



Forest Health Monitoring in the Northeast Temperate Network

2013 Summary Report

Natural Resource Technical Report NPS/NETN/NRTR—2014/894



ON THE COVER

Mary Short and Camilla Seirup sampling a forest plot in Morristown National Historical Park
Photograph by: Kate Miller, NPS

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Executive Summary

The 2013 field season marked the Northeast Temperate Network (NETN) Inventory and Monitoring Program's 8th consecutive year of forest health monitoring, and nearly all 351 plots in NETN have been sampled twice. This report contains an ecological integrity scorecard for all of the parks monitored by NETN for forest health, along with comparisons of ecological integrity metrics between cycle 1 (2006 – 2009) and cycle 2 (2010 – 2013). Parks included in this report are 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).

Ecological Integrity

Acadia National Park

Ecological integrity metrics related to forest structure suggest that forests in ACAD are beginning to reach mature stages, but continue to lack late-successional structure such as medium to large snags. Several plots transitioned from pole in the first cycle to mature in the second cycle. Comparisons of snag abundance between cycles suggested that snag abundance in forests on Mount Desert Island (MDI) is declining due to stands moving into more mature stages of succession. Tree regeneration in ACAD was rated Good for abundance, and impacts from deer browse were minimal. Patterns of regeneration compared to late-successional forest were indicative of young 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 Forest Inventory and Analysis (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 during the last eight years of monitoring.

Marsh-Billings-Rockefeller National Historical Park

Ecological integrity metrics indicate that while over half of the plots in MABI are classified as late-successional in cycle 2, 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. These results are consistent with forests managed for timber production. 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 at low levels in MABI, and do not appear to be increasing in abundance. Beech bark disease was the only reported exotic pest/pathogen during the last 8 years of monitoring. 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 potentially increasing, 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.

Morristown National Historical Park

An overabundance of white-tailed deer and invasive exotic species continue to significantly impact forest health in MORR, with the most severe impacts in successional stands. Tree regeneration is well below levels required to restock the future forest, and is especially low in successional stands. Invasive exotic species are pervasive throughout MORR, averaging over five indicator invasive exotic species per plot and comprising most of the plant cover in the understory of successional forests. Tree condition was Good, with only a few cases of elevated insect herbivory and minor beech bark disease reported. Tree growth rates are lower than the regional growth rates calculated from the FIA program, but the higher proportion of late-successional stands in MORR may be lowering growth rates in the park. Overall tree mortality is within desired ranges, and is lowest for oak species (*Quercus* spp.). As forests respond to the effects of Hurricane Sandy, tree growth and mortality rates may show a temporary spike in the next cycle.

The damage from Hurricane Sandy was widespread in MORR and plainly visible in the forest plots. Many of the trees that were down in 2013 were still barely alive, and counted as live trees and not CWD. While snag abundance and CWD were below desired levels in the second cycle, we expect most of the wind-thrown trees to be dead in the next cycle, and this will likely result in an improved CWD rating. We also expect to see responses in the understory due to the canopy gaps created by Hurricane Sandy. The degree of deer browse pressure and competition from invasive species will be important factors controlling whether native tree species are able to capitalize on the newly formed canopy gaps.

Roosevelt-Vanderbilt National Historic Sites

Eleanor Roosevelt National Historic Site & Home of Franklin D. Roosevelt National Historic Site

While CWD is at expected levels in ELRO/HOFR, snags are lacking both in overall abundance and in abundance of medium to large diameter snags. Tree regeneration and deer browse indicator species metrics both suggest moderate deer browse impacts. Although average percent cover of invasive exotic species is low, indicator invasive exotics occur in 21 out of 24 plots, and plots have an average of more than two indicator invasive exotic species. Hemlock woolly adelgid (HWA: *Adelgis tsugae*) and Elongate Hemlock Scale (EHS: *Fiorinia externa*) continue to be observed on most eastern hemlocks (*Tsuga canadensis*) in ELRO/HOFR, and this is the primary cause of Significant Concern ratings for tree condition. Mortality of eastern hemlock remains low, with only 1

out of 40 hemlock trees dying between the first and second cycle. While no other major tree conditions have been reported for ELRO/HOFR, several plots had slightly elevated levels of leaf loss, necrotic leaves, and insect herbivory. Tree growth rates are below regional FIA rates, likely due to differences in structural stage between ELRO/HOFR and FIA plots. The overall tree mortality rate was Good in ELRO/HOFR. White ash (*Fraxinus americana*) had an elevated mortality rate, and this could be due to emerald ash borer (*Agrilus planipennis*) although we have yet to detect this pest in a plot.

Vanderbilt Mansion National Historic Site

VAMA had the highest CWD volume and CWD ratio of any park in the network. Overall snag abundance was also relatively high, although medium to large snags were slightly below desired levels. At least one indicator invasive species was found in every plot in VAMA, and the number of indicator invasive species per plot may be increasing. With the highest average seedling density in NETN, tree regeneration in VAMA appeared adequate, although the stocking index was 43% lower in cycle 2. HWA and EHS were observed on one plot in VAMA. While no other major tree conditions were reported for VAMA, several plots had elevated insect herbivory and leaf loss. Tree growth and mortality rates were both within accepted ranges.

Saint-Gaudens National Historic Site

While coarse woody debris volume and snag abundance were higher in SAGA than most network parks, levels were still lower than those 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, potentially 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 pest/pathogen detected over the last 8 years of monitoring. 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 excessive deer browse. Exotic shrubs, particularly bush honeysuckles (*Lonicera* spp.), have invaded large areas of the park, are suppressing forest succession of old-field habitats, and appear to be increasing in quadrat richness and percent cover. 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 few tree species with seedlings capable of penetrating the thicket and forming a canopy. Deer browse may also be impacting forest regeneration, particularly in early successional stands.

Soil chemistry data indicated that soils in SARA are vulnerable to N saturation and robust to acidification. 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*).

