in a 4 ha deer enclosure in MORR. Because this point was part of the random GRTS sample and met the pre-defined target population guidelines, it was not excluded from analyses. However, major differences between this plot and those outside of enclosures will be noted in ecological integrity metrics and trend analyses.

The permanent plot design is illustrated in Figure 1. Tree and stand measurements are made within fixed-area, square plots ($15 \times 15 \text{ m}^2$ at ACAD; $20 \times 20 \text{ m}^2$ at the other parks). Square plots in ACAD are smaller because tree density is considerably higher. Tree regeneration is measured within three 2-m radius circular microplots embedded within each square plot ($37.70 \text{ m}^2/\text{plot}$). 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-m^2 quadrats, and soil samples are obtained from a location adjacent to the plot. For a more detailed description of the forest monitoring protocol, including background information, field methods, and sample design, refer to Tierney et al. (2012).

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	

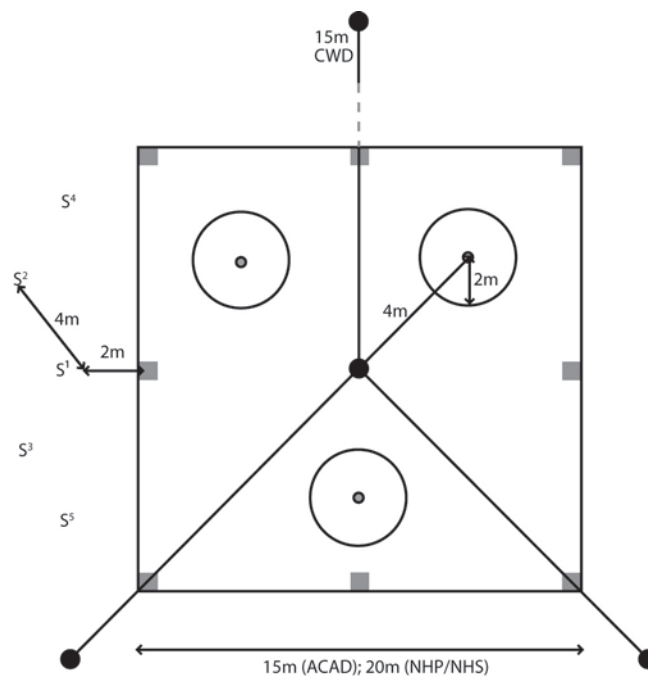


Figure 1. Plot layout showing square tree plot with three nested 2-m radius regeneration microplots (hollow circles), eight 1 m² vegetation quadrats (grey squares), and three 15-m coarse woody debris (CWD) transects. S^x is location of soil sample.

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 desired or acceptable 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 a metric’s justification, calculation and confidence, refer to the Ecological Integrity Reporting SOP in Tierney et al. (2012).

Metric calculations are based on the most recent full cycle (four panels, or one visit to each plot) of data collected from a given park. Thus, most metrics in ACAD are calculated every year. Due to our alternating sampling schedule in national historical parks (NHP) and national historic sites (NHS), metrics for those parks are calculated every 2 years. Tree condition is the only exception to this approach, as annual changes 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. After we complete the fourth panel of plots in the second cycle, we will compare metrics between the first and second cycle in a trend report.

The following metrics are reported for parks sampled in 2012 (ACAD, MABI, MIMA, SAGA, and SARA): structural stage distribution, coarse woody debris, snag abundance, tree condition and forest pests, tree regeneration, deer browse indicator species, invasive exotic plant indicator species, and tree growth and mortality. Baseline results for forest patch size, anthropogenic land use and biotic homogenization metrics were reported in Miller et al. (2011), and will not be included in this report. We will examine change in biotic homogenization in future reports, after two full sampling cycles have been completed. In addition to reporting metrics at the park level, metrics were rated for groups within parks where sample size was sufficient (i.e., at least 10 plots per group). In ACAD, metrics were calculated overall, and by the following park subunits: Isle au Haut (IAH), eastern section of Mount Desert Island (MDI), western section of MDI, and Schoodic Peninsula (Schoodic). In MABI metrics were rated overall, and by “Natural” and “Plantation” stand types. In SARA, forest plots were stratified post-sampling based on land use history. The “Field” category represents areas that were open field in 1927 when the park was established, and the soils in these areas were likely plowed and some soil amendment (e.g., manure, liming) may have occurred. Many of these areas have since succeeded to forest, including areas where forest plots are located. The “Forest” category includes sites that were forest or woodland in 1927 and have been continuously forested since 1927. Field and Forest configurations were delineated by SARA and NPS staff from rubber-sheeted georeferenced aerial photos. Note that all but one plot was cleared at some point between 1777 and 1927.

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 ²	> 15% live tree volume	5 - 15% live tree volume	< 5% live tree volume
Composition	Tree regeneration	NHPs: Seedling ratio ≥ 0	NHPs: Seedling ratio < 0	NHPs: Stocking index < 25 ³
		ACAD: Stocking index ≥ 20 and sapling: small seedling ratio ≤ 0.11	ACAD: Stocking index ≥ 20 and sapling: small seedling ratio > 0.11	ACAD: Stocking index < 20
	Tree condition and forest pests	Foliage problem < 10% <i>and</i> no Priority 1 or Priority 2 pests ⁴ <i>and</i> BBD ⁴ ≤ 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 ⁵	No change	Increasing homogenization ⁵	
	Indicator species: invasive exotic plants	< 0.5 indicator species per plot	0.5 to < 3.5 indicator species per plot	3.5 or more indicator 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 ⁵	Growth ≥ 60% mean <i>and</i> Mort ≤ 1.6%	Growth < 60% mean <i>or</i> Mort > 1.6%	
	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 CWD metric ratings were developed for forested habitats, and do not include plots in woodland habitats in ACAD.

³ Assessment point is only applicable to MORR, ROVA and WEFA.

⁴ 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).

⁵ Significant Concern rating has not been defined for these metrics.

Structural Stage Distribution

Background

Prior to European settlement, the northern hardwood and spruce-fir forests of the northeastern US were predominantly in late-successional and old growth stages of forest succession (Frelich and Lorimer 1991, Lorimer and White 2003). Natural disturbance regimes consisted primarily of frequent, small-scale disturbances (< 20% canopy removal), and stand replacing disturbances were rare (as high as 1,000-7,500 years for inland northern hardwood forests). Presettlement forests were primarily composed of shade-tolerant tree species, and characterized by a multi-aged or multi-cohort age structure, abundant standing dead and down trees at varying stages of decay, and an understory composed of advanced regeneration of shade-tolerant tree species (Mosseler et al. 2003, Fraver et al. 2009). The onslaught of logging and land-clearing for agriculture post-European settlement constituted a major disruption in the natural processes and disturbance regimes of these forests (Foster 1998, Hall et al. 2002), and the second-growth forests of today are structurally and compositionally different than late successional and old growth forests (Scheller and Mladenoff 2002, Mosseler et al. 2003, Burton et al. 2009). While natural disturbance rates in eastern oak forests were higher due to greater fire disturbance, roughly 25-40% of the presettlement Eastern oak forests were old growth (Lorimer and White 2003).

The distribution of structural stages is important for maintaining a full complement of native species, which vary in their dependence upon different successional stages. Human alteration and management have greatly changed the structural stage distributions of eastern forests such that younger forests are far more abundant, and amount of late successional and old-growth forest has been greatly reduced compared to presettlement times (Lorimer and White 2003, Mosseler et al. 2003, Whitman and Hagan 2007). These distributions will be further affected by altered disturbance regimes coincident with global climate change and outbreaks of exotic pests and pathogens (Dale et al. 2001). Comparison of existing distributions with those expected under natural disturbance regimes provides an indicator of altered disturbance regimes as well as habitat availability.

Structural stage distribution is calculated from tree size and canopy position measurements, using a method similar to that of Frelich and Lorimer (1991), but substituting basal area for exposed crown area (Goodell and Faber-Langendoen 2007). Plots are classified as pole, mature, or late-successional based on relative basal area of live canopy trees within pole, mature and large size classes. For all parks except ACAD, size classes are 10-25.9 cm DBH (pole), 26-45.9 cm DBH (mature) and ≥ 46 cm DBH (large). Dominant trees of coastal Maine (balsam fir and red spruce) are typically smaller in size than dominant trees at the other NETN parks, and ACAD size classes have been adjusted to be 10-19.9 cm DBH (pole), 20-34.9 cm DBH (mature), and ≥ 35 cm DBH (large).

We assign assessment points based on expected percentage of late successional forest stages across the landscape as compiled by Frelich and Lorimer (1991) and Lorimer and White (2003), and ratings are based on proportion of plots that are late successional and mature forest. Plots classified in the field as early successional forest (i.e., $\leq 60\%$ canopy cover and dominated by open-grown trees), were not reclassified as pole, mature or late-succession, but were included to calculate proportion of plots in mature and late successional stages. Plots classified in the field as woodland, which have $\leq 60\%$ canopy cover due to harsh growing conditions, were not included

in this metric. Expected structural stage distributions vary among forest ecosystem types; thus assessment points vary among parks, and are based on the matrix forest ecosystem dominant at each park. Assessment points were based on the following matrix forest ecosystems at each park: Acadian Low-Elevation Spruce-Fir-Hardwood Forest at ACAD; both Appalachian Hemlock-Northern Hardwood Forest and Laurentian-Acadian Northern Hardwoods Forest at MABI; Northeastern Interior Dry-Mesic Oak Forest at MIMA; Appalachian Hemlock-Northern Hardwood Forest at SAGA; and both Appalachian Hemlock-Northern Hardwood Forest and Northeastern Interior Dry-Mesic Oak Forest at SARA. At parks with more than one matrix forest ecosystem type, assessment points were based conservatively on the type with lower late successional structure. Assessment points are defined as follows:

Good: At least 70% (MABI and SAGA), 50% (ACAD), and 25% (MIMA and SARA) late-successional structure across the park

Caution: Less than 70% (MABI and SAGA), 50% (ACAD), and 25% (MIMA and SARA) late-successional structure across the park

Sig. concern: Less than 70% (MABI, SAGA), 50% (ACAD), and 25% (MIMA and SARA) combined mature and late-successional structure across the park

Results and Discussion

Desired levels of late successional forest were only met at MIMA and in the Forest group at SARA, and both were rated Good (Table 3). While MABI and SAGA had proportionately more plots in late successional forest than MIMA and SARA, these parks also have higher expected levels of late successional forest due to differences in the dominant forest type, and both MABI and SAGA were rated Caution. This metric follows predictable patterns by land use history in SARA, with plots that have succeeded to forest since 1927 more likely to be in early successional or pole stages than plots that have been forested since 1927 (Figure 2). Structural stage distribution is similar between Natural and Plantation stands in MABI.

Only a small percent of plots were in late successional forest in ACAD, and all park subunits but eastern MDI were rated Caution. Eastern MDI had a much higher proportion of plots in the pole stage due to the 1947 fire, and due to a lack of late successional forest, was rated Significant Concern. As long as forests are left to succeed under natural disturbance regimes, this metric is expected to improve for all parks over time.

While not part of the metric, it is notable that over a quarter of the plots on IAH and Schoodic are in woodlands, which tend to occur in areas with exposed bedrock, and have < 60% canopy cover due to the harsh growing conditions. Plots in woodlands are not expected to succeed into later successional forest, and may be more sensitive to stressors due to already stressed growing conditions.

Coarse Woody Debris and Snag Abundance

Background

Dead wood, in the form of fallen coarse woody debris (CWD) and standing dead trees (snags), is an important structural feature of forests that provides habitat for many taxonomic groups,

Table 3. Structural stage distribution of plots in NETN parks.

Park	Group	# Plots	% Late Succ.	% Mature and Late Succ.	Rating
ACAD	Overall	137	13.1	56.9	Caution
	IAH	12	0.0	58.3	Caution
	MDI East	69	11.6	43.5	Sign. Conc.
	MDI West	53	18.9	71.7	Caution
	Schoodic	3	0.0	100.0	Caution
MABI	Overall	24	58.3	95.8	Caution
	Natural	13	61.5	92.3	Caution
	Plantation	11	54.5	100.0	Caution
MIMA		20	30.0	75.0	Good
SAGA		21	42.9	90.5	Caution
SARA	Overall	31	19.4	54.8	Caution
	Field	24	16.7	50.0	Caution
	Forest	7	28.6	71.4	Good

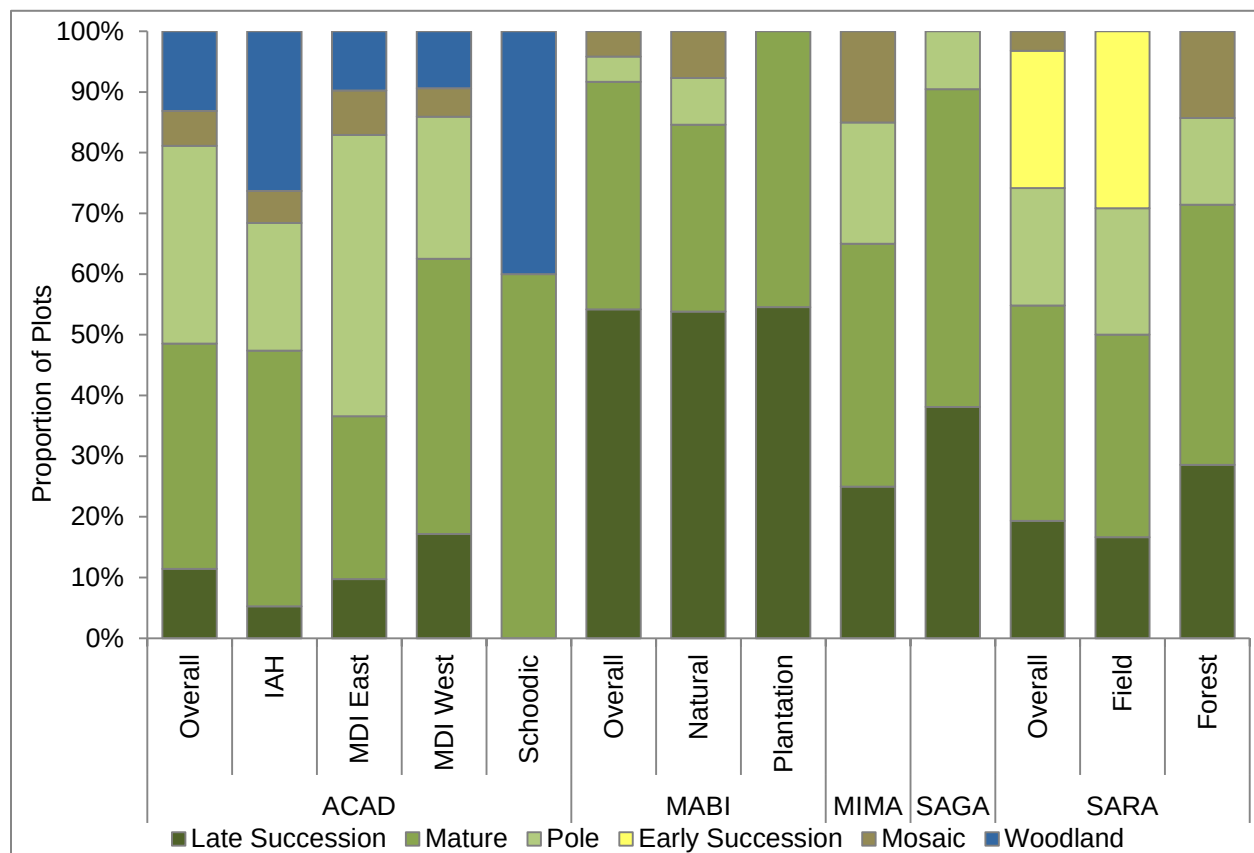


Figure 2. Proportion of plots in each structural stage (Late Succession, Mature, and Pole) and field stand structure class (Early Succession, Mosaic and Woodland), based on data collected between 2009 and 2012. Structural stages are based on proportion of basal area by size class. Field stand structure classes are determined in the field and not classified into structural stages. Woodlands are excluded from the structural stage distribution metric.

including mammals, birds, herpetofauna, and insects. In addition, tip-up mounds caused by wind-throw contribute to forest soil turnover and create important microhabitats for vegetation such as tree seedlings and bryophytes (Jonsson and Esseen 1990, Ulanova 2000, Samonil et al. 2010). 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 vary substantially across ecosystems, with site conditions, and with stand age (Tyrrell et al. 1998). However, positive relationships 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). In addition, large-diameter snags provide habitat for a greater number of vertebrate species (Cline et al. 1980, Wynne and Sherburne 1984, DeGraaf and Shigo 1985) and persist longer than smaller-diameter snags (Morrison and Raphael 1993, Garber 2005). Therefore density of large-diameter snags is also an important indicator of habitat quality and availability. 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 a CWD ratio, which is the ratio of CWD volume to live tree volume and is expressed as a percent. The CWD ratio is calculated for each plot, and is then averaged for a park or group. 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. Plots in woodland habitats (ACAD only) are also excluded from the CWD metric, as expected ratios of CWD volume to live tree volume in woodlands are unknown.