Weir Farm National Historic Site

Forest health appears to be impacted by a number of factors in WEFA. CWD and abundance of snags were both below expected levels. Tree regeneration and deer herbivory indicator species metrics suggest relatively high deer browse impacts. Invasive exotic species are also a concern in WEFA. Japanese barberry (*Berberis thunbergii*) occurred in nine out of 10 plots, and the average number of indicator invasive species per plot and per quadrat may be increasing. Tree condition was influenced by hemlock woolly adelgid in one plot and by elevated leaf loss and necrosis in wet areas. Tree growth rates were the lowest of NETN parks and below the regional FIA average. A high proportion of forest plots in wet areas may partially explain the low growth rates in WEFA. However, growth rates should be interpreted as preliminary due to the small sample size and measurement issues associated with vines. The overall mortality rate is within the expected range.

Ecological Integrity Scorecard: 2010-2013

Park	Structural Stage Distribution	CWD Ratio	Snag Abundance	Invasive Exotic Plants	Tree Condition/ 1 Forest Pests	Tree 2 Regeneration	Deer Browse Indicator Species	Tree Growth and Mortality	Soil Ca:Al	Soi C:N
ACAD	Caution	Caution	Caution	Good			Good	Good	Caution	Good
MABI	Caution	Caution	Sign. Conc.	Caution			Good	Caution	Good	Sign. Conc.
MIMA	Good	Sign. Conc.	Caution	Sign. Conc.			Good	Good	Caution	Sign. Conc.
MORR	Good	Caution	Sign. Conc.	Sign. Conc.			Caution	Caution	Good	Sign. Conc.
ROVA ELRO/HOFR	Good	Good	Caution	Caution			Caution	Caution	Good	Sign. Conc.
VAMA	Good	Good	Caution	Sign. Conc.			Caution	Caution	Good	Caution
SAGA	Caution	Caution	Caution	Caution			Good	Caution	Sign. Conc.	Sign. Conc.
SARA	Caution	Caution	Caution	Caution			Caution	Caution	Good	Sign. Conc.
WEFA	Good	Caution	Caution	Sign. Conc.			Caution	Caution	Caution	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.

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 important to maintaining forest condition. NETN parks often lack late-successional structure compared with benchmark conditions. 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 over time.

Acknowledgements

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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. 2013). 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; Figure 1). 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 nearly all 351 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 are open to working with managers at other parks.

This report contains an ecological integrity scorecard for all of the parks monitored by NETN for forest health, along with comparisons of ecological integrity metrics between cycle 1 (2006 –2009) and cycle 2 (2010 – 2013). Quality Assurance/Quality Control results and issues related to the 2013 field season are summarized in Appendix A.

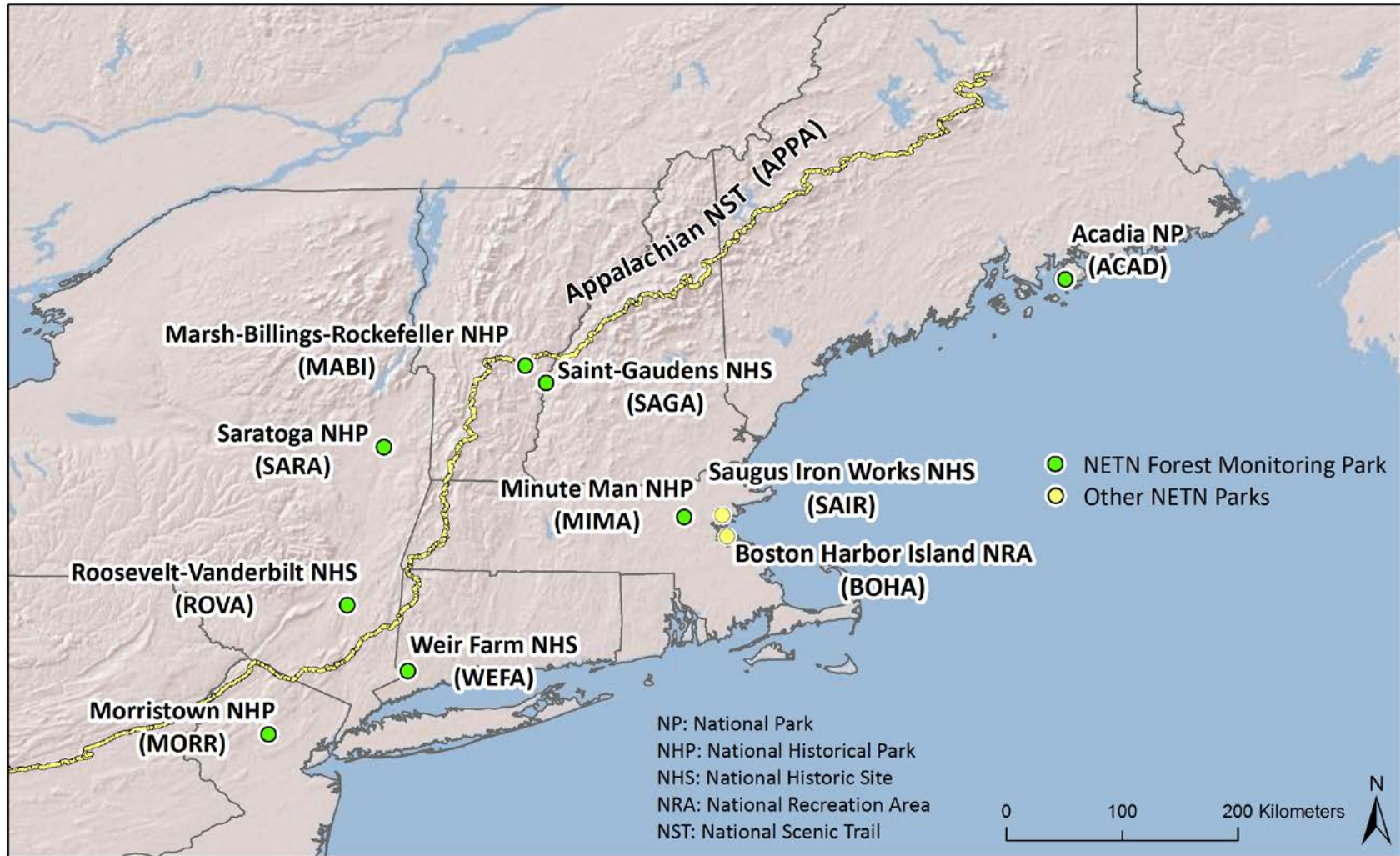


Figure 1. Map of the Northeast Temperate Network

Methods

Sampling 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 are sampled 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 at each park are sampled 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 should 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 2. Tree and stand measurements are made within fixed-area, square plots (15 m x 15 m at ACAD; 20 m x 20 m 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 (the area sampled by the microplots is 37.70 m²/plot). Coarse woody debris (CWD) is assessed using line intersect sampling along three 15-m transects originating at plot center. Understory diversity is monitored within eight 1-m² quadrats, and soil samples are obtained from a location adjacent to the plot. Plots are permanently marked and measured at the same location every cycle, but nested plots (e.g., quadrats) may shift slightly due to missing plot markers or misalignment along the plot boundary. For a more detailed description of the forest monitoring protocol, including background information, field methods, and sample design, refer to Tierney et al. (2013).

Data Analysis

Where possible, we compared forest metrics between cycle 1 (2006 – 2009) and cycle 2 (2010 – 2013) using paired t-tests for each park. Because the primary objective of this trend analysis is to screen for potential forest health issues, running numerous simultaneous t-tests is a valid approach (Roback and Askins 2005). Any potential issues exposed by this screening will be investigated in detail using more rigorous statistical testing and modeling, and more defined hypotheses. Given the large number of paired t-tests (n=186) in this analysis, there is a high likelihood that some of the

significant p-values are due to chance alone (i.e., Type I Errors). To account for this, we generated q-values for each p-value using the q-value package in R (R Core Team 2012, Dabney and Storey 2014). The q-value approach takes into account the number of multiple tests that are being conducted simultaneously, reduces the chance of a Type I Error based on the number of simultaneous t-tests, and has more power to detect trends than more common multiple comparison corrections, such as Bonferroni correction (Roback and Askins 2005).

Q-values were calculated for each p-value using the complete list of paired t-test p-values (n=186) that were generated for this trend analysis, and the q-values (rather than the p-values) were used to determine significant differences in metrics between cycles. It is important to note that q-values perform best when all tests are independent. However, q-values can be used in situations where tests are not independent (e.g., CWD ratio and CWD volume), but may be more conservative than for independent tests (Benjamini and Yekutieli 2001). In addition to reporting q-values and degrees of freedom associated with the paired t-tests, we report effect size (ES) for each significant test as the percent change between cycles (i.e., $(\text{mean}_{\text{cycle2}} - \text{mean}_{\text{cycle1}}) / \text{mean}_{\text{cycle1}}$), where a negative ES suggests a decline and a positive ES suggests an increase. Paired t-tests only included plots that were sampled in both cycles and metrics that were sampled using the same methods in both cycles. We ran diagnostics on the data to check for violations of paired t-test assumptions (e.g., normal error distribution and constant variance between cycles). Boxplots were used to check for constant variances between cycles. We used dot density plots of residuals between the observed difference between cycles and the overall mean difference between cycles to check for normal error and outliers. Overall residuals were approximately normally distributed with mean 0. Metrics with outliers were run with the outlier(s) removed to determine their influence. If the outlier(s) changed the results of the paired t-test, we included the results from both in the report.

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	

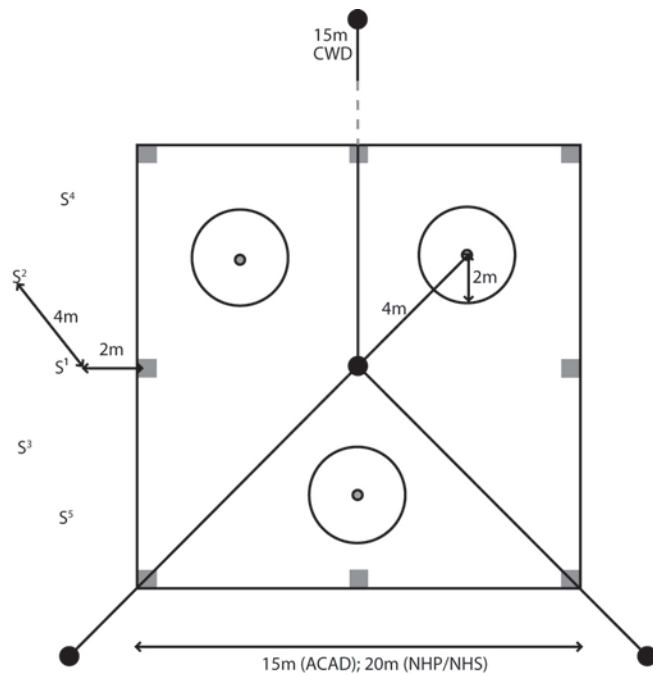


Figure 2. Plot layout showing square tree plot with three nested 2-m radius regeneration microplots (hollow circles), eight 1 m² vegetation quadrats (grey squares), and three 15-m coarse woody debris (CWD) transects. S^x is location of soil sample.

Ecological Integrity Scorecard

The Ecological Integrity 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. (2013).