Snag abundance metric ratings are based on the percent of standing trees that are snags and are calculated on all plots to distinguish between Good and Caution ratings. The assessment point for Significant Concern is based on best management practices developed by the US Forest Service, which recommends leaving 5-10 medium or large (> 30cm DBH) snags per ha for wildlife needs (USFS 1980). 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.

At the request of MABI staff, we began recording the presence of small and large tree cavities on live and dead trees as a tree condition in 2012. While cavity data are not used to rate the tree condition metric, tree cavities are important wildlife habitat that are often lacking in younger and managed forests. Cavity data are summarized as the average number of live and dead trees with a small or large cavity per hectare. Small cavities are 3 to 5 cm diameter, and large cavities are over 5 cm diameter.

Results and Discussion

The western section of MDI in ACAD and the Field group in SARA were the only groups to receive a Good rating for CWD (Table 4). With the exception of MIMA, remaining parks and subunits were rated Caution for CWD. MIMA was rated Significant Concern, and had the lowest CWD ratio and CWD volume of all the parks sampled in NETN.

The CWD ratio in ACAD Overall was very close to the 15% assessment point that distinguishes between Good and Caution, and has fluctuated slightly over and under 15% during the last 5 years of reporting. The switch between Good and Caution does not likely represent an actual trend in CWD, but rather reflects variability in the data. In addition, the number of plots included in the CWD rating for ACAD has decreased by 10 plots since the first survey cycle. This is the result of plots being misclassified as multi-aged forest during the first survey, and correctly reclassified as woodlands, which are excluded from this metric, during the second survey cycle.

The different ratings for the Field and Forest groups in SARA relate primarily to live tree volume. Plots in the Field group tend to have relatively low live tree volume, and older stands (i.e., Forest group) have higher live tree volume. Therefore, even though the Field and Forest groups having similar average CWD volumes, the CWD ratio and corresponding rating in the Field group were higher.

Despite a relatively high volume of CWD, MABI and SAGA were rated Caution because live tree volume was also relatively high in these parks. Based on field observations in MABI, CWD volume may be considerably higher than our current sampling methods capture. On several occasions we have encountered CWD pieces in plantations that were originally 10+ m long and that had been cut into 1 - 2 m lengths. While the volume of the combined pieces may be high, our methods only measure the length to the first cut. With less exposed surface area, intact logs are likely to persist longer and provide better quality habitat over time. Where possible, we recommend CWD pieces be left intact or kept as long as equipment will allow.

Ratings for Snag Abundance were more variable across NETN parks (Table 5). ACAD had the highest snag density of all parks sampled in NETN. However, due to a lack of medium to large snags (diameter at breast height [DBH] ≥ 30 cm), the eastern section of MDI and Schoodic were rated Significant Concern. While IAH was the only subunit to receive a Good rating, ACAD Overall and western MDI narrowly missed a Good rating due to having just under 10% of trees ≥ 30 cm DBH that are snags. The Field group in SARA was the only other group to receive a Good rating for snag abundance, and the high abundance of snags is primarily due to die back of American elm (*Ulmus americana*) from Dutch elm disease, and stem exclusion of old-field white pine (*Pinus strobus*) stands. Both Natural stands and Plantations in MABI had lower than 10% standing trees as snags. The Plantation group had a slightly higher abundance of snags than Natural stands, but was rated Significant Concern due to the absence of snags ≥ 30 cm DBH.

Abundance of tree cavities varied by park, with the highest cavity detections in SAGA and the lowest in MABI and MIMA (Table 6). In general, dead trees tended to have more cavities than live trees, and few large cavities were found on live trees (Table 6).

Forested systems in most NETN parks are relatively young, and are likely to fall short of desired late successional levels of CWD and snags for some time (decades to centuries). As long as forests are left to mature and management activities (e.g., cutting and/or removing coarse woody debris) do not reduce the potential for development of CWD and large diameter snags, we expect these metrics to improve with time.

Table 4. Coarse woody debris (CWD) metric ratings, ratios, and volume calculations for NETN parks based on data collected from 2009 to 2012. Metric ratings are based on CWD ratio, which is the ratio of coarse woody debris volume to live tree volume and is expressed as a percent. The CWD ratio is calculated for each plot in a group and then averaged, and will differ from the mean CWD divided by the mean live tree volume. Only plots with complete stand height data are included in the analysis (i.e., no early successional plots). Groups with fewer than 10 plots were not rated for CWD, and woodland plots are not included in the ACAD ratings. 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)		Live Tree Volume (m ³ /ha)	
				Mean	SE	Mean	SE	Mean	SE	Mean	SE
ACAD	Overall	151	Caution	13.04%	1.45%	24.69	2.61	352.86	37.25	207.80	9.97
	IAH	14	Caution	11.74%	2.92%	23.03	5.53	329.10	79.00	191.05	30.97
	MDI East	74	Caution	10.28%	1.91%	15.91	3.02	227.35	43.11	182.17	16.01
	MDI West	57	Good	17.20%	2.76%	36.79	5.11	525.75	73.00	243.64	11.90
	Schoodic	6	---	10.59%	3.18%	21.96	7.53	313.85	107.57	222.50	61.13
MABI	Overall	23	Caution	7.29%	1.92%	35.09	7.94	501.48	113.52	532.50	42.78
	Natural	12	Caution	7.18%	3.10%	31.30	13.04	447.38	186.33	457.31	42.01
	Plantation	11	Caution	7.41%	2.34%	39.22	9.11	560.51	130.19	614.52	70.78
MIMA		19	Sign. Conc.	3.48%	1.31%	8.91	3.24	127.27	46.28	327.16	51.75
SAGA		21	Caution	7.49%	2.61%	31.76	7.21	453.88	103.08	577.17	66.93
SARA	Overall	24	Caution	14.64%	4.48%	22.72	5.06	324.67	72.35	285.18	33.24
	Field	17	Good	16.66%	5.98%	22.14	6.05	316.45	86.44	262.62	38.66
	Forest	7	---	9.75%	5.22%	24.11	9.97	344.62	142.50	339.99	64.28

Table 5. Snag abundance ratings and calculations for NETN parks based on data collected from 2009 to 2012. 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. Groups with fewer than 10 plots were not rated for this metric. 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	Overall	176	Caution	171.46	10.87	6.82	1.41	16.09%	8.44%
	IAH	19	Good	116.96	16.72	9.36	5.46	12.76%	12.12%
	MDI East	82	Sign. Conc.	146.34	14.66	4.88	1.73	14.63%	7.20%
	MDI West	65	Caution	203.76	19.87	9.57	2.67	17.23%	9.46%
	Schoodic	10	Sign. Conc.	271.11	47.06	0.00	0.00	24.21%	0.00%
MABI	Overall	24	Sign. Conc.	42.71	9.21	4.17	1.94	8.49%	2.55%
	Natural	13	Caution	38.46	13.46	7.69	3.33	7.38%	5.56%
	Plantation	11	Sign. Conc.	47.73	12.82	0.00	0.00	9.91%	0.00%
MIMA		20	Caution	53.75	8.94	6.25	2.48	10.97%	5.05%
SAGA		21	Caution	79.76	16.51	14.29	3.69	12.59%	7.19%
SARA	Overall	31	Caution	92.74	18.26	8.87	3.19	20.50%	8.59%
	Field	24	Good	93.75	21.24	9.38	3.93	21.63%	10.11%
	Forest	7	Caution	89.29	38.13	7.14	4.61	17.24%	5.13%

Table 6. Tree cavity summary statistics for each park.

	# Plots	Small Cavities				Large Cavities			
		# Live Trees/ ha		# Dead Trees/ ha		# Live Trees/ ha		# Dead Trees/ ha	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE
ACAD	44	5.05	2.59	7.07	3.52	4.04	1.95	5.05	2.15
MABI	12	2.08	2.08	4.17	2.81	0	0	4.17	2.81
MIMA	10	5.00	3.33	5.00	3.33	0	0	0	0
SAGA	11	6.82	3.52	13.64	7.04	6.82	4.87	11.36	9.15
SARA	16	1.56	1.56	10.94	5.09	4.69	3.40	10.94	3.20

Tree Regeneration

Background

This metric assesses the quantity and composition of 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, acid deposition, 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).

In the NHPs, this metric is rated using a seedling ratio and stocking index. The seedling ratio 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). This ratio takes the species richness in browsed (30-100 cm) minus species richness of un-browsed (15-30 cm) size classes and divides this by the sum of species richness in the browsed and un-browsed size classes. This metric only considers the preferred browse species listed in 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, and SAGA).

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. The stocking index in NETN plots is averaged over three 2-m radius microplots. A stocking index less than 25 is considered inadequate for mid-Atlantic hardwood stands with low deer densities, 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, the stocking target (25) is based on experimental data collected in oak/hickory forests in Pennsylvania, and it is unknown whether these numbers are appropriate for the northern hardwood forests common in northern NETN parks.

The deer browse index 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 7). 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 data from 2010 to 2012 for ACAD, 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 into the tree regeneration metric.

Table 7. Index of deer browse impacts assessed for each plot in national historical parks and historic 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 exclosure, 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 exclosure, 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.

NETN recently developed a tree regeneration metric for ACAD using data collected in late successional spruce-fir stands (Miller et al. in review). The regeneration metric for ACAD evaluates whether current patterns and abundance of regeneration are consistent with those expected in late successional forests. The metric uses the stocking index to assess regeneration abundance for all stand types, and a ratio of sapling to small (15-100 cm) seedling density to assess regeneration patterns for upland forests. The expectation is that regeneration in late successional stands is abundant and, while both are present, small seedlings are more abundant than saplings. To account for the high spatial variability in regeneration, this metric requires a minimum of ten plots to be rated, and will be summarized at the group level, rather than by proportion of plots in each rating. The assessment points for tree regeneration in ACAD were determined as follows:

Good: stocking index ≥ 20 , and sapling:small seedling density ratio ≤ 0.11 .

Caution: stocking index ≥ 20 , and sapling:small seedling density ratio > 0.11 .

Significant Concern: stocking index < 20 .

In the absence of data that can distinguish healthy from impacted condition in northern hardwood forests, we will examine the seedling ratio, stocking index, seedling densities and deer browse index collectively to assess tree regeneration in the parks currently without a Significant Concern assessment point (MABI, MIMA, SAGA and SARA).

Results and Discussion

In MABI, MIMA, SAGA and SARA, a high percentage of plots were rated Caution due to negative seedling ratios (Figure 3). The average deer browse index is fairly low in MABI, MIMA and SAGA, and other factors such as stand development and/or invasive species may be behind the negative seedling ratios. In MABI, Natural stands have a higher seedling ratio and stocking index than Plantations, and larger seedlings are more abundant in Natural stands (Figure 4). These patterns are expected, as even-aged plantations tend not to support an abundant understory. In SARA, the average deer browse index is approaching 3, indicating moderate impacts, and is highest in the Field group (Table 8). Regeneration patterns also differ between the Field and Forest groups. Seedlings of all sizes are represented in the Forest group and the average stocking index is over 100. In contrast, seedlings over 1 m are rare in the Field group (Figure 4), and the average stocking index is considerably lower (Table 8). Based on field observations from 2012, heavy browsing on hardwood seedlings was noted in several plots in the Field group, and browsing was less evident in plots in the Forest group. It is possible that deer browse is keeping seedlings from reaching larger height classes in the Field group, and this, along with invasive species, may be hindering forest succession in these habitats.

Based on the new metric for ACAD, forests across all subunits and successional stages in ACAD have sufficient levels of regeneration, but patterns of regeneration reflect those of earlier stages of forest succession (Table 9). Therefore, all units of ACAD were rated Good for the stocking index, and Caution for the sapling:small seedling ratio. As forests mature and move towards more uneven-aged stands, we expect the sapling:seedling density ratios across ACAD subunits to approach the ratio observed in reference stands.

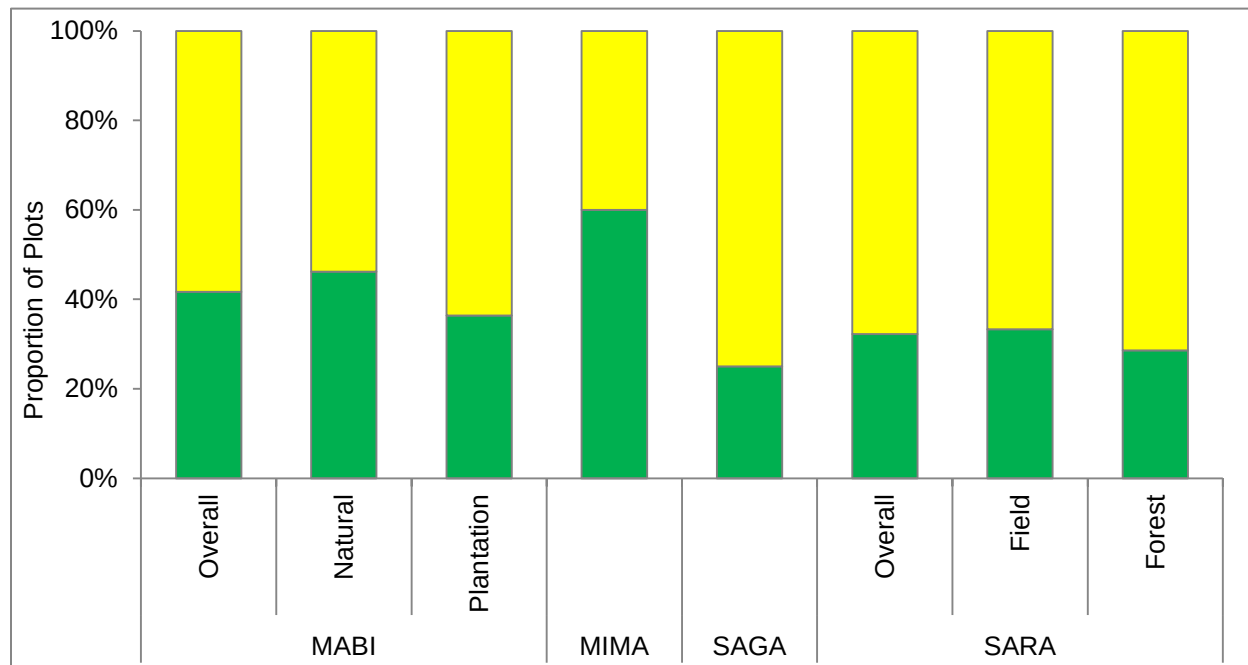


Figure 3. Proportion of plots in NHPs receiving Good (green), and Caution (yellow) ratings for tree regeneration. An assessment point for Significant Concern has not been defined for this group of parks.

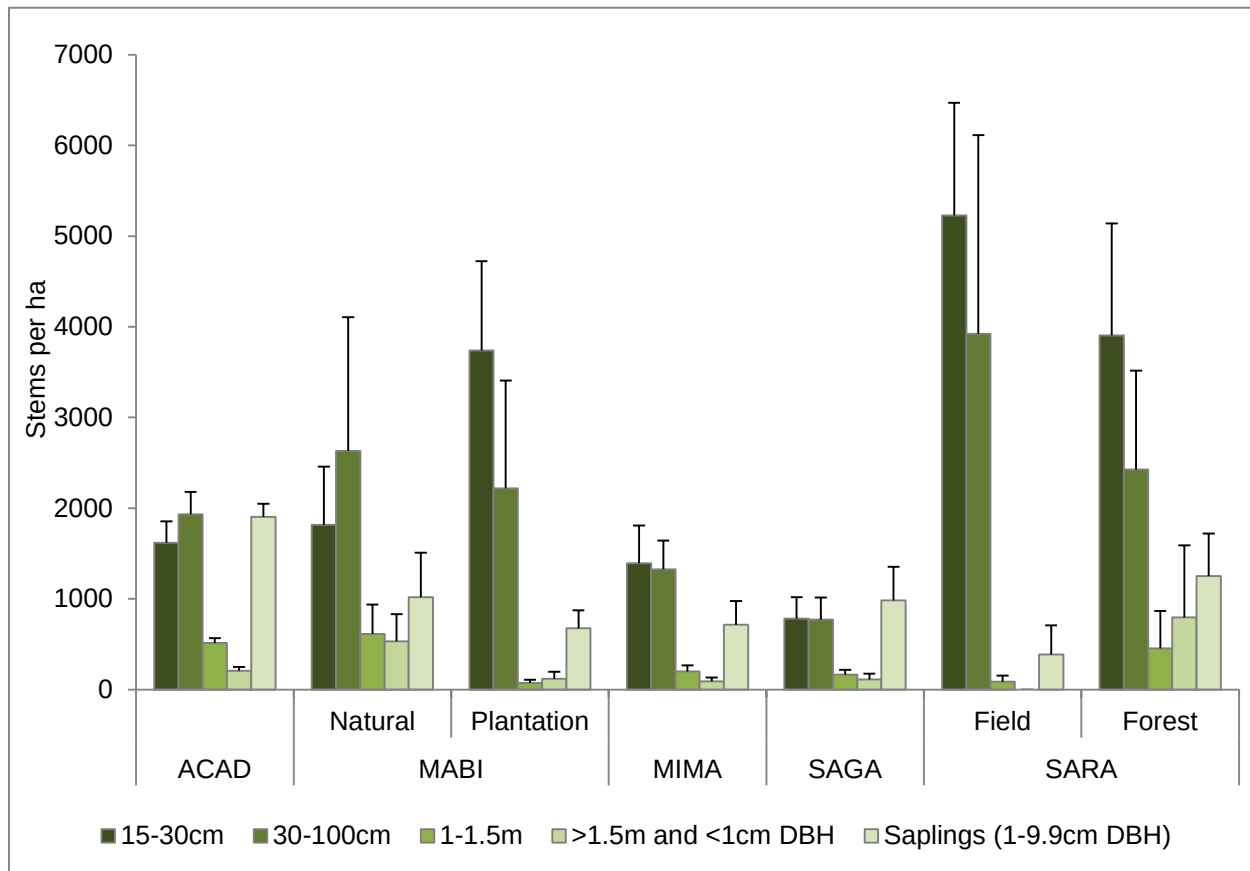


Figure 4. Mean seedling and sapling density (stems/ha) based on data collected from 2009-2012. Error bars denote +1 standard error around the mean.

Table 8. Mean stocking index and seedling ratio averaged over three 2-m radius microplots, and based on data collected from 2009-2012 for the NHPs. Plots without browse preferred species are not included in the seedling ratio summaries. The deer browse index was not used to rate the regeneration metric.

Park	Group	Stocking Index			Seedling Ratio			Deer Browse Index		
		Mean	SE	N	Mean	SE	N	Mean	SE	N
	Overall	58.78	22.70	24	-0.18	0.15	21	2.45	0.12	24
MABI	Natural	87.77	40.52	13	-0.08	0.21	11	2.46	0.14	13
	Plantation	24.52	6.39	11	-0.29	0.22	10	2.45	0.21	11
MIMA		44.82	12.83	20	0.22	0.16	17	2.60	0.11	20
SAGA		70.03	18.32	18	-0.25	0.12	15	2.40	0.11	20
	Overall	49.08	21.73	30	-0.38	0.09	30	2.90	0.10	31
SARA	Field	31.10	9.45	24	-0.37	0.11	23	2.96	0.11	24
	Forest	110.71	92.00	7	-0.39	0.17	7	2.71	0.18	7

Table 9. Regeneration metric summaries for ACAD. Standard error (SE) for the ratio accounts for the uncertainty in the estimates of sapling and seedling abundance. Mosaic and forested swamp plots were excluded from the stocking index, and only upland forests were included in the sapling:small seedling ratio. The deer browse index was not used to rate the regeneration metric.

ACAD Group	Stocking Index				Sapling: Small Seedling Ratio				Deer Browse Index	
	N	Mean	SE	Rating	N	Mean	SE	Rating	Mean	SE
Overall	165	132.22	10.45	Good	140	0.53	0.09	Caution	2.53	0.05
IAH	18	153.43	32.09	Good	13	1.14	0.53	Caution	2.58	0.16
MDI East	79	116.01	14.91	Good	70	0.72	0.20	Caution	2.50	0.06
MDI West	58	148.95	18.60	Good	52	0.39	0.10	Caution	2.53	0.07
Schoodic	10	125.03	29.86	Good	5	0.15	---	---	2.70	0.21

Tree Condition and Forest Pests

Background

This metric assesses tree condition based on qualitative observations of specific tree health problems and canopy foliage condition. 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 any combination of soil chemistry, climate, pathogens, or other drivers and stressors. In particular, exotic pests and pathogens have the potential to severely impact forest tree composition as well as structure and function. Several species of exotic pests pose serious threats to northeastern forests if they advance into the region; these NETN “Priority 1” pests are Asian longhorned beetle (*Anoplophora glabripennis*; ALB), emerald ash borer (*Agrilus planipennis*; EAB), hemlock woolly adelgid (*Adelges tsugae*; HWA), and sudden oak death (*Phytophthora ramorum*; SOD). Other forest pests can cause problems that are not quite as severe, and/or may already be widespread in the NETN region. These NETN “Priority 2” pests are balsam woolly adelgid (*Adelges piceae*; BWA), beech bark disease (BBD), butternut canker (*Sirococcus clavigignenti-juglandacearum*; BC), and elongate hemlock scale (*Fiorinia externa*; EHS). As we learn more about the distribution and impacts of winter moth (*Operophtera brumata*), a recently introduced pest in the Northeast, we may add this species to one of the priority lists.

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 (< 10%) averaged across a plot and within individual species, minor damage from BBD (BBD index ≤ 2), and no evidence of damage by Priority 1 or other Priority 2 pests and pathogens. More extensive foliage problems (10-50%), more extensive BBD damage (BBD index > 2), or evidence of damage by one of the other Priority 2 pests and pathogens indicate cause for concern, and are rated Caution. 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 Priority 1 pests have reached NETN forests indicates a significant concern which might still be controlled by management action.

It is important to note that after the last reporting cycle, HWA was changed from a Priority 2 pest to a Priority 1 pest. While HWA has been in the southern region of NETN for over a decade, hemlock remains a significant component of forests in ROVA and northern NETN parks. The loss of hemlock due to HWA can result in cascading effects throughout the ecosystem, and is a major threat to the more northern parks in the network (Orwig and Foster 1998, Jenkins et al. 1999, Eschtruth et al. 2006). Therefore, we felt it was more appropriate to treat HWA as a Priority 1 pest. This change means that plots where HWA is detected are automatically rated Significant Concern.

Results and Discussion

Tree condition in 2012 was similar to the 4-year average for ACAD, MABI, SAGA and SARA (Figure 5). Balsam woolly adelgid (BWA) and beech bark disease (BBD) were the only pests/pathogens on the priority list that were detected in 2012 (see Table 2). BWA was only detected in ACAD, and occurred in five plots in the western section of MDI and one plot on the eastern section of MDI. BBD was detected in all parks but SARA, with the most detections in MABI (7 plots) and SAGA (6 plots). BBD was the main reason for Caution ratings in MABI and SAGA. Slightly elevated levels of leaf loss, necrosis (dead leaves/needles) and holes (herbivory), primarily on hardwood species, were the main factors for Caution ratings in ACAD and SARA.

Four out of the ten plots sampled in MIMA in 2012 were rated Significant Concern, and these were all due to elevated insect herbivory (i.e., holes in leaves) on red maple (*Acer rubrum*). While the species behind the increased herbivory are unknown, our main concern is that this may

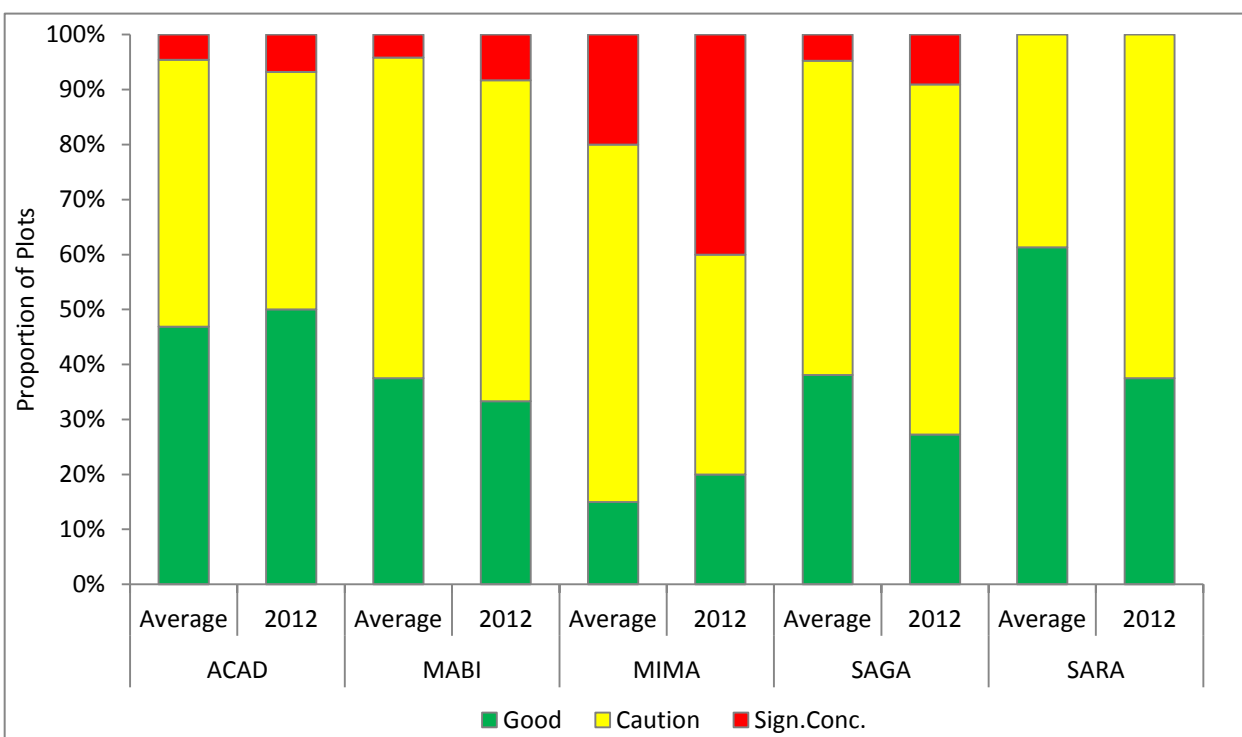


Figure 5. Proportion of plots receiving Good (green), Caution (yellow), and Significant Concern (red) ratings for tree condition for each park sampled in 2011. Average bars include 4 years (2008 – 2011) of data for ACAD, and 2009 and 2011 data for remaining parks. 2011 bars only include data collected in 2011.

be the result of winter moth (*Operophtera brumata*). Winter moth is a non-native insect that feeds on the leaves of a range of hardwood and deciduous shrub species, including maples, oaks and blueberries (U.S. Forest Service 2012). Winter moth was first detected in New England in 2003 in eastern Massachusetts, and has since spread throughout Coastal New England including, most recently, Mount Desert Island. Repeated defoliation by winter moth can increase tree mortality either directly, or through increased susceptibility to other stressors (e.g., drought, secondary defoliators, and fungal pathogens). Winter moths are best identified when the pale brown male moths emerge and swarm in November, a time of year when few other insects are out. However, adults still must be sent to a lab for DNA analysis to distinguish winter moth from the native Bruce spanworm (*Operophtera bruceata*). Larvae of the winter moth are hard to distinguish from other species in the Geometridae (inchworm) family, and are pale green caterpillars with a white stripe running down each side of the body. For more information on winter moth identification and spread, refer to the UMass Extension website (<http://extension.umass.edu/landscape/fact-sheets/winter-moth-overview>). Note that because red maple was the main species with a high rate of herbivory, and defoliation of oak species was not as high, winter moth may not be the herbivore in MIMA. We will continue to monitor herbivory with special attention to potential winter moth infestations in MIMA and ACAD.

The known range of the emerald ash borer (EAB) continues to expand in the eastern US. EAB has officially been detected in two trees in VAMA that were being monitored by the NY Department of Environmental Conservation (Roosevelt-Vanderbilt National Historic Sites, Dave Hayes, Natural Resource Program Manager , 12 March 2013, personal communication). EAB was also detected in 2011 in a single prism trap in Selkirk, New York. This location is only approximately 40 miles south of SARA, a park where EAB poses a significant threat. White ash (*Fraxinus americana*) is a common forest species in SARA, and it appears to be one of the few tree species capable of penetrating and persisting in the exotic shrub thickets in the park.

American elm can also penetrate the exotic thickets, but it does not persist long in the canopy due to Dutch elm disease. White ash is also the most abundant seedling in the 15-30 and 30-100 cm height classes (Miller et al. 2010). Loss of ash in SARA is expected to cause major changes in forest composition and structure.

EAB was also recently detected in central New Hampshire, western Massachusetts and southwestern Connecticut. Continued vigilance for detection and outreach for prevention by park staff, cooperators and volunteers is important to slow the spread of EAB. For more information on EAB, and strategies for slowing the spread of EAB, check the Collaborative Emerald Ash Borer Program website (<http://www.emeraldashborer.info>).

Invasive Exotic Plant Indicator Species

Background

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 exotic species are monitored in NETN forest plots, and the Eastern Rivers and Mountains Network and NETN are implementing a separate protocol for early detection of invasive exotic species and forest pests.

To better understand the threat posed by invasive exotic plants, we developed a list of 22 indicator plant species that are highly invasive in northeastern forest, woodland, and successional habitats (Appendix C). 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 greater 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. Thus, total abundance of exotic species may be higher than reported here for indicator species. In addition to the average number of indicator invasive exotic species per plot, we calculated average percent cover and average number of species at the quadrat level to assess degree of invasion in each park. In MABI and SARA, we performed ANOVAs on the three metrics by land use group in R 2.15.2 (R Core Team 2012). Where modified Levene's tests (car package; Fox et al. 2012) indicated a difference in variance between groups at $p\text{-value} < 0.10$, we performed weighted least squares ANOVA using the bstats package in R (Wang 2012). In most cases, data were not normally distributed, and while ANOVA is robust to violations of normality, significant results should be treated as suggestive rather than definitive. For next year's trend report, we will examine trends in invasive exotic species cover, frequency, and diversity.

Results and Discussion

With indicator species found in only three out of 176 plots, all units of ACAD were rated Good for indicator invasive exotic species (Table 10). Natural stands in MABI also had few indicator invasive exotic species and this group was rated Good. MABI Overall and Plantations, SAGA and SARA Overall were rated Caution. Averaging nearly five species per plot, MIMA had the highest number of indicator invasive exotic species per plot, and was rated Significant Concern.

Ratings and degree of invasion varied by land use group in MABI and SARA. Plots in the Forest group in SARA had a significantly lower number of indicator invasive exotic species per quadrat ($p\text{-value} = 0.010$, $df = 1, 29$), and significantly lower percent cover of indicator invasive exotic species per quadrat ($p\text{-value} = 0.004$, $df = 1, 29$) than plots in the Field group. MABI follows a similar pattern, despite relatively small values, with the less disturbed Natural stands having significantly lower percent cover ($p\text{-value} = 0.009$, $df = 1, 22$) and fewer species per quadrat ($p\text{-value} = 0.009$, $df = 1, 22$) of indicator invasive exotics than Plantations.

The list of the top five most frequent indicator invasive exotics for each park demonstrates that NETN parks have a lot of invasive exotic species in common (Table 11). Exotic bush honeysuckles (*Lonicera* spp.) are the most frequent indicator invasive exotic across all of the parks sampled in 2012. Common buckthorn (*Rhamnus cathartica*), glossy buckthorn (*Frangula alnus*), oriental bittersweet (*Celastrus orbiculatus*), and multiflora rose (*Rosa multiflora*) are also relatively common across NETN parks. These species represent some of the most invasive species in the Northeast, and it is critical that park managers continue to detect, manage and prevent the introduction and spread of these species in their parks.