Metric ratings 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 for the most recent four-year window of data, and may span two sampling cycles. 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 and may also span multiple sampling cycles. Now that the entire second cycle of sampling has been completed, we will also compare metrics between the first and second cycle using plots that were sampled in both cycles. Three plots were either partially or entirely missed in the second cycle, including SARA 015 and ACAD 029 which were entirely missed, and SAGA 008, which is missing regeneration data. In addition, seven plots were added at ACAD in the second cycle. Therefore, 342 plots (341 plots for regeneration metrics) were included in the metric comparisons between cycles.

The following metrics are included in this report: 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.

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. Natural stands are second growth forests that are primarily composed of naturally regenerated hardwood species. Plantations consist of forests that were planted with conifer species. In MORR, metrics were rated overall and by “Mature” and “Successional” stand types. Mature stands were defined as second growth stands that originated from areas cleared by General Washington’s forces around 1779 to 1780.

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	NHP and NHS: Seedling ratio ≥ 0 ACAD: Stocking index ≥ 20 and sapling: small seedling ratio ≤ 0.11	NHP and NHS: Seedling ratio < 0 ACAD: Stocking index ≥ 20 and sapling: small seedling ratio > 0.11	NHP and NHS: Stocking index < 25 ³ 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-large 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.

While these stands may have been repeatedly or selectively logged, they have never been plowed or cultivated, and are thought to have returned directly to forest after the end of the encampment (Ehrenfeld 1982, Shaw and Patterson 2006). The successional category represents younger stands that originated on abandoned field or pasture around 1927 or later. Soils in successional stands have likely been plowed, and forests are mostly even-aged (Shaw and Patterson 2006). 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.

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), such as single tree-fall. Stand replacing disturbances were rare, with return intervals as high as 1,000-7,500 years for inland northern hardwood forests (Lorimer and White 2003). 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 et al. 1998, Hall et al. 2002), and the second-growth forests of today are structurally and compositionally different from 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 the 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 diameter at breast height (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 diameter 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 the 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 the 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; both Appalachian Hemlock-Northern Hardwood Forest and Northeastern Interior Dry-Mesic Oak Forest at ELRO/HOFR and VAMA; Northeastern Interior Dry-Mesic Oak Forest at MORR and WEFA; 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 on the matrix type with the lowest expected proportion of late-successional structure. Assessment points are defined in Table 2. As more cycles of data are available, we will also examine how diameter distributions change over time, and may consider other methods, such as the Departure Index, to assess forest structure (Menning et al. 2007).

Results and Discussion

Based on the second cycle of data, desired levels of late-successional forest were met in MIMA, MORR, ELRO/HOFR, VAMA, and WEFA (Table 3; Appendix B: Table 1). While MABI and SAGA had proportionately more plots in late-successional forest than several of the parks that were rated Good, they also have higher expected levels of late-successional forest due to differences in the dominant forest type, and both parks were rated Caution. Only a small percentage of plots were in late-successional forest in ACAD (Figure 3), and ACAD was also rated Caution. While not part of the metric, over 15% of the plots in ACAD are 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.

Comparisons between cycles yielded some interesting results. In every park, one or more plots moved into a later successional category, and this was most distinct for MABI and WEFA. While not statistically significant, we were surprised by the amount of change in only 4 years. We reviewed the data closely to determine if this was the result of metric variability or an unintended consequence of a protocol change or management (e.g. harvesting in MABI). In most cases, the change from Pole to Mature or Mature to Late-succession was the result of one or two trees on a plot reaching the next largest DBH size category in the second cycle. There were also very few examples of plots moving into earlier successional categories. Therefore we believe these are real changes. We will continue to track changes in this metric and will test for trends after the third cycle of data are collected. As more data are available, we expect to have a better understanding of patterns of forest succession and how they relate to this metric in NETN parks.

Table 3. Summary of plot structural stage distributions in NETN parks by cycle. Data summaries only include plots that were sampled in both cycles, and metric ratings are based on the complete set of plots for each cycle. “Diff.” is the change between cycle one and two, and “Succ.” is “Successional”.

Park	Cycle	# Plots	% Late-succ.	Diff.	% Mature and Late-succ.	Diff.	Rating
ACAD	1	139	15.1	-0.7	57.6	3.6	Caution
	2	139	14.4		61.2		Caution
MABI	1	24	41.7	16.7	91.7	4.2	Caution
	2	24	58.3		95.8		Caution
MIMA	1	20	30.0	0.0	75.0	0.0	Good
	2	20	30.0		75.0		Good
MORR	1	28	67.9	3.6	100.0	0.0	Good
	2	28	71.4		100.0		Good
ROVA	1	40	47.5	2.5	87.5	2.5	Good
	2	40	50.0		90.0		Good
SAGA	1	21	38.1	0.0	85.7	4.8	Caution
	2	21	38.1		90.5		Caution
SARA	1	31	22.6	0.0	45.2	12.9	Caution
	2	31	22.6		58.1		Caution
WEFA	1	10	40.0	10.0	90.0	0.0	Good
	2	10	50.0		90.0		Good