Table 10. Indicator invasive exotic plant species ratings for NETN parks. Metric ratings are based on the mean number of indicator species found per plot from 2009 to 2012. Average indicator invasive exotic

percent cover (Mean % Cover / Quad), and mean number of indicator invasive exotic species per quadrat (Mean # / Quad) were used to interpret this metric, but were not involved in the metric rating.

Park	Group	N	Mean #/ Plot	Mean % Cover / Quad	Mean #/ Quad	Rating
ACAD	Overall	175	0.02	<0.01	<0.01	Good
	IAH	19	0	0	0	Good
	MDI East	82	0.05	<0.01	<0.01	Good
	MDI West	64	0	0	0	Good
	Schoodic	10	0	0	0	Good
MABI	Overall	24	0.71	<0.01	0.02	Caution
	Natural	13	0.46	0	0	Good
	Plantation	11	1.00	<0.01 ¹	0.03 ¹	Caution
MIMA		20	4.95	13.97	1.35	Sign. Conc.
SAGA		21	0.67	1.06	0.05	Caution
SARA	Overall	31	3.45	14.79	1.04	Caution
	Field	24	3.75	18.06 ¹	1.17 ¹	Sign. Conc.
	Forest	7	2.43	3.56	0.57	Caution

¹ Indicates a significant difference ($p < 0.05$) between land use group in MABI and SARA, and denotes the higher mean value.

In addition to ecosystem impacts, recent studies suggest that exotic shrub thickets can have an indirect effect on human health. By creating a more favorable humid microclimate, exotic shrub thickets can harbor higher densities of blacklegged ticks (*Ixodes scapularis*) than uninvaded forests (Elias et al. 2006, Williams and Ward 2010). Research has also found higher incidences of blacklegged ticks that are infected with human pathogens in exotic shrub thickets due to altered movement and habitat use by mammals that disperse ticks (Williams et al. 2009, Allan et al. 2010). Blacklegged tick populations and infection rates dramatically decreased when the exotic shrub thickets were removed.

Deer Browse Indicator Species Background

A recurring trend that has been observed throughout eastern U.S. forests is a compositional shift in forest understories in response to sustained high deer densities (Horsley et al. 2003, Rooney et al. 2004, Weigmann 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). Negative browse impacts have been documented where deer densities are as low as 8 per km² for 10 or more years, and severe impacts have been observed with deer densities ≥ 20 per km² (Horsley et al. 2003, Augustine and deCalesta 2003).

This metric monitors the change in quadrat frequency of indicator herbaceous species over time. The indicator list of species includes 15 common, highly-visible herbaceous species that are preferred by deer, and/or have been shown or predicted to be intolerant of deer browsing due to life history traits (Augustine and deCalesta 2003). Also included on the list are three species and one genus considered unpalatable to deer, and that have been shown to increase in abundance under heavy deer browse pressure. Frequency is calculated for each indicator species,

Table 11. Most frequent indicator invasive exotic species in NETN forest plots by park from 2009 to 2012. Percent plot frequency is the percent of plots with a given species per park or group.

Park	Group	Latin	Common	# Plot Occurrences	% Plot Frequency
ACAD	MDI-East	<i>Berberis thunbergii</i>	Japanese barberry	1	1.2
		<i>Frangula alnus</i>	glossy buckthorn	2	2.4
		<i>Lonicera</i> spp.	exotic bush honeysuckle	1	1.2
MABI	Natural	<i>Berberis vulgaris</i>	common barberry	4	30.8
		<i>Celastrus orbiculatus</i>	oriental bittersweet	1	7.7
		<i>Rhamnus cathartica</i>	common buckthorn	1	7.7
	Plantation	<i>Berberis vulgaris</i>	common barberry	2	18.2
		<i>Lonicera</i> spp.	exotic bush honeysuckle	6	54.6
		<i>Rhamnus cathartica</i>	common buckthorn	3	27.3
MIMA		<i>Acer platanoides</i>	Norway maple	9	45.0
		<i>Celastrus orbiculatus</i>	oriental bittersweet	16	80.0
		<i>Frangula alnus</i>	glossy buckthorn	18	90.0
		<i>Lonicera</i> spp.	exotic bush honeysuckle	11	55.0
		<i>Rosa multiflora</i>	multiflora rose	17	85.0
SAGA		<i>Berberis thunbergii</i>	Japanese barberry	3	14.3
		<i>Celastrus orbiculatus</i>	oriental bittersweet	2	9.5
		<i>Euonymus alata</i>	winged burning bush	1	4.8
		<i>Ligustrum</i> spp.	privet	1	4.8
		<i>Lonicera</i> spp.	exotic bush honeysuckle	6	28.6
		<i>Rhamnus cathartica</i>	Common buckthorn	1	4.8
SARA	Field	<i>Alliaria petiolata</i>	Garlic mustard	9	37.5
		<i>Ligustrum</i> spp.	Privet	4	16.7
		<i>Lonicera</i> spp.	Exotic bush honeysuckle	24	100.0
		<i>Rhamnus cathartica</i>	Common buckthorn	23	95.8
		<i>Rosa multiflora</i>	Multiflora rose	17	70.8
	Forest	<i>Alliaria petiolata</i>	Garlic mustard	2	28.6
		<i>Celastrus orbiculatus</i>	Oriental bittersweet	2	28.6
		<i>Lonicera</i> spp.	Exotic bush honeysuckle	5	71.4
		<i>Rhamnus cathartica</i>	Common buckthorn	4	57.1
		<i>Rosa multiflora</i>	Multiflora rose	3	42.9

based on presence or absence in eight herbaceous quadrats per plot, and is summarized at the park unit or group level for each survey cycle. Note that this metric relies on change in species frequency, and therefore has limited value for sites already highly impacted by deer browse.

Indicator species are listed in Appendix D. Metric ratings are based on the change in frequency of indicator species between time periods, and therefore only include data from plots that have been sampled more than once. Only plots sampled in panels two and three were included in this metric because of quadrat sampling inconsistencies between 2006 and 2010 (i.e., parks were sampled in reverse order in 2006 from all following years, and phenological differences may bias analyses). With only one panel of plots to rate this metric in most parks, results are preliminary.

Results and Discussion

SARA is the only park unit where more than half of browse-preferred species decreased in frequency and more than half of browse-avoided species increased in frequency between survey cycles (Table 12). These results would put SARA in the Significant Concern category for this Metric. However, because these results are based on only one panel of data, we will not assign a Significant Concern rating until our dataset is complete. If the decrease in browse-preferred species at MABI and SAGA continues, this will also be a concern. MIMA and ACAD only showed slight changes in browse-preferred and browse-avoided species and were rated Good for this metric.

Table 12. Deer browse indicator species ratings for plots resampled in 2012. % Decrease Browse-Preferred is the proportion of browse-preferred species that declined in frequency between survey cycles. % Increase Browse-Avoided is the proportion of browse-avoided species that increased in quadrat frequency between survey cycles.

Park	N	% Decrease Browse-Preferred Species	% Increase Browse-Avoided Species	Rating
ACAD	88	0	33.3	Good
MABI	12	40.0	33.3	Good
MIMA	10	0	25.0	Good
SAGA	11	50.0	33.3	Good
SARA	16	66.7	66.7	Caution

Tree Growth and Mortality Rates

Background

Tree growth and mortality rates are important indicators of tree health and vitality. Tree growth rates can decline in response to environmental factors or anthropogenic stress, and tree mortality is often preceded by some years of reduced tree growth (Ward and Stephens 1997, Pedersen 1998, Dobbertin 2005). Decreased growth or elevated mortality rates in trees of a particular species can indicate a particular health problem for that species (Duchesne et al. 2003, Hyink and Zedeker 1987); while altered vital rates for multiple species across a region may indicate a regional environmental stress, such as acid deposition (Steinman 2004, Dobbertin 2005). Growth and mortality rates are also influenced by structural stage.

To account for differences in growth and mortality rates due to site characteristics, stand structural stage, and by tree species, size and crown class (i.e., tree position in canopy), both rates will be calculated for canopy trees (i.e., dominant, co-dominant, or intermediate crown

classes) in stands that have succeeded to a mature or late successional stage (based on the structural stage metric). To examine patterns of tree growth, we use relative basal area growth (% basal area / year), which is calculated as the percent change in basal area from successive diameter at breast height (DBH) measurements on individual trees, converted to an annual rate. Relative basal area growth rate is then averaged for canopy trees across the plot, and also by species within the plot. Metric ratings are based on regional growth rates, and are derived from U.S. Forest Service Forest Inventory and Analysis (FIA) data collected from plots in the same Ecological Subsection of each NETN park.

Annual mortality rate is calculated from successive observations as the percent of stems that died between sample events (not including trees that were cut) and is converted to an annual basis. Annual mortality rate is calculated for each plot and for individual species within a plot, and then averaged by park or group of plots. Assessment points for this metric are based on annual mortality rates that have been documented in old-growth forests, which range from 0.3 to 1.6% (Busing 2005, Runkle 2000, Woods 2000).

Growth and mortality rates presented in this section represent all of the monitoring plots in MABI, MIMA, SAGA and SARA, and three quarters of the plots in ACAD. Species growth and mortality rates were only calculated for species with five or more individuals in a park, and overall growth and mortality rates include all species. It is also important to note that DBH measurements were checked for potential errors that could skew growth rate calculations. Trees that differed more than 6 cm between surveys were likely the result of a data entry error, and were omitted from the analysis.

Results and Discussion

Average growth rates were lower for NETN parks than FIA average growth rates, and only MIMA and SARA had an overall growth rate within 60% of the FIA growth rate (Table 13). Growth rates in NETN parks are based on a higher proportion of later successional stands (Miller et al. 2012). Trees in late successional stands tend to have slower growth rates than trees in younger stands, and this may explain at least some of the differences in growth and mortality rates. Differences in species composition and management regimes (e.g., timber harvesting) may also explain the higher growth rates in FIA plots.

Several species in NETN had particularly high growth rates, including black walnut (*Juglans nigra*) in MIMA, and white ash (*Fraxinus americana*) in SARA. The black walnut growth rate is based on five trees from a plot in a historic walnut orchard, and is only relevant to this area. The high growth rate of white ash in SARA is of more interest. White ash can occupy early-successional habitats as a pioneer species, and the species is a gap exploiter in later successional stands. It will be important to continue tracking white ash growth rates, as a reduction in growth rate could indicate the arrival of emerald ash borer, and a change in growth rate may be observed before an increase in mortality is detected.

In all but SARA, average mortality rates were similar between NETN parks and FIA plots (Table 14). The average mortality rate in SARA was somewhat higher than in FIA plots, and was high

Table 13. Average growth rates (% basal area / year) overall, and by tree species in each park. The growth rate calculation includes canopy trees (i.e., dominant, co-dominant, or intermediate crown classes) in stands that have succeeded to a mature or late successional stage (based on the structural stage metric). U.S. Forest Inventory and Analysis (FIA) data were derived from plots located within the same Ecological Subsection as each park. Common names of tree species are listed in Appendix E. --- indicates less than five individuals of the species on the plots.

Species	ACAD		MABI		MIMA		SAGA		SARA	
	Park	FIA	Park	FIA	Park	FIA	Park	FIA	Park	FIA
<i>Abies balsamea</i>	2.21	4.21	---	---	---	---	---	---	---	---
<i>Acer platanoides</i>	---	---	---	---	1.71	---	---	---	---	---
<i>Acer rubrum</i>	1.50	2.40	1.64	2.08	1.27	2.22	0.96	2.08	2.13	2.81
<i>Acer saccharum</i>	---	---	1.43	2.41	---	---	1.15	2.41	1.65	2.55
<i>Betula alleghaniensis</i>	0.93	---	1.59	1.79	---	---	1.45	1.79	---	---
<i>Betula lenta</i>	---	---	---	2.56	0.54	2.65	1.20	2.56	---	---
<i>Betula papyrifera</i>	1.20	1.48	---	1.55	---	2.09	---	1.55	---	---
<i>Carya cordiformis</i>	---	---	---	---	---	---	---	---	2.70	5.75
<i>Carya ovata</i>	---	---	---	---	---	---	---	---	2.29	---
<i>Fagus grandifolia</i>	---	---	1.60	2.98	---	2.55	1.59	2.98	---	---
<i>Fraxinus americana</i>	2.53	---	1.62	6.26	1.38	3.85	1.94	6.26	5.30	4.16
<i>Juglans nigra</i>	---	---	---	---	6.76	---	---	---	---	---
<i>Larix decidua</i>	---	---	1.42	---	---	---	---	---	---	---
<i>Picea mariana</i>	0.85	---	1.09	---	---	---	---	---	---	---
<i>Picea rubens</i>	1.86	3.14	---	---	---	---	---	---	---	---
<i>Pinus resinosa</i>	1.70	---	0.78	---	---	---	---	---	---	---
<i>Pinus strobus</i>	2.62	---	1.57	2.27	1.90	2.41	0.61	2.27	2.37	2.82
<i>Pinus sylvestris</i>	---	---	1.00	---	---	---	---	---	---	---
<i>Populus grandidentata</i>	2.19	2.50	---	---	---	---	---	---	---	---
<i>Populus tremuloides</i>	---	2.52	---	---	---	---	---	---	4.43	3.08
<i>Quercus alba</i>	---	---	---	---	0.81	1.56	---	---	---	---
<i>Quercus rubra</i>	2.38	---	2.18	3.07	3.13	3.12	1.83	3.07	---	2.72
<i>Quercus velutina</i>	---	---	---	---	1.70	2.97	---	---	2.68	---
<i>Robinia pseudoacacia</i>	---	---	---	---	0.60	---	---	---	---	---
<i>Thuja occidentalis</i>	0.94	1.84	---	---	---	---	---	---	---	---
<i>Tsuga canadensis</i>	---	---	1.25	2.81	---	3.57	1.09	2.81	---	1.62
<i>Ulmus americana</i>	---	---	---	---	---	---	---	---	2.69	5.86
Overall	1.69	2.84	1.39	2.57	1.73	2.59	1.17	2.57	2.62	3.10
Park Rating	Caution		Caution		Good		Caution		Good	

Table 14. Average annual percent mortality rate by tree species in each park. The mortality rate calculation includes only plots in mature and late successional stands, and only canopy trees (i.e., dominant, co-dominant and intermediate crown class). U.S. Forest Service Forest Inventory and Analysis (FIA) data were derived from plots located in the same Ecological Subsection as each park. Common names of tree species are listed in Appendix E. --- indicates less than five individuals of the species on the plots.

Species	ACAD		MABI		MIMA		SAGA		SARA	
	Park	FIA	Park	FIA	Park	FIA	Park	FIA	Park	FIA
<i>Abies balsamea</i>	4.81	4.91	---	---	---	---	---	---	---	---
<i>Acer platanoides</i>	---	---	---	---	0	---	---	---	---	---
<i>Acer rubrum</i>	0.22	0.68	0	0.56	0	0.80	1.14	0.56	0	1.16
<i>Acer saccharum</i>	---	---	1.20	0.14	---	---	0	0.14	0	0
<i>Betula alleghaniensis</i>	0	---	0	0.31	---	---	0	0.31	---	---
<i>Betula lenta</i>	---	---	---	0	0	0	0	0	---	---
<i>Betula papyrifera</i>	0.66	2.75	---	5.87	---	0.88	---	5.87	---	---
<i>Carya cordiformis</i>	---	---	---	---	---	---	---	---	0	0
<i>Carya ovata</i>	---	---	---	---	---	---	---	---	0	---
<i>Fagus grandifolia</i>	0	---	2.94	4.71	---	0.33	1.85	4.71	---	---
<i>Fraxinus americana</i>	0	---	0.86	0.06	2.50	1.15	0	0.06	0	2.78
<i>Juglans nigra</i>	---	---	---	---	0	---	---	---	---	---
<i>Larix decidua</i>	---	---	0	---	---	---	---	---	---	---
<i>Ostrya virginiana</i>	---	---	4.55	---	---	---	---	---	---	---
<i>Picea abies</i>	---	---	0	---	---	---	---	---	---	---
<i>Picea mariana</i>	0.96	---	---	---	---	---	---	---	---	---
<i>Picea rubens</i>	1.23	0.54	---	---	---	---	---	---	---	---
<i>Pinus resinosa</i>	0	---	3.00	---	---	---	---	---	---	---
<i>Pinus strobus</i>	0	---	2.88	3.13	0	1.14	1.64	3.13	3.65	0
<i>Pinus sylvestris</i>	---	---	3.57	---	---	---	---	---	---	---
<i>Populus grandidentata</i>	1.83	0.95	---	---	---	---	---	---	---	---
<i>Populus tremuloides</i>	---	0.36	---	---	---	---	---	---	2.73	2.08
<i>Prunus serotina</i>	---	---	---	---	---	---	---	---	0	2.78
<i>Quercus alba</i>	---	---	---	---	0	0	---	---	---	---
<i>Quercus rubra</i>	0.76	---	0	0	1.67	0.51	0	0	---	0
<i>Quercus velutina</i>	---	---	---	---	1.43	0.57	---	---	0	---
<i>Robinia pseudoacacia</i>	---	---	---	---	0	---	---	---	---	---
<i>Thuja occidentalis</i>	0	0.58	---	---	---	---	---	---	---	---
<i>Tilia americana</i>	---	---	---	---	---	---	0	---	---	---
<i>Tsuga canadensis</i>	---	---	0	0	---	0.72	1.61	0	---	0
<i>Ulmus americana</i>	---	---	---	---	---	---	---	---	7.35	8.33
Overall	1.05	1.16	1.40	0.99	0.66	0.61	0.97	0.99	2.00	0.51
Park Rating	Good		Good		Good		Good		Caution	

enough for SARA to be rated Caution for this metric. The elevated mortality rate for white pine (*Pinus strobus*) in SARA is likely due to successional white pine stands that are undergoing stem exclusion. American elm (*Ulmus americana*) in SARA had the highest mortality rate of NETN parks and FIA plots, and is likely due to Dutch elm disease (*Ophiostoma ulmi*). High mortality rates for balsam fir (*Abies balsamea*) and American beech (*Fagus grandifolia*) may also be the result of exotic pests, with balsam woolly adelgid (*Adelges piceae*) affecting balsam fir, and beech bark disease affecting American beech. It is unclear why hophornbeam (*Ostrya virginiana*) has a high mortality rate in MABI. NETN will continue to monitor growth and mortality rates, and compare rates with regional datasets where available.

Soil Chemistry

Background

NETN monitors soil chemistry to understand the effects of atmospheric deposition on forest health, which is a special concern for forests in the northeast that tend to grow on thin soils with low soil buffering capacity. Acid deposition occurs when emissions derived from the combustion of fossil fuels and industrial processes react with water and oxygen in the atmosphere to produce acidic anions of sulfur (S) and nitrogen (N), and then fall to earth in dry or wet form (Connolly et al. 2007). Impacts of atmospheric deposition include soil acidification, base cation leaching, increased availability of toxic aluminum (Al), and altered N cycling (Bailey et al. 2005, Connolly et al. 2007). Acid deposition has also dramatically increased inputs of N and S to forested ecosystems in the Northeast, and concern has arisen that excess N may “saturate” forest soils, causing excess nitrification and N leaching and exacerbating the effects of acidification (Aber et al. 1998). All of these impacts can reduce plant growth and increase susceptibility of trees to other stresses (Bullen and Bailey 2005).

At each plot, we collect a composite of up to three soil samples from each O and A horizon per plot. The thickness of each horizon is recorded for each sample, and the presence or absence of earthworms (as determined by their visual presence or signs, such as middens or castings) is recorded for each plot. In most cases, the composited sample for each layer is composed of three replicate samples. However in extremely rocky or root-laden habitats, there are occasions where only one or two samples can be collected. If no soil horizons are apparent, NETN collects a composite of the upper soil containing fine roots to a maximum depth of 10 cm.

Post collection, soil samples are oven dried at 33 °C within two weeks of collection, and then sent to the Analytical Laboratory at the University of Maine for chemical analysis. Soil pH is measured in distilled water. Organic matter is measured by loss on ignition at 550 °C. % total N (TN) and % total C (TC) are measured by combustion analysis at 1,350 °C. Exchangeable acidity is extracted in potassium chloride and measured by titration. Exchangeable cations are extracted in ammonium chloride and measured by inductively coupled plasma optical emission spectrometry (ICP-OES). Effective cation exchange capacity is calculated by summation of milliequivalent levels of Ca, K, Mg, and Sodium (Na), and acidity. From the chemical analysis results provided by the University of Maine Analytical Laboratory, we calculate additional variables, including % base saturation (Table 15).

Table 15. Chemistry variables available for NETN soil samples.

Soil Chemistry Variable	Code	Soil Chemistry Variable	Code
Soil pH	soil pH	Carbon: Nitrogen ratio	C:N
Effective cation exchange capacity	ECEC	Nitrogen: Phosphorus ratio	N:P
% Base Saturation	BaseSat	% Total Carbon	TC
Calcium: Aluminum Ratio	Ca:Al	% Total Nitrogen	TN
Calcium % Saturation	Ca%Sat	% Loss of Ignition	LOI
Aluminum % Saturation	Al%Sat	Phosphorus (mg/kg)	P
Calcium (mg/kg)	Ca	Exchangeable acidity (meq/100g)	acidity
Aluminum (mg/kg)	Al	Iron (mg/kg)	Fe
Magnesium (mg/kg)	Mg	Manganese (mg/kg)	Mn
Potassium (mg/kg)	K	Zinc (mg/kg)	Zn
Sodium (mg/kg)	Na		

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.

More detailed analyses of soil chemistry and forest health indicators will be included in periodic trend reports. We also include boxplot summaries of the last four years of soil chemistry data by O and A horizons in Appendix F. Soil chemistry summaries in Appendix F were corrected for horizon, using 20% TC as the break between O horizons ($\geq 20\%$ TC) and A horizons ($< 20\%$ TC). Where the % TC check resulted in duplicate samples of the same horizon, we adjusted soil chemistry variables by calculating weighted averages using the depth collected for each sample as weights.

Results and Discussion

Soil chemistry results vary across the network (Table 16). Based on the median Ca:Al ratio, soil acidification may be an issue in SAGA, and potentially ACAD and MIMA. All parks but ACAD were rated “Significant Concern” for the C:N ratio, indicating that these parks may be vulnerable to N deposition. These results mostly follow the findings from the more thorough soil chemistry analysis that was performed in the previous forest report (Miller et al. 2012).

Analyses continue to suggest that SARA is most vulnerable to N saturation, and ACAD is least vulnerable to N saturation. Relative to acidification risk, results are also similar to the previous report, with SARA soils being the least at risk to acidification. The only major difference in results relates to the order of parks most at risk to acidification, with SAGA considered most at risk of acidification by these metrics. With median Ca:Al ratios below 4, ACAD and MIMA are also at high risk of acidification. It will be important to track soil chemistry over time, and to relate trends in soil chemistry to indicators of forest health to improve our soil chemistry metrics.

NETN parks vary in degree of earthworm invasion, with ACAD being least invaded and SARA most invaded. Earthworms are not native to parks in NETN (MORR may be an exception), and their invasion has the potential to drastically alter forest soils and understory communities.

Table 16. Soil chemistry ratings for NETN parks from 2009 to 2012. % of Plots with Earthworms are based on a rapid search for signs of earthworms, and may not detect earthworms at low levels. Plots recorded as inconclusive for earthworms were treated as an absence.

Park	% of Plots with Earthworms	Median Ca:Al	Ca:Al Rating	Median C:N	C:N Rating
ACAD	6.4%	2.77	Caution	31.71	Good
MABI	41.7%	14.12	Good	14.82	Significant Concern
MIMA	30.0%	1.22	Caution	14.92	Significant Concern
SAGA	38.1%	0.56	Significant Concern	19.40	Significant Concern
SARA	76.7%	31.85	Good	12.74	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 and a low sapling to seedling ratio. As long as forest composition metrics remain stable (e.g., no new invasive species, stable tree condition/forest pests, and continued regeneration), late successional structure is expected to develop over time. Invasive species and forest pests are the major controllable threats to forest health in ACAD. Ongoing exotic plant management and early detection efforts are vitally important to maintaining forest health in ACAD. Continued vigilance and outreach are equally important to preventing the spread of forest pests such as hemlock woolly adelgid, winter moth, and emerald ash borer.

Marsh-Billings-Rockefeller National Historical Park

Coarse woody debris and snag abundance continue to be lower than expected for late successional hardwood stands. Based on field observations in MABI, CWD volume may be considerably higher than our current sampling methods capture, as many pieces have been cut into 1-2 m lengths. While the volume of the combined pieces may be high, our methods only measure the length to the first cut. With less exposed surface area, intact logs are likely to persist longer and provide better quality habitat over time. Where possible, we recommend CWD pieces be left intact or kept as long as equipment will allow.

Continued efforts to eradicate invasive species, particularly in plantation stands slated for harvesting, are important to maintaining forest health in MABI. 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.

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. Forest pests also pose a significant threat to forest health in MIMA, particularly Asian longhorned beetle (ALB), emerald ash borer (EAB), and winter moth, which are all found in isolated areas of Massachusetts. Early detection and rapid response of ALB and

EAB are particularly important, not just for the health of forests in MIMA, but for hardwood forests in the northeastern US.

Saint-Gaudens National Historic Site

Ecological integrity metrics related to forest structure (e.g., coarse woody debris and snag abundance) suggest that forests in SAGA still lack late successional structure such as medium to large snags. As long as forest composition metrics remain stable (e.g., no new invasive species, stable tree condition/forest pests, and continued regeneration), late successional structure is expected to develop over time.

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. Emerald ash borer (EAB) poses a significant threat to forests in SARA. Early detection and outreach efforts to prevent spread of EAB into SARA are extremely important, especially considering their continued spread in NY. Eradication efforts focused on managing exotic shrub species are equally important to create and maintain conditions where other tree species can regenerate.

Forest Inventory and Analysis Comparisons

Introduction

The U.S. Forest Service (USFS) Forest Inventory and Analysis (FIA) program has been monitoring forest resources in the Eastern U.S. since the 1930s. The primary focus of FIA has been on attributes related to timber supply, such as forest cover, ownership, and tree volume. In the 1990s, the FIA program went through a major revision which included standardizing plot configurations, measurement protocols, and sample designs across the country, and adding a Forest Health Monitoring component to a subset of monitoring plots (McRoberts et al. 2005). The newly revised FIA protocols were implemented in 2000, and plots have been sampled on a roughly 5-year interval. Currently, FIA has completed at least one full census cycle in every state in the Northeast Temperate Network (NETN).

The FIA program collects and reports data on status and trends in forest resources across the country, examining metrics such as forest area and ownership, species composition, tree volume, tree growth and mortality, and tree health. Data are collected from permanent plots at a scale of about one plot per 6,000 acres (2,400 ha) in the Northeastern U.S. (McRoberts et al. 2005). A subset of plots are analyzed for additional forest health variables, such as soil chemistry, vegetation structure and dead woody material, and these data are collected on about one plot per 96,000 acres (39,000 ha). FIA protocols have undergone extensive development by the USFS with academic and other government agency partners and have been used to develop a substantial and ongoing database revealing trends in forest resource capacity and health across regions and the country. For these reasons, the NETN Long-term Forest Monitoring Protocol was based on the FIA program. This allows us to take advantage of the larger dataset to examine regional trends and compare NPS forests with the surrounding matrix of forest lands that are under different management regimes and protection.

Methods

To compare forests in NETN parks with the surrounding forest matrix, we developed an MS Access database that contains FIA plot data and calculates metrics such as forest cover, land ownership, and metrics of forest ecological integrity. Metrics are calculated from FIA plots that are in the same ecological subsection as each NETN park (U.S. Forest Service 2007), and are based on the publicly available fuzzed, swapped FIA plot locations (Figure 6). Because MORR falls in two subsections, FIA plots from both were included in the metric calculations for this park. Where FIA methods and data were compatible, we calculated and rated the ecological integrity metrics that were developed for the NETN Long-term Forest Monitoring Protocol (Tierney et al. 2012).

Results

Land Cover

The ecological subsections containing NETN parks vary widely in the extent of forestland (Figure 7). Based on area in potential and actual FIA plots, the vast majority of the subsections containing ACAD, MABI and SAGA are forested, and slightly more than half of the subsections surrounding MIMA and WEFA are forested. With less than 25% of the area across both subsections classified as forest, MORR has the lowest extent of surrounding forestland in the network. Regardless of the extent, the vast majority of forestlands surrounding all parks are under private ownership (Figure 8), and only a small percent are reserved from timber

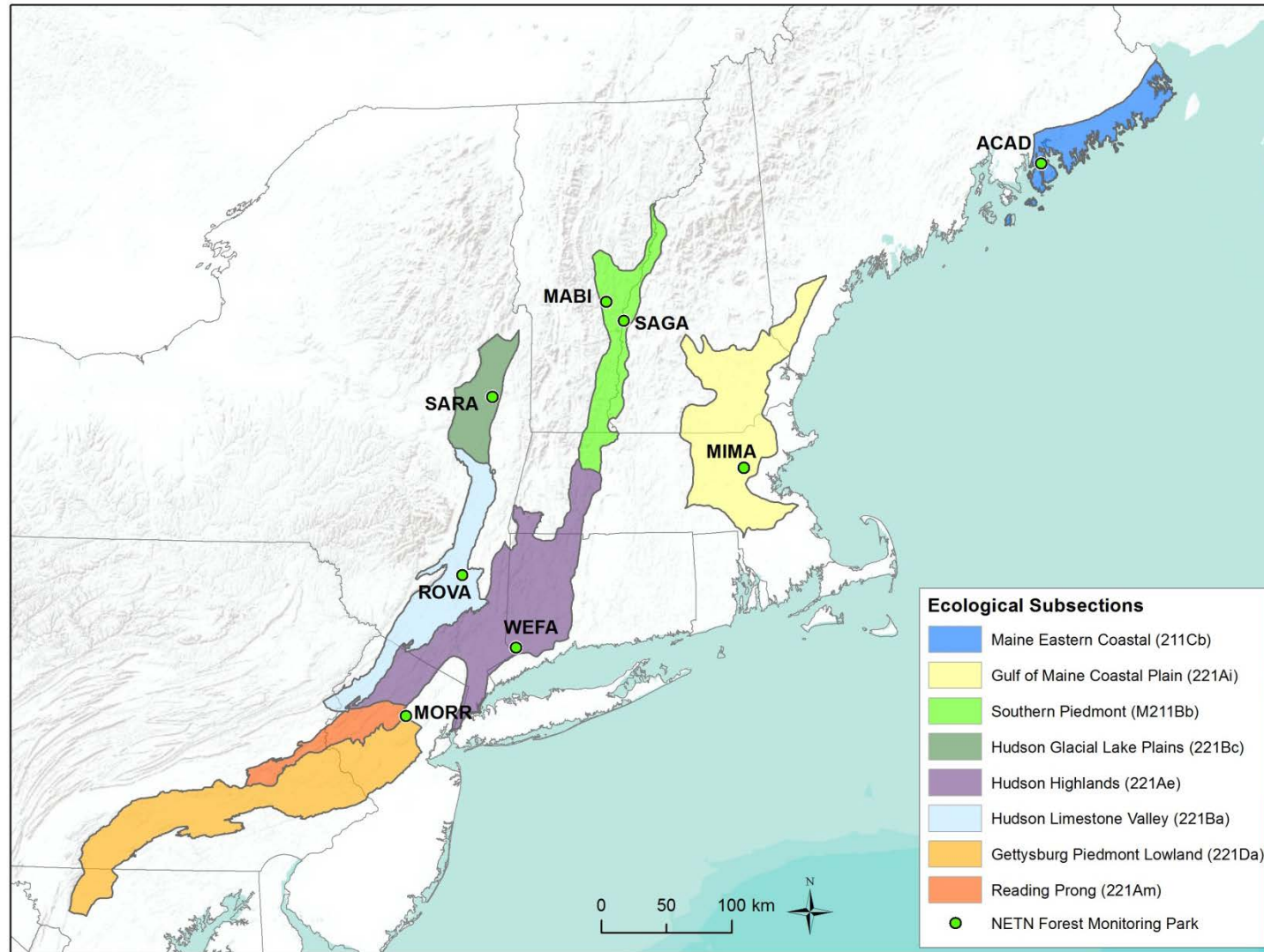


Figure 6. Map of Ecological Subsections used for comparisons between FIA data with NETN parks.