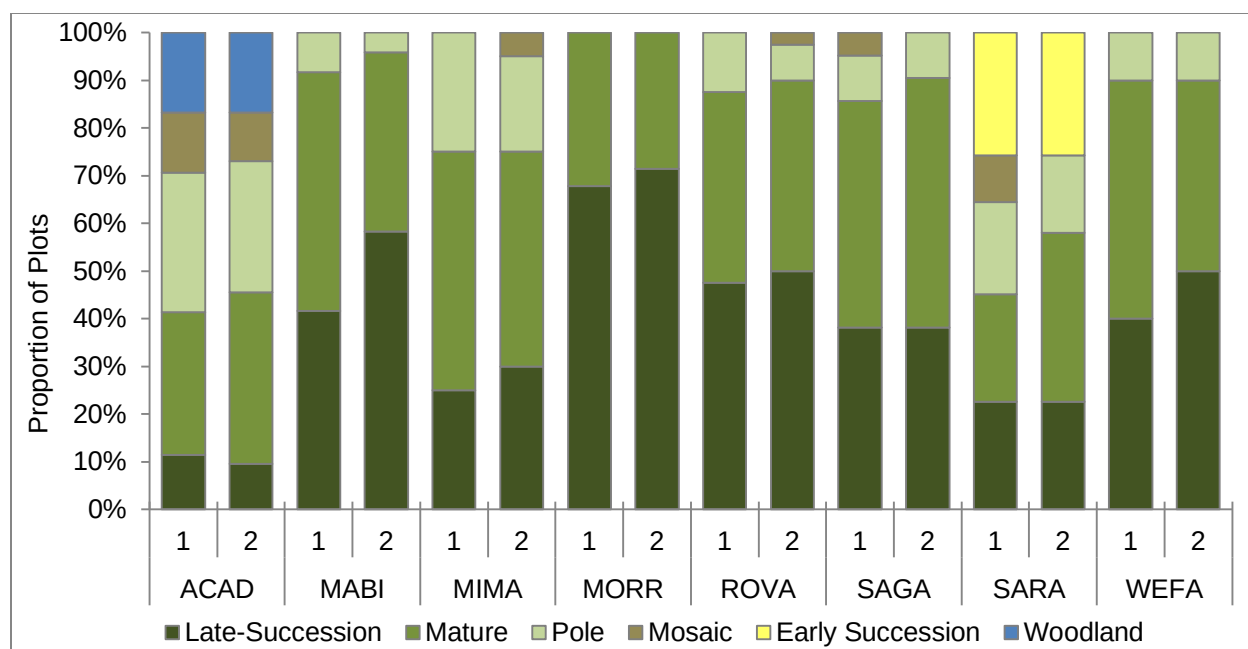


Figure 3. Proportion of plots in each structural stage (Late-succession, Mature, and Pole) and field stand structure class (Early Succession, Mosaic, and Woodland) for plots sampled in both cycle 1 (2006-2009) and cycle 2 (2010-2013). Structural stages are based on proportion of basal area by size class. Field stand structure classes are determined in the field and not classified into structural stages. Woodlands are not included in the metric rating.

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, including mammals, birds, fungi, herpetofauna, and insects. In addition, tip-up mounds caused by wind-throw contribute to forest soil turnover and create important microhabitats for 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, studies have documented positive relationships between live and dead tree density and between live tree volume and CWD volume (Sippola et al. 1998, Ferguson and Archibald 2002, and Stewart et al. 2003). Therefore live tree density (for snags) and live tree volume (for CWD) can control for site differences in determining expected levels of snag abundance and CWD volume (Tierney et al. 2013). 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 (≥ 30 cm 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 for all NETN parks. 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

MIMA continues to have the lowest CWD volume and CWD ratio, and was rated Significant Concern (Table 4). In contrast, ROVA had the highest CWD volume and CWD ratio in NETN, and was rated Good. CWD volume was particularly high in VAMA (Appendix B: Table 2). Remaining parks were rated Caution, and all except ACAD had the same rating in both cycles. The CWD metric in ACAD has alternated between Good and Caution over the last few years of reporting, primarily because the CWD ratio in ACAD is close to the assessment point that distinguishes Good from Caution. Considering that CWD volume does not differ significantly between cycles, the change from Good to Caution is more likely due to sample variability than an actual change. Based on paired t-tests, there were no significant differences at $\alpha = 0.10$ in CWD volume or the CWD ratio between cycles in any park. There was a marginally significant decrease in live tree volume in the second cycle in ACAD ($ES = -8.2\%$, $q = 0.097$, $df = 138$). While there are potential ecological explanations, such as birch and aspen die back in ACAD, we also suspect that these results are due to several confounding issues in the data. First, live tree volume is sensitive to tree crown classes on a plot, and we used slightly different definitions of crown classes early on (2006 to 2008) than we currently use. The live tree volume calculation is also very sensitive to the plot stand height measurement, and QA/QC results indicate that the stand height measurement has a lot of sample variability. We have worked to improve stand height measurements, particularly in the second cycle. Improvements include averaging the height of three codominant trees instead of one, using a laser

hypsonometer instead of a clinometer to measure distance and angle, requiring the distance measure to be at least 10 meters from the base of the tree, and building a stand height calculator into the database. In 2013 we also began measuring stand height for intermediate trees to improve our live tree volume calculation. Despite all of these improvements, the stand height measurement continues to have relatively high sample variability. This is an issue widely recognized by foresters and forest monitoring programs, including the US Forest Service Forest Inventory and Analysis Program (FIA), which is currently revising methods for calculating live tree volume on FIA plots. We will continue to look for alternative CWD metrics that are based on more repeatable measurements, along with improving the live tree volume metric, and will follow FIA approaches where possible. We will also continue to track and report CWD volume, which is a more stable metric, and trends in this metric will probably be more meaningful than the CWD ratio in the long run. It is also important to recognize that in the early years of protocol implementation, we were still refining sampling methods, and many improvements were made between the first and second sampling cycle. The current forest protocol is more stable and only very minor changes are expected from now on. Therefore comparisons of CWD metrics between the second and future cycles will avoid most of the potential problems described above.

Table 4. Coarse woody debris (CWD) metric ratings, ratios, and volume calculations for NETN parks by cycle. Data summaries only include plots that were sampled in both cycles, and metric ratings are based on the complete set of plots for each cycle. 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 park 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). Plots with missing stand heights due to sampling error were corrected using stand heights from the other cycle, if available. Groups with fewer than 10 plots were not rated for CWD, and woodland plots were not included in the ACAD ratings. SE refers to 1 standard error around the mean. Significance levels from paired t-tests are indicated by *, where * is significant at q-value < 0.1, ** is significant at q-value < 0.05, and *** is significant at q-value < 0.01, and are denoted on the higher mean.

Park	Cycle	# 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	1	139	Good	16.43%	4.11%	25.30	2.82	361.63	40.00	232.33*	13.76
	2	139	Caution	11.94%	1.21%	24.62	2.43	351.80	33.40	213.34	9.78
MABI	1	24	Caution	7.34%	1.88%	33.70	7.32	481.61	104.54	544.97	55.50
	2	24	Caution	7.93%	1.95%	35.55	7.62	508.00	108.88	518.74	43.20
MIMA	1	20	Sign. Conc.	3.13%	0.74%	8.81	2.27	125.86	32.45	330.99	58.37
	2	20	Sign. Conc.	4.61%	1.67%	9.87	3.22	141.00	46.00	316.21	50.30
MORR	1	28	Caution	8.01%	1.79%	26.78	6.00	382.79	85.72	413.02	30.63
	2	28	Caution	7.90%	2.39%	25.46	5.67	363.83	81.04	433.07	35.72
ROVA	1	40	Good	26.12%	8.10%	58.04	11.42	829.42	163.23	371.76	31.50
	2	40	Good	23.62%	8.30%	52.17	12.64	745.58	180.64	358.23	26.37
SAGA	1	21	Caution	8.36%	2.72%	37.73	9.28	539.17	132.56	622.91	74.67
	2	21	Caution	7.49%	2.61%	31.76	7.21	453.88	103.08	577.17	66.93
SARA	1	23	Caution	11.56%	3.38%	24.79	5.61	354.35	76.74	337.13	42.43
	2	23	Caution	14.77%	4.68%	23.50	5.22	335.90	74.65	295.85	32.88
WEFA	1	10	Caution	5.19%	3.27%	22.49	13.15	321.44	187.87	424.77	48.49
	2	10	Caution	6.56%	3.62%	22.15	11.45	316.61	163.66	381.80	40.36

As a result of Hurricane Sandy, we expected CWD volume to increase and live tree volume to decrease between cycle 1 and 2 in MORR, at least in panel 4. CWD volume in cycle 2 of panel 4 was slightly higher than in cycle 1, but the difference was not significant (Appendix B: Figure 1). Live tree volume was very similar between cycles. While the damage from Hurricane Sandy was widespread in MORR and plainly visible in several forest plots, many of the trees that were down in 2013 were still barely alive, and therefore counted as live trees and not CWD. We expect most of those trees to be dead in the next cycle, and as long as management actions do not reduce the abundance or size of CWD, we expect to see improvements in the CWD metric in MORR. The blowdown areas are visually striking, and there may be a temptation to remove or cut the down logs. However, leaving the CWD and tip-up mounds intact where possible will, in the long run, benefit forest health in MORR. CWD is critically important habitat for numerous organisms, including insects, fungi, bryophytes, amphibians, and several eastern tree species for regeneration, and it is typically deficient in managed forests in the eastern US (Goodburn and Lorimer 1998). In addition, the tip-up mounds created by windthrow are an important soil cycling process that generally only occurs in older forests. Therefore, while the blowdowns created by Hurricane Sandy may seem destructive in the short term, the disturbance may benefit forest health in the long run.

All parks were rated Caution or Significant Concern for snag abundance in cycle 2, and this is primarily due to a lack of snags ≥ 30 cm DBH (Table 5). As forests mature, these metrics are expected to improve over time in most parks. In MABI, snag abundance and CWD volume may continue to be lower than desired levels, and this is a common issue in forests managed for timber production (Goodburn and Lorimer 1998). Adapting forest management approaches to encourage more snag and CWD retention may be necessary to improve these important structural components.

ACAD, which had the highest density of snags, narrowly missed a Good rating because the percentage of trees ≥ 30 cm DBH that are snags was just under the 10% assessment point. The snag abundance metric includes plots in woodlands, which are areas of sparse canopy cover due to harsh growing conditions (e.g., thin, acidic soils). Woodlands are less likely than closed-canopy forest to have trees that can reach 30 cm DBH, and it may not be appropriate to include woodland plots in the snag abundance metric. We will examine the snag abundance metric in more detail and consider revising it for future reports. ROVA also narrowly missed a Good rating overall, and both ELRO/HOFR and VAMA received a Caution rating in the second cycle (Appendix B: Table 3). MORR and WEFA had the lowest overall snag densities, and MORR and MABI had the lowest density of snags ≥ 30 cm DBH.

Snag abundance ratings for MIMA, SARA, and WEFA improved from Significant Concern in cycle 1 to Caution in cycle 2. While not statistically significant, the improved ratings for MIMA, SARA, and WEFA were all the result of a slight increase in snags ≥ 30 cm DBH. In ACAD several snag metrics differed significantly between cycles and snags appear to be more dynamic than for the rest of NETN. Based on paired t-tests, the number of snags/ha (ES = -10.3%, $q = 0.04$, $df = 166$), and the % of trees that are snags (ES = -10.9%, $q = 0.02$, $df = 166$) were significantly lower in ACAD in cycle 2. These lower values were primarily driven by changes on MDI, where over 80% of forest plots are located. Snags on Schoodic and IAH appeared to be more stable.

Table 5. Snag abundance ratings and calculations for NETN parks by cycle. Data summaries only include plots that were sampled in both cycles, and metric ratings are based on the complete set of plots for each cycle. 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. Significance levels are indicated by *, where * is significant at q-value < 0.1 , ** is significant at q-value < 0.05 , and *** is significant at q-value < 0.01 , and are denoted at the higher mean.