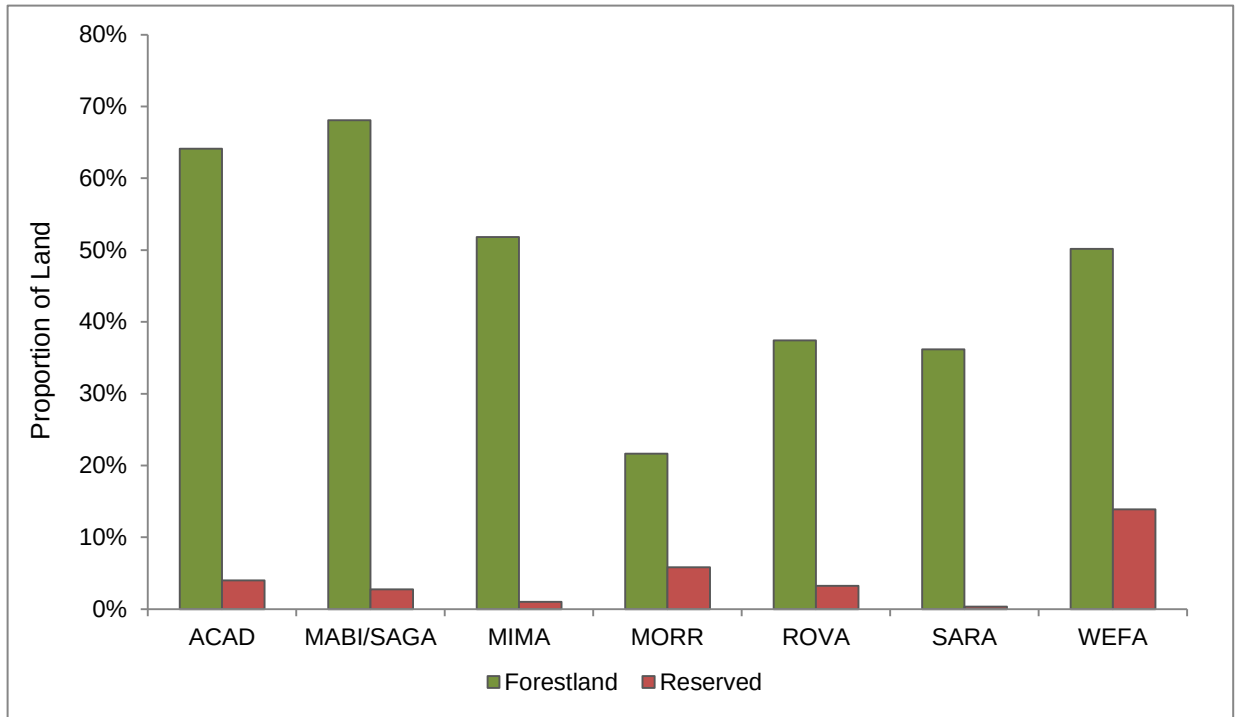


Figure 7. Percent of forestland and reserved forestland, based on area in potential and actual FIA plots summed across the Ecological Subsection containing each park. Reserved represents forestlands that are out of production from timber harvesting, and can be under any type of ownership.

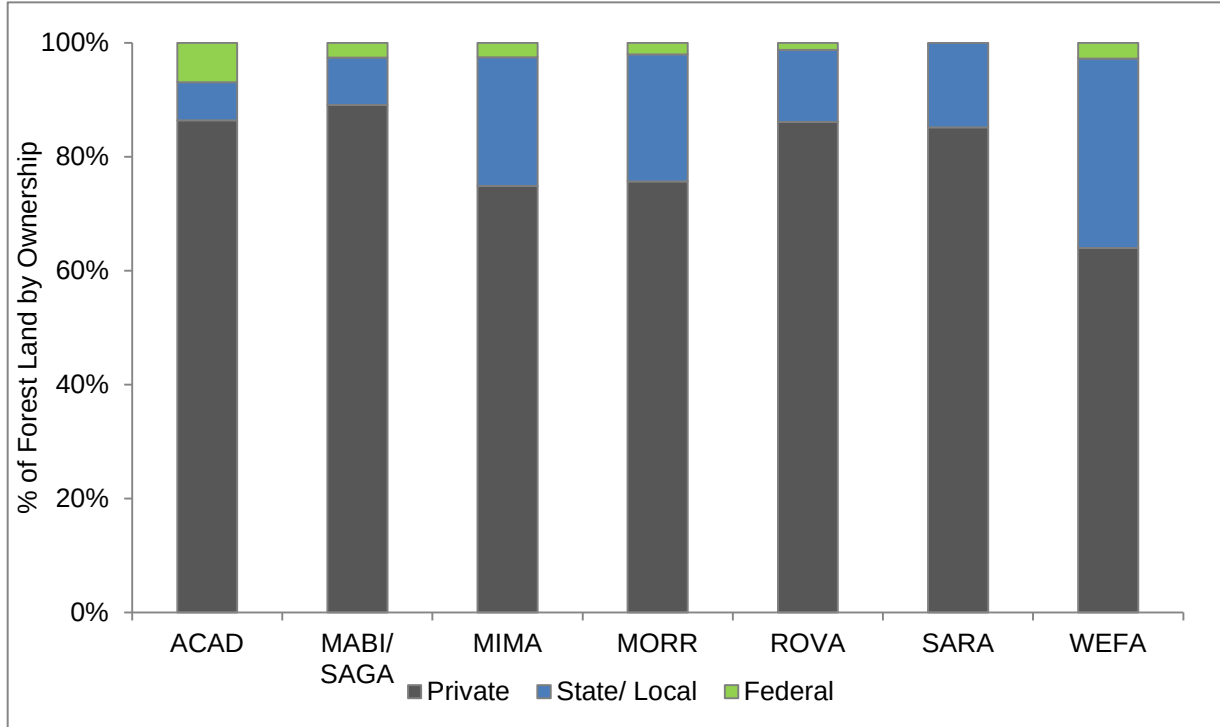


Figure 8. Percent of forestland by ownership group, based on area of forest in FIA plots summed across the Ecological Subsection containing each park.

production (Figure 7). Therefore, while NETN parks are relatively small, they may represent a proportionately high degree of protected lands in the area.

Structural Stage Distribution

The proportion of late successional forest is consistently higher in NETN parks than surrounding forestlands, and ACAD also has a higher proportion of mature forest (Figure 9). Most notably, over 60% of plots in MORR are classified as late successional forest versus less than 25% of plots in surrounding forestlands. Given the small amount of forest cover in surrounding lands, the extent of older forests in MORR may be regionally significant.

NETN parks tend also to have a higher density of large trees than the surrounding matrix of forestlands. ACAD has nearly twice the density of trees ≥ 30 cm DBH as surrounding forestlands (Figure 10A). MABI, MIMA, ROVA, SAGA and WEFA all have considerably higher densities of trees ≥ 60 cm DBH than the surrounding matrix (Figure 10B).

Coarse Woody Debris and Snag Abundance

Coarse woody debris (CWD) metrics are somewhat variable between NETN parks and FIA (Table 17). CWD volume is considerably higher in ACAD, MORR and ROVA than the surrounding forest matrix. Conversely, CWD volume is much lower in MIMA, SARA and WEFA than the surrounding area. Interestingly, live tree volume is consistently higher in every NETN park than the nearby FIA plots, which may suggest that NETN park forests are more

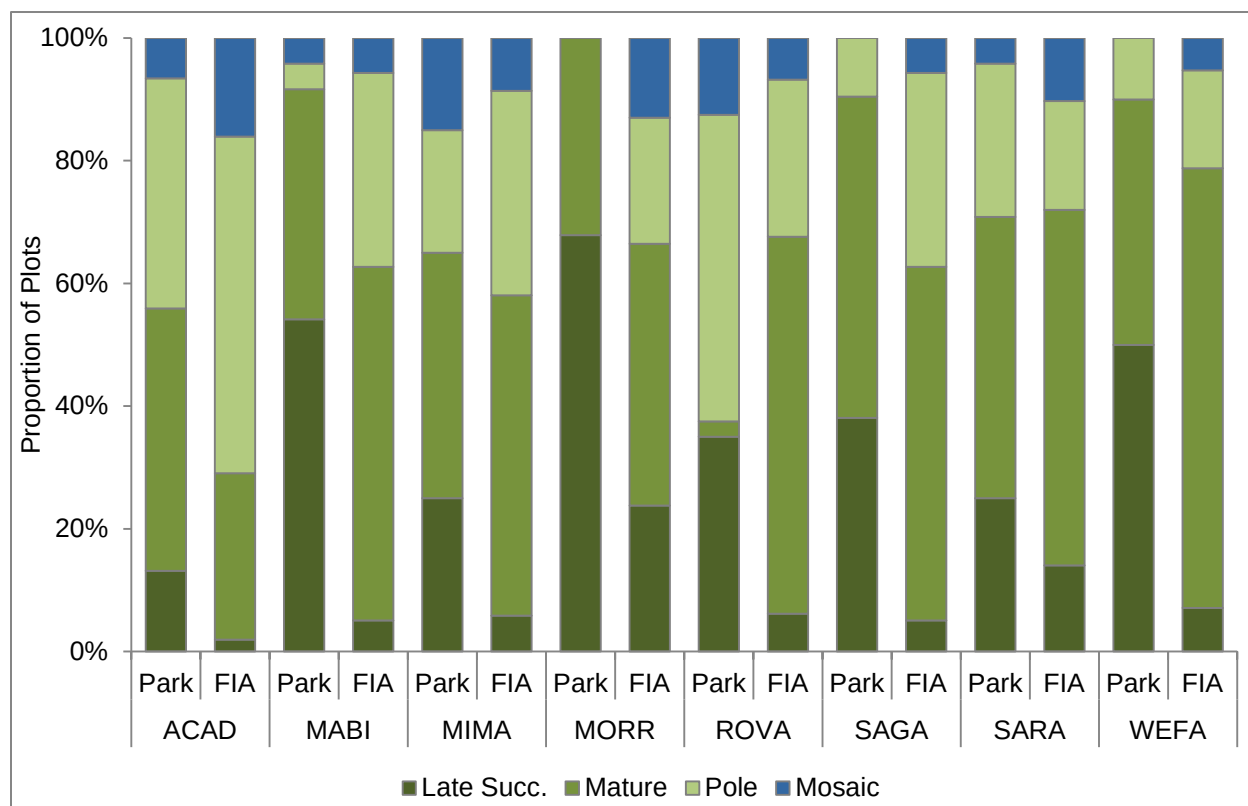


Figure 9. Percent of forest plots by structural stage in NETN parks and FIA plots within the same Ecological Subsection of each park.

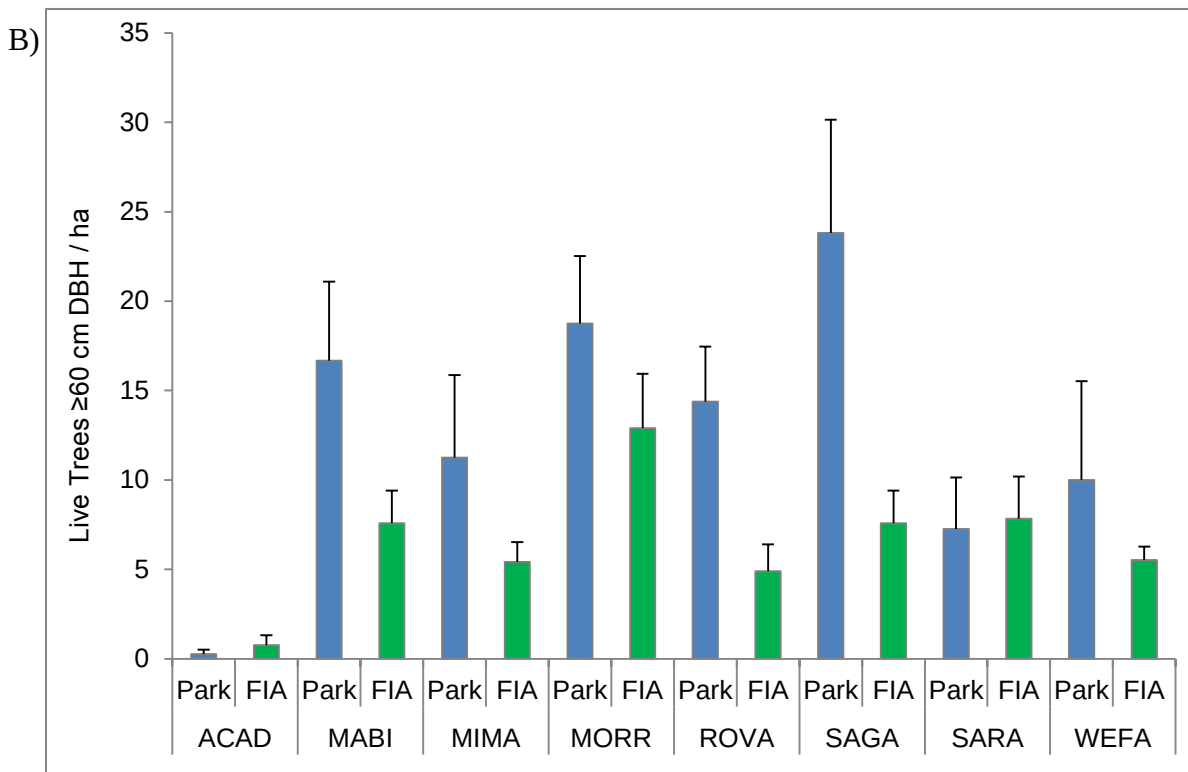
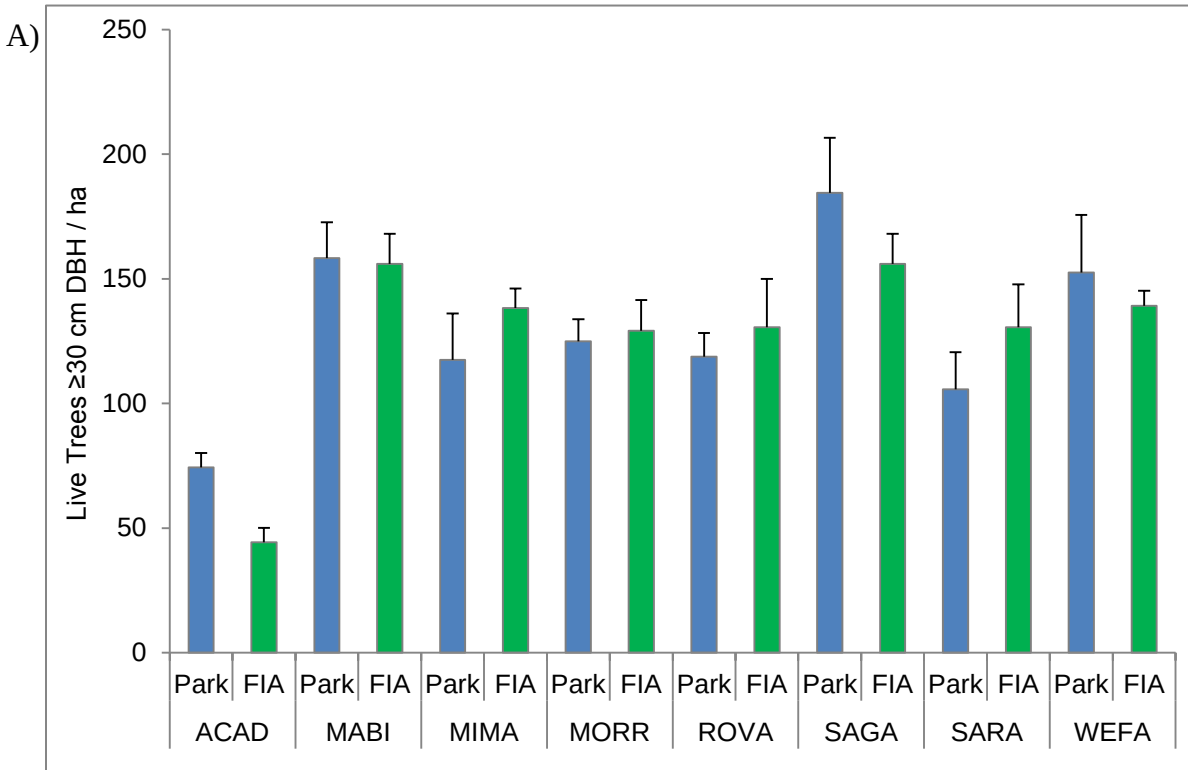


Figure 10. Average density of live trees per hectare that are A) ≥ 30 cm DBH and B) ≥ 60 cm DBH for NETN parks and FIA plots located in the same Ecological subsection as each park.

Table 17. Coarse woody debris metrics for NETN parks and FIA plots within the same Ecological Subsection of each park, and based on the most recent full survey cycle from both datasets. The CWD Ratio is the ratio of CWD volume to live tree volume, and is expressed as a percent.

	Group	# Plots	CWD Volume (m ³ /ha)		CWD: Live Tree Volume		Live Tree Volume (m ³ /ha)	
			Mean	SE	Mean	SE	Mean	SE
ACAD	PARK	151	24.69	2.61	13.04	1.45	207.80	9.97
	FIA	6	2.52	1.43	16.10	11.20	113.32	47.95
MABI	PARK	23	35.09	7.94	7.29	1.92	532.50	42.78
	FIA	11	41.25	10.60	14.33	3.56	314.86	44.37
MIMA	PARK	19	8.91	3.24	3.48	1.31	327.16	51.75
	FIA	10	18.17	8.74	6.91	2.68	257.81	54.89
MORR	PARK	28	23.38	5.14	6.66	1.67	430.09	34.22
	FIA	7	0.84	0.84	0.37	0.37	232.50	42.87
ROVA	PARK	40	57.53	12.62	25.87	8.36	359.03	27.27
	FIA	8	16.30	5.91	8.82	4.26	265.60	62.01
SAGA	PARK	21	31.76	7.21	7.49	2.61	577.17	66.93
	FIA	11	41.25	10.60	14.33	3.56	314.86	44.37
SARA	PARK	24	22.72	5.06	14.64	4.48	285.18	33.24
	FIA	5	72.25	57.73	56.14	49.13	210.14	66.38
WEFA	PARK	10	21.43	12.29	6.35	3.78	374.13	45.63
	FIA	15	36.19	13.56	21.85	11.04	222.78	15.92

heavily stocked. It is also possible that the differences in live tree volume are a result of protocol differences. FIA measures stand height for all live trees on a plot, and volume estimates for each plot are calculated using the height and diameter at breast height measurement of each tree. In NETN, we only measure the height of three codominant trees per plot, and multiply the codominant stand height by constants for dominant, intermediate and subcanopy trees to calculate live tree volume. Starting in 2013 we will collect tree height measurements for three intermediate trees in addition to three codominant trees to improve live tree volume estimates. Note that the metrics presented for FIA in Table 17 only include data from Phase 3 plots (Forest Health Monitoring plots), which often consists of fewer than 10 plots, and should be treated as preliminary.

Snag abundance varies widely between NETN and FIA plots (Table 18). Density of snags is similar between park and FIA plots in MIMA, MORR, ROVA and WEFA, whereas snag densities in ACAD, SAGA and SARA are considerably higher than surrounding forestlands. Across all snags, and with snags >30cm DBH, snag abundance is lower in MABI than surrounding forestlands. MABI is the only NETN park with active timber management, and this may partially explain the lower snag abundances. Note that land use history, successional stage, species composition, and management regime are all important factors influencing snag abundance in NETN parks and surrounding forestlands, and they are difficult to control for in these calculations.

Discussion

Parks vary in the extent of forest in surrounding lands, with the highest proportion of forest around parks in New England. Forestlands surrounding NETN parks are largely under private ownership and in timber production, whereas forests in NETN parks are primarily reserved from timber production. The difference in management regimes has resulted in forests in NETN parks that are distinct from the surrounding matrix of forestlands. The proportion of plots in late successional forest is higher in every park, and the proportion of plots in mature forest is higher in most NETN parks than surrounding forestlands. Indicators of older forest structure, such as coarse woody debris, large snags, and large live trees are more abundant in many NETN parks than the surrounding matrix of more intensively managed forests. These results suggest that, despite their relatively small size, forests in NETN parks may represent islands of regionally significant, older forest habitat in a sea of human development and more intensively managed forests.

Table. 18. Snag abundance metrics for NETN parks and FIA plots within the same Ecological Subsection of each park, and based on the most recent full survey cycle from both datasets. % Snags is the percent of standing trees that are snags, and includes trees >10cm DBH (All Sizes), and trees > 30 cm DBH (M-L Snags). SE refers to 1 standard error around the mean.

Park	Group	#Snags/ha		# M-L Snags/ha		% of Trees as Snags	
		Mean	SE	Mean	SE	All Sizes	M-L Snags
ACAD	Park	171.46	10.87	6.82	1.41	16.09	8.44
	FIA	99.31	0.48	6.86	1.51	16.04	13.80
MABI	Park	42.71	9.21	4.17	1.94	8.49	2.55
	FIA	56.77	0.55	8.89	0.80	9.11	5.67
MIMA	Park	53.75	8.94	6.25	2.48	10.97	5.05
	FIA	47.40	0.69	6.83	1.86	8.41	4.78
MORR	Park	32.14	6.15	1.79	1.24	11.08	1.41
	FIA	30.59	6.88	5.36	3.01	7.08	4.27
ROVA	Park	39.38	7.38	10.00	3.20	8.94	7.77
	FIA	38.26	0.80	4.62	1.32	8.16	3.49
SAGA	Park	79.76	16.51	14.29	3.69	12.59	7.19
	FIA	56.77	0.55	8.89	0.80	9.11	5.67
SARA	Park	92.74	18.26	8.87	3.19	20.50	8.59
	FIA	43.86	2.65	5.53	7.42	8.86	3.65
WEFA	Park	35.00	12.47	5.00	3.33	7.78	3.17
	FIA	36.55	5.50	7.03	1.93	7.43	4.73

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Appendix A. Protocol implementation for the 2012 field season.

2012 Sampling Inconsistencies and Data Issues

Overall data quality for the 2012 field season was very good. The 2012 dataset had fewer data errors and missing records than any previous year. While an exceptional forest crew is no doubt a major reason for the excellent data quality, enhancements to the data checker function in the forest database also continue to improve data quality. Starting this year, tree diameter at breast height (DBH) measurements were checked against the previous measurement. When DBH measurements were 2 cm less than or 3 cm more than the previous survey, an error message popped up and displayed the difference between measurements. This allowed the crew to catch DBH measurements that were incorrectly recorded during the previous survey, and eliminated transcription errors this year. Interestingly, we also discovered that it is not uncommon for trees to shrink between surveys, and the ones that do often exhibit obvious signs of poor health and decline (e.g., advanced decay, cankers, leaf loss, etc.).

Quality Control and Quality Assurance (QA/QC)

To verify data quality and quantify sampling error, we resample 5% (four plots) of the forest plots that crews sample every year. Plots are randomly selected for QA/QC, with two plots located in ACAD and two plots located in a randomly selected national historical park or national historic site. MIMA plots 014 and 016, and ACAD plots 082 and 106 were sampled for QA/QC in 2012.

Data comparisons between the forest crew and the QA/QC crew were very close for tree diameter at breast height (DBH) measurements and microplot data. Coarse woody debris (CWD) measurements and quadrat data did not correspond as closely as we would like on the two plots in MIMA. The QA/QC plots in MIMA were sampled by the QA/QC team before the crew sampled due to logistical issues/conflicts. After the QA/QC team sampled the plots, the crew had to move several of the stakes in each of the MIMA plots. This explains at least partially why the data are different, as quadrats and CWD transects both rely on plot stakes for orientation. Because of these results, we decided to always conduct future QA/QC sampling after the crew measures the plots.

Resampling and Protocol Revision

The forest crew encountered several unusual situations in the field relating to CWD and tree forks that were not adequately addressed in the forest protocol. To continue consistency with U.S. Forest Service Forest Inventory and Analysis (FIA) protocols, we adopted the FIA methods where possible. The CWD situation related to a large dead branch that was attached to a live down tree. Following the FIA protocol, the large dead branch is only considered CWD if more than 50% of the branch is severed from the live tree. In the process of looking up FIA's CWD SOP, we also discovered that FIA no longer tallies suspended pieces of CWD. To be consistent with FIA, and because QA/QC results have suggested that we often miss suspended pieces of CWD, we decided to no longer tally suspended CWD pieces. From now on, a piece of CWD must be touching the ground at some point along its length.

The unusual fork situation related to a stump sprout that was large enough to be a sapling, and that originated at the base of a much larger live tree. The question was whether the stump sprout

Appendix A. Protocol implementation for the 2012 field season (continued)

counted, as seedling-size stump sprouts that originate from a live tree are not counted. We adopted the FIA protocol, which only counts forks that are at least 1/3 the size of the main stem. In the case of the sapling-size stump sprout, the fork should not be sampled because it was much smaller than the main stem. In addition to this forking rule, we added more clarification on measuring forks, based on the FIA protocol.

Several other changes to the forest protocol were made to the protocol that will be implemented in 2013. To improve stand height measurements, which QA/QC results continue to suggest are sensitive to observer bias, we are tracking the exact trees that are measured between years, and requiring the same tree be measured through time, where possible. Starting in 2013 we will also measure stand height for three intermediate trees, in addition to the three codominant trees we already sample. Finally, due to inconsistent orientation of photopoints, we are requiring crews to center the stake of interest in each view.

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. Key indicator invasive exotic plant 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 D. Herbaceous indicator species of deer browse pressure in northeastern U.S. forests.

Latin name	Common Name	Deer Preference	Citations
<i>Ageratina altissima</i> var. <i>altissima</i> (formerly <i>Eupatorium rugosum</i>)	white snakeroot	Avoided	Augustine and Jordan 1998
<i>Aralia nudicaulis</i>	wild sarsaparilla	Browsed	Balگوoyen and Waller 1995
<i>Eurybia divaricata</i>	white wood aster	Browsed	Williams et al. 2000
<i>Carex</i> spp.	sedge	Avoided	Williams et al. 2000, Augustine and deCalesta 2003, Horsley et al. 2003
<i>Clintonia borealis</i>	blue bead lily	Browsed	Balگوoyen and Waller 1995
<i>Dennstaedtia punctilobula</i>	hayscented fern	Avoided	Horsley et al. 2003
<i>Maianthemum (Smilacina)</i> spp. (<i>racemosum</i> , <i>stellatum</i>)	Canada mayflower and false Solomon's seal	Browsed	Fletcher et al. 2001, Augustine and deCalesta 2003
<i>Polygonatum</i> spp. (<i>biflorum</i> , <i>pubescens</i>)	smooth Solomon's seal	Browsed	Augustine and deCalesta 2003, Webster et al. 2005, Kraft et al. 2004
<i>Sanguinaria canadensis</i>	bloodroot	Browsed	Augustine and deCalesta 2003
<i>Thelypteris noveboracensis</i>	New York fern	Avoided	Williams et al. 2000, Horsley et al. 2003
<i>Trillium</i> spp. (<i>cernum</i> , <i>erectum</i> , <i>grandiflorum</i> , <i>undulatum</i>)	trillium	Browsed	Anderson 1994, Augustine and Frelich 1998, Rooney 2001, Augustine and deCalesta 2003, Webster et al. 2005
<i>Uvularia</i> spp. (<i>grandiflora</i> , <i>perfoliata</i> , <i>sessifolia</i>)	bellwort	Browsed	Fletcher et al. 2001, Augustine and deCalesta 2003, Webster et al. 2005

Appendix E. Scientific and common names of tree species mentioned in the Tree Growth and Mortality metric.

Scientific Name	Common Name
<i>Abies balsamea</i>	balsam fir
<i>Acer platanoides</i>	Norway maple
<i>Acer rubrum</i>	red maple
<i>Acer saccharum</i>	sugar maple
<i>Betula alleghaniensis</i>	yellow birch
<i>Betula lenta</i>	sweet birch
<i>Betula papyrifera</i>	paper birch
<i>Carya cordiformis</i>	bitternut hickory
<i>Carya ovata</i>	pignut hickory
<i>Fagus grandifolia</i>	American beech
<i>Fraxinus americana</i>	white ash
<i>Juglans nigra</i>	black walnut
<i>Larix decidua</i>	European larch
<i>Liriodendron tulipifera</i>	tulip poplar
<i>Ostrya virginiana</i>	hophornbeam
<i>Picea abies</i>	Norway spruce
<i>Picea mariana</i>	black spruce
<i>Picea rubens</i>	red spruce
<i>Pinus resinosa</i>	red pine
<i>Pinus strobus</i>	eastern white pine
<i>Pinus sylvestris</i>	Scots pine
<i>Populus grandidentata</i>	bigtooth aspen
<i>Populus tremuloides</i>	quaking aspen
<i>Quercus alba</i>	white oak
<i>Quercus rubra</i>	northern red oak
<i>Quercus velutina</i>	black oak
<i>Robinia pseudoacacia</i>	black locust
<i>Thuja occidentalis</i>	northern white cedar
<i>Tilia americana</i>	American basswood
<i>Tsuga canadensis</i>	eastern hemlock
<i>Ulmus americana</i>	American elm

Appendix F. Soil Chemistry boxplots for samples collected between 2009 and 2012.

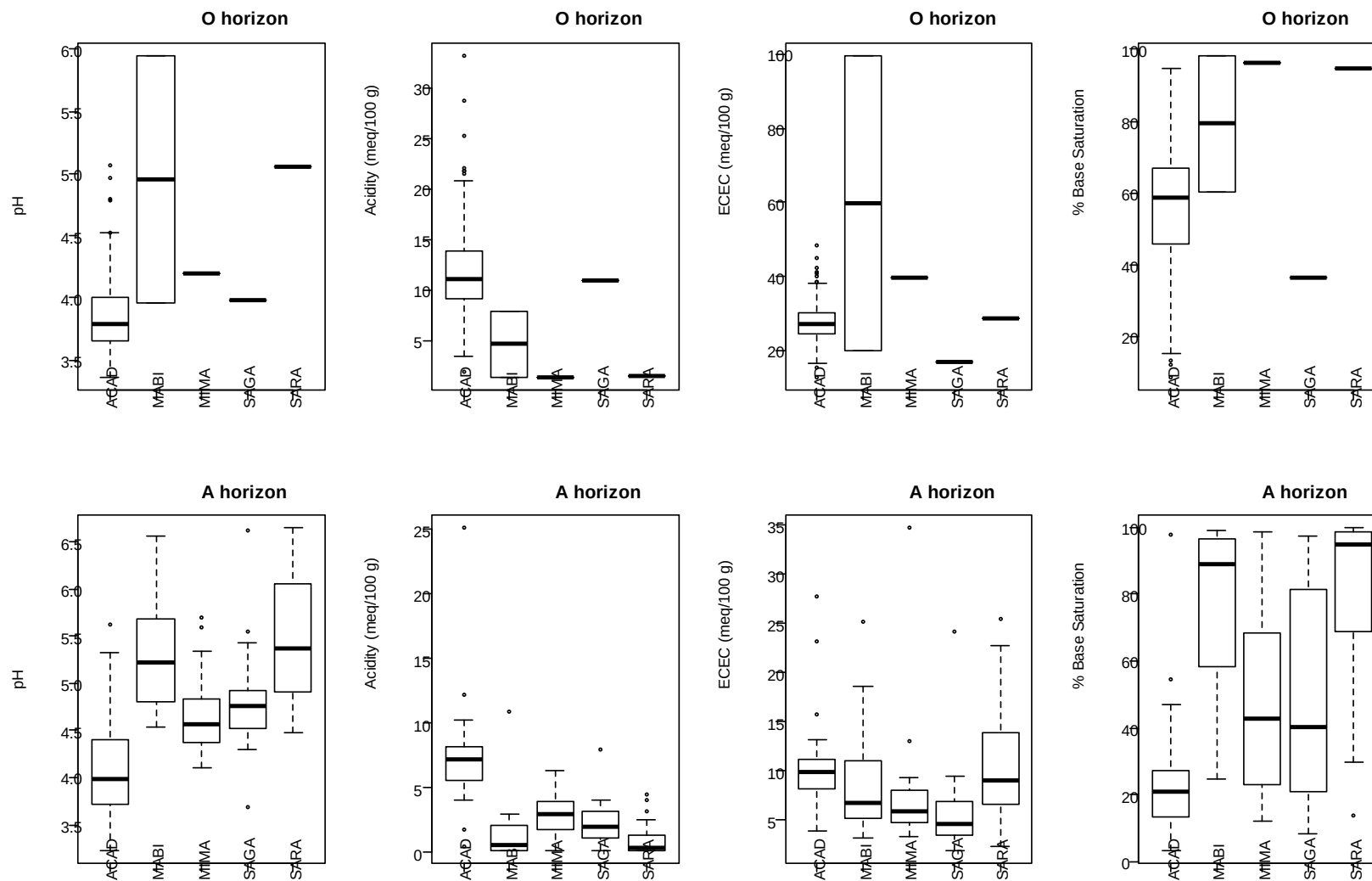


Figure F-1. Soil parameters for each park by horizon. Parks with only one sample for a parameter are represented by a single bar.