Park	Cycle	# Plots	Rating	# of Snags/ha		# of M-L Snags/ha		% of Trees as Snags	
				Mean	SE	Mean	SE	All Sizes	M-L Snags
ACAD	1	167	Caution	188.95**	13.15	7.72	1.56	18.01%**	10.07%
	2	167	Caution	169.53	10.91	7.98	1.62	16.06%	9.29%
MABI	1	24	Sign. Conc.	42.71	8.84	3.13	1.72	8.23%	1.80%
	2	24	Sign. Conc.	42.71	9.21	4.17	1.94	8.49%	2.55%
MIMA	1	20	Sign. Conc.	47.50	8.68	3.75	2.05	9.55%	3.23%
	2	20	Caution	53.75	8.94	6.25	2.48	10.97%	5.05%
MORR	1	28	Sign. Conc.	32.14	5.28	3.57	2.12	10.91%	2.80%
	2	28	Sign. Conc.	27.68	5.80	3.57	1.68	9.94%	2.74%
ROVA	1	40	Caution	46.25	8.08	11.25	3.09	10.26%	8.78%
	2	40	Caution	40.00	8.00	10.63	3.34	9.03%	7.87%
SAGA	1	21	Caution	90.48	17.88	10.71	4.07	13.67%	5.29%
	2	21	Caution	79.76	16.51	14.29	3.69	12.59%	7.19%
SARA	1	31	Sign. Conc.	76.61	16.68	3.23	1.92	16.73%	3.33%
	2	31	Caution	92.74	18.26	8.87	3.19	20.50%	8.59%
WEFA	1	10	Sign. Conc.	30.00	11.06	2.50	2.50	6.67%	1.56%
	2	10	Caution	27.50	10.17	5.00	3.33	6.18%	3.17%

While both sections of MDI had significantly lower snag density in cycle 2, patterns behind the decline in snag density differed between eastern and western sections of MDI (Appendix B: Figures 2 and 3). On eastern MDI, forests that originated after the 1947 fire are shifting from early successional birch and aspen dominated to spruce-fir dominated. Much of the birch and aspen have already died back, and the rate of birch and aspen snag production in these stands appears to have slowed over time ($ES = -14.6\%$, $q=0.05$, $df=78$; Appendix B: Figures 2A and 3A). As spruce and fir replace birch and aspen in the canopy, these stands are reaching a successional stage of rapid spruce-fir growth where fewer snags are produced (Davis 1961). A significant increase in mean live tree density on eastern MDI ($ES = 3.5\%$, $q = 0.06$, $df = 78$) is further evidence for this, as this increase is primarily the result of an increase in conifer density (Appendix B: Figures 2B and 3B). Based on changes in snag and live tree density, we expected CWD volume to increase in cycle 2, but this was not the case. There were no significant differences in CWD volume between cycles, and birch and aspen volume were similar between cycles (Appendix B: Figure 4). One possible explanation for not detecting a change in CWD volume relates to size cutoffs in the NETN long-term forest monitoring protocol. For a CWD piece to be tallied, it must intersect at least one of three 15-m transects on the plot, must be at least 10 cm diameter where it crosses the line and must be at least 1 m long (while at least 10 cm diameter). Based on field observations, aspen and birch snags decompose much faster than spruce or maple species, and they often break into pieces as they decompose and fall. The early successional species, especially birch, also tend to be close to the 10 cm DBH as trees, and often shrink below that diameter by the time they fall. Therefore it is possible that CWD volume of aspen and birch are increasing, but only for diameters that are too small to be picked up by our protocol.

Patterns of snags and live tree densities on western MDI are suggestive of more mature forests than eastern MDI. Snag density is significantly lower in cycle 2 due to a decrease in conifer snag density ($ES = -8.8\%$, $q = 0.08$, $df = 60$; Appendix B: Figures 2 and 3). The difference in mean live tree density is also higher in the second cycle ($ES = 3.1\%$), with a higher density (primarily of conifers) in the second cycle, but this difference is not statistically significant. As on eastern MDI, CWD volume is not significantly different between cycles on western MDI. The majority of plots on western MDI are approaching or are in mature, even-aged forest, and snag production tends to be low in mature forests until they begin to transition to late-successional forest (Davis 1961). While we believe these changes are likely real, it is still surprising that we detected significant differences in snag density and live tree density in only 4 years. As more cycles of data are collected, it will be important to examine patterns of tree growth, mortality and recruitment, along with stand ages determined by our coring efforts, to validate these claims and to have a better understanding of forest dynamics as they relate to snag and CWD production.

Note that CWD volume of conifer species in ACAD appeared to increase considerably between cycles, especially on western MDI (Appendix B: Figure 4). This is not a real change, as crews in the first cycle classified more pieces as unknown, and crews in the second cycle classified more pieces as conifer. When CWD volume of the conifer and unknown groups are combined, the average CWD volume between cycles is very close.

Table 6. Tree cavity summary statistics for each park for Panels 3 and 4 in cycle 2 (2012-2013).

	# 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	88	5.56	1.73	10.10	2.76	6.06	1.79	10.61	2.69
MABI	12	2.08	2.08	4.17	2.81	0.00	0.00	4.17	2.81
MIMA	10	5.00	3.33	5.00	3.33	0.00	0.00	0.00	0.00
MORR	14	8.93	4.23	3.57	2.43	5.36	2.85	3.57	2.43
ROVA	20	12.50	3.85	3.75	2.05	13.75	3.84	7.50	3.67
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
WEFA	5	10.00	10.00	5.00	5.00	10.00	6.12	5.00	5.00

Patterns and abundance of tree cavities varied by park (Table 6). Both small and large cavities on live trees were most abundant in ROVA and WEFA, and least abundant in MABI. Small and large cavities on dead trees were most abundant in ACAD, SAGA, and SARA. It is important to note that the probability of detecting tree cavities, particularly small cavities, decreases with tree height and density of the canopy. It is possible in MABI, where trees are relatively tall and the canopy is multilayered, that true cavity densities are higher than our data suggest. These data are only based on one survey from half of the plots in each park and should be considered preliminary.

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 km^2 , well above pre-settlement estimates of 3-4 deer per km^2 in the northeastern U.S. (Russell et al. 2001, Augustine and deCalesta 2003).