Appendix F. Soil Chemistry boxplots for samples collected between 2009 and 2012 (continued).

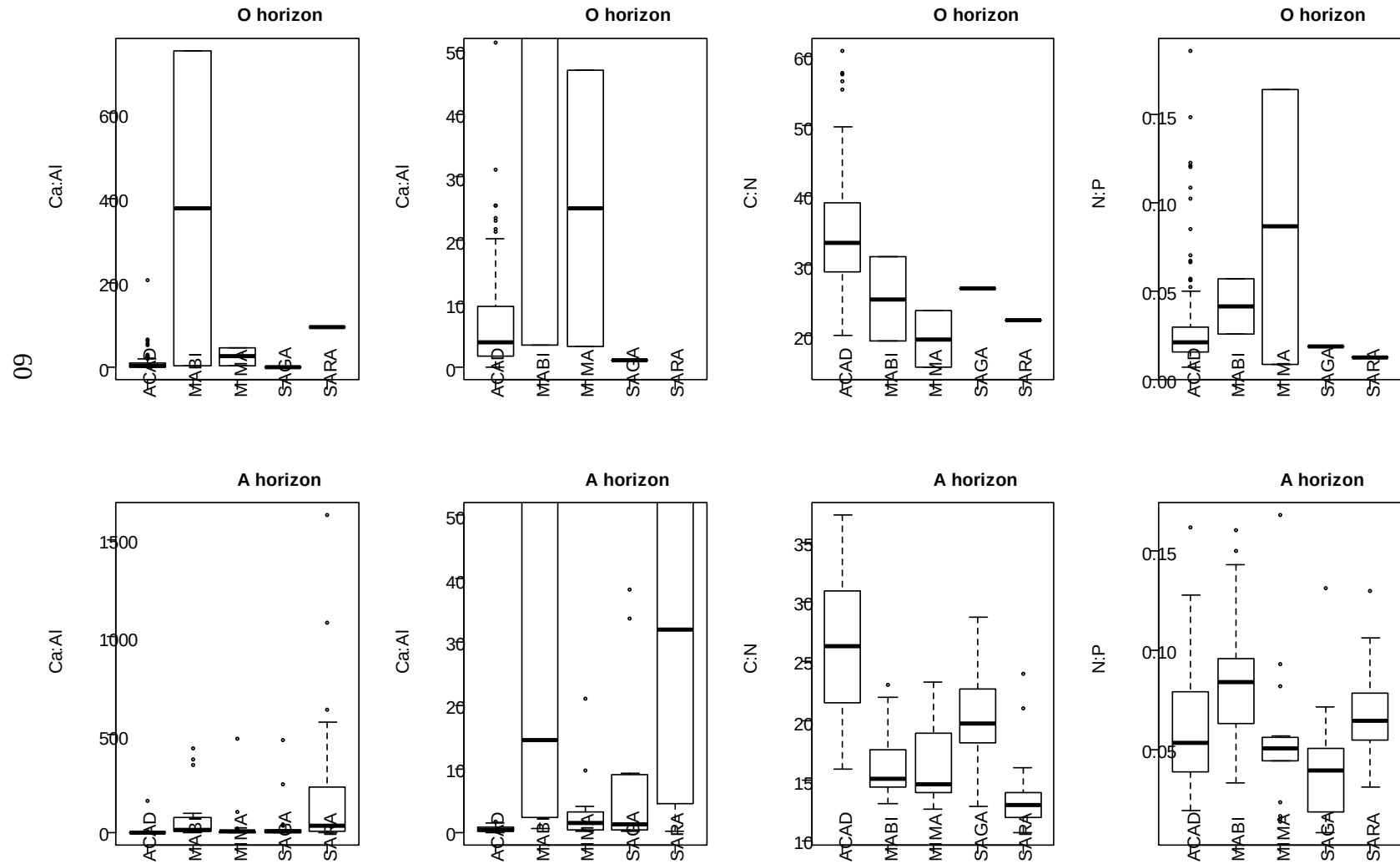


Figure F-2. Ca:Al, C:N, and N:P ratios for each park unit by horizon. The second column of Ca:Al shows the lower range of ratios for the parks. Parks with only one sample for a parameter are represented by a single bar.

Appendix F. Soil Chemistry boxplots for samples collected between 2009 and 2012 (continued).

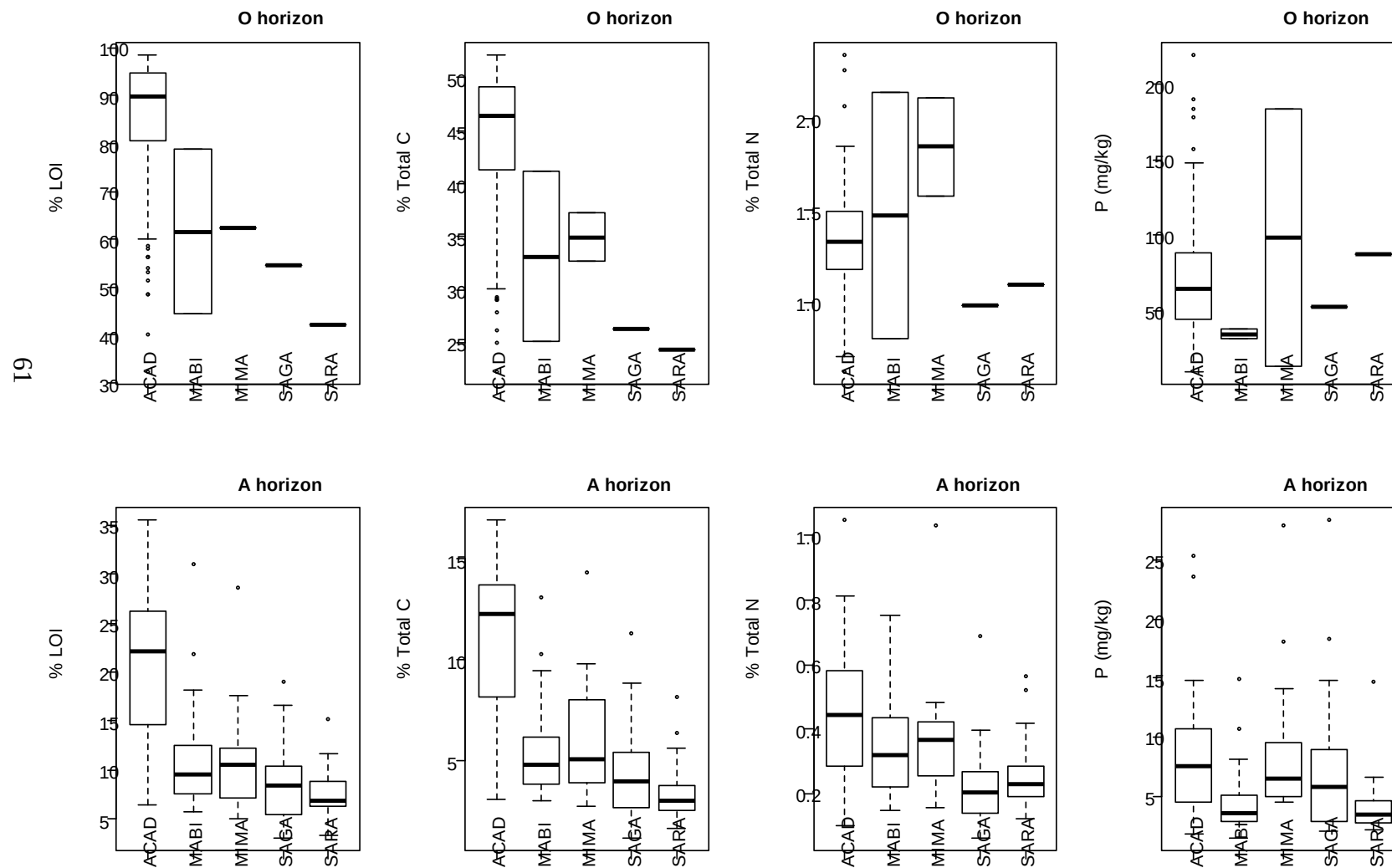


Figure F-3. C, N and P parameters for each park unit by horizon. Parks with only one sample for a parameter are represented by a bar.

Appendix F. Soil Chemistry boxplots for samples collected between 2009 and 2012 (continued).

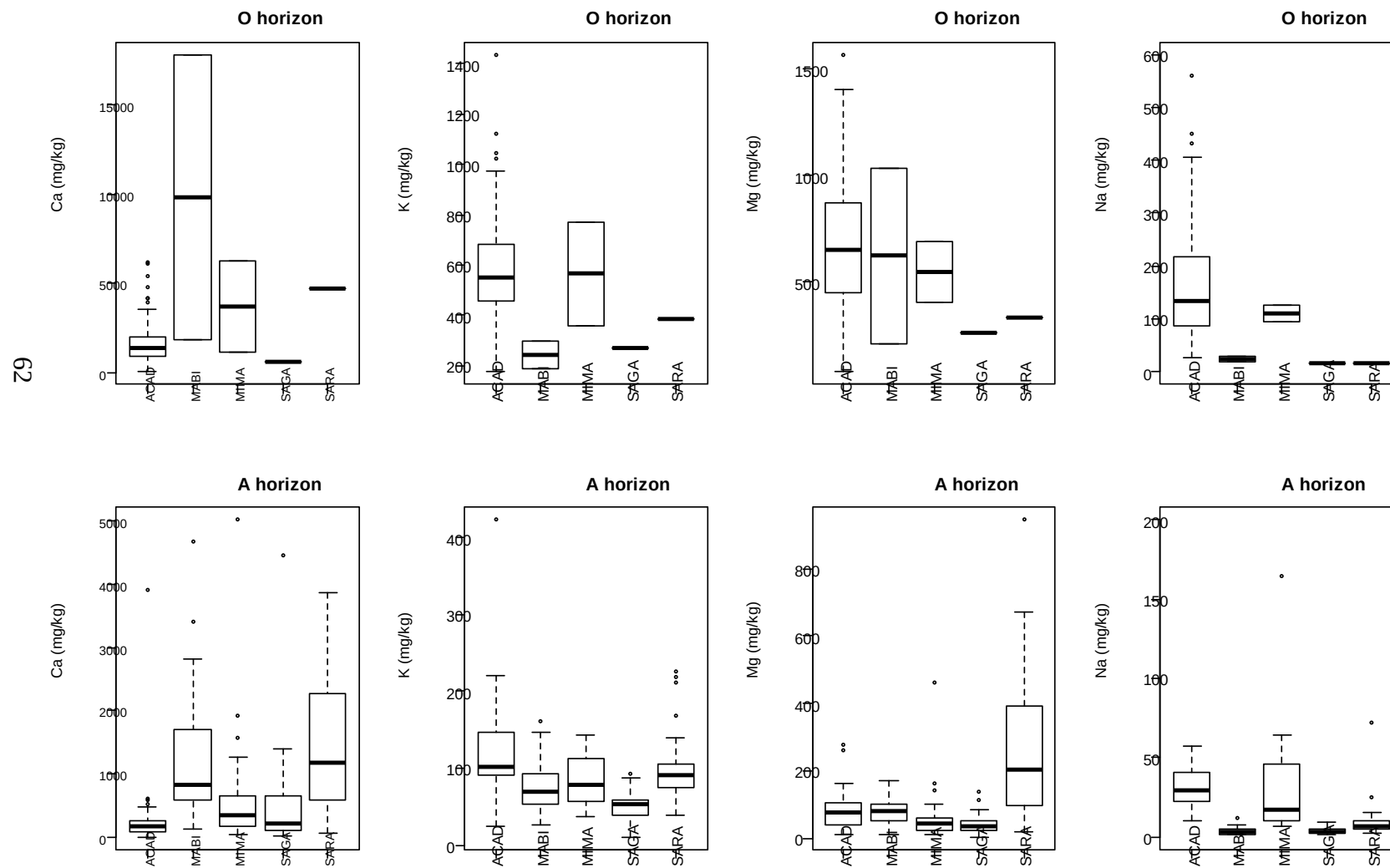


Figure F-4. Base cations for each park unit by horizon. Parks with only one sample for a parameter are represented by a bar.

Appendix F. Soil Chemistry boxplots for samples collected between 2009 and 2012 (continued).

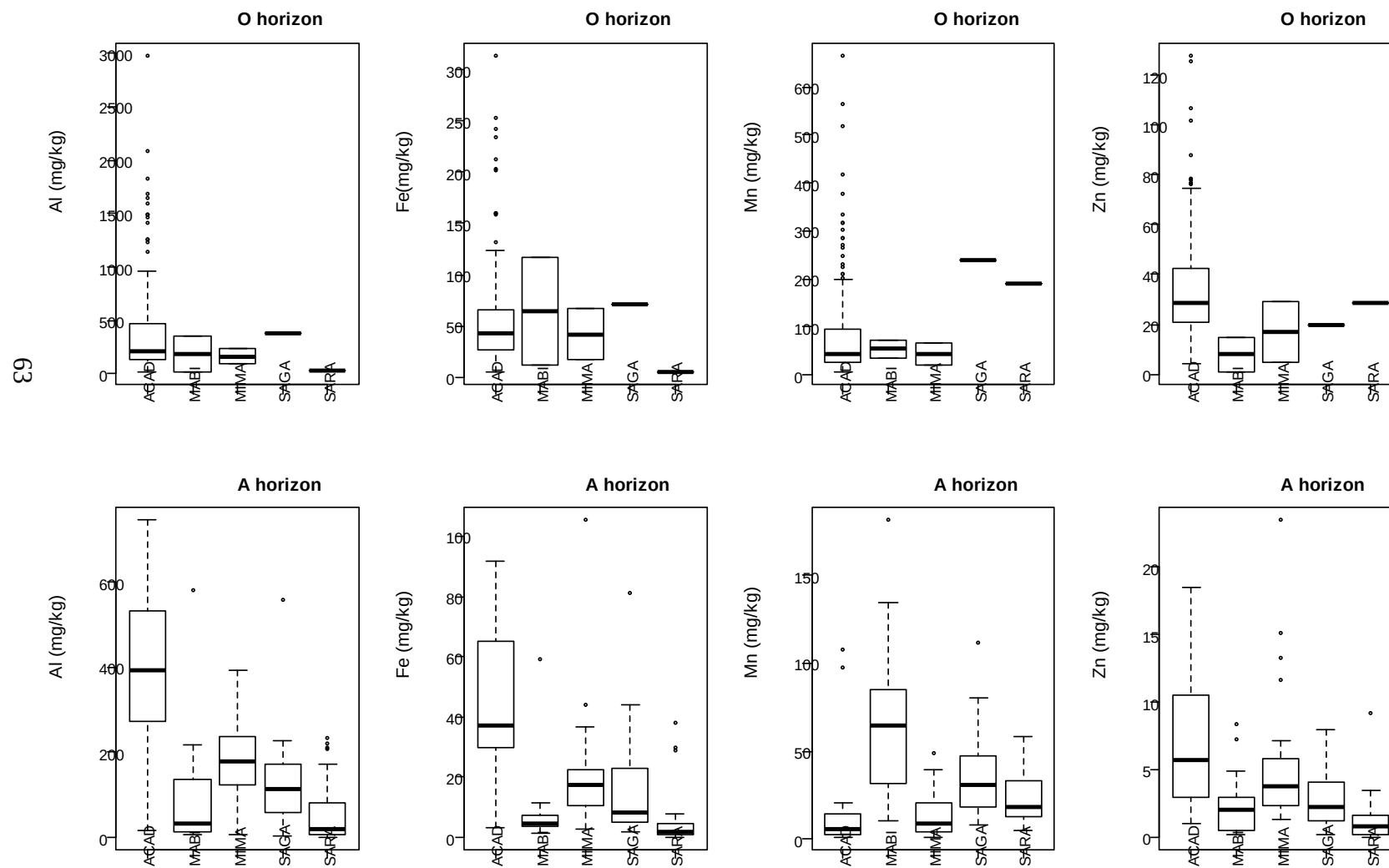


Figure F-5. Acid cations for each park unit by horizon. Parks with only one sample for a parameter are represented by a bar.

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.

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