In most of the network, 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 the tall, preferentially browsed size class (30-100 cm) minus species richness of short, unbrowsed (15-30 cm) size class and divides this by the sum of species richness in the tall and short size classes. This metric only considers the preferred browse species listed in Appendix C. Negative ratios suggest that deer browse is reducing diversity of the tall, preferentially browsed size class. 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).

Table 7. Index of deer browse impacts assessed for each plot in national historical parks (NHP) and historic sites (NHS) and ACAD (adapted from Brose et al. 2008 and Perles et al. 2010).

Parks	Level	Browse Impact	Description
NHP and NHS	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.

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 2013 (i.e., cycle 2), 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. NETN recently developed a tree regeneration metric for ACAD using data collected in late-successional spruce-fir stands (Miller et al. 2013a). 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 10 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 are defined in Table 1.

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

Metrics in MORR continue to indicate severe deer impacts and inadequate regeneration. In cycle 2, only one plot was rated Good in MORR for regeneration, and this plot is located in the deer exclosure that was established in 2007 (Figure 4). MORR also had the lowest seedling densities (Figure 5) and the highest average deer browse index (Table 8) in NETN. Seedling densities were especially low in Successional stands in MORR (Appendix B: Figure 6). In WEFA, all plots were either rated Caution or Significant Concern, seedling densities were low, and average deer browse index was 4.0 (High), suggesting that impacts from deer overabundance are likely also occurring in WEFA.

In MABI, MIMA, SAGA, and SARA, a high percentage of plots were rated Caution due to negative seedling ratios (Figure 4). The average deer browse index was fairly low in MABI, MIMA, and SAGA, and other factors such as stand development and/or invasive species (particularly in MIMA) may be behind the negative seedling ratios. The average seedling ratio in MIMA changed from a negative ratio in cycle 1 to a positive ratio in cycle 2. Some of the change may be because we only sampled one microplot per plot in 2006, and we found through preliminary analyses that one microplot was not enough to characterize regeneration in a plot. However, panel 3 also shows a shift from negative seedling ratio to positive seedling ratio in MIMA. It is unclear what the causes behind the seedling ratio improvement are in MIMA. It will help to have more cycles of regeneration data to better understand if this is a real change or a result of protocol changes and/or observer bias.

While overall seedling densities in SARA were the highest in the network, small seedlings (i.e., below 100 cm tall) made up the bulk of the seedling density, and the average deer browse index was close to 3 (Table 8). These results indicate moderate impacts to tree regeneration may be occurring in SARA (Table 8). The average stocking index in the Forest category in SARA showed a considerable increase in cycle 2, but the difference was not significant (Appendix B: Table 4). The Forest category only includes 7 plots, and the large increase in the stocking index was primarily due to SARA plot 017. Shortly before plot 017 was established in 2008, a prescribed fire in a nearby field partially spread into the understory. The regeneration data and photopoints taken in plot 017 in 2008 and 2012 indicate a clear positive response in understory woody species.

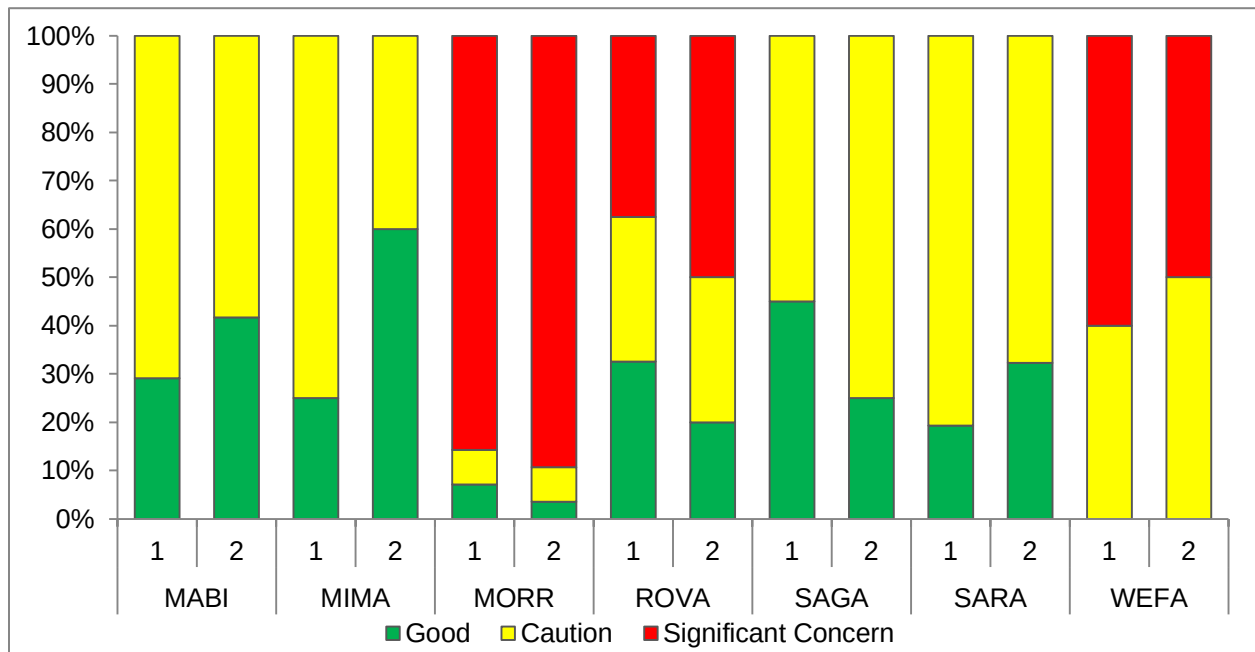


Figure 4. Proportion of plots in NHP and NHS parks receiving Good (green), Caution (yellow) and Significant Concern (red) ratings for tree regeneration for cycle 1 (2006-2009) and cycle 2 (2010-2013). Metric ratings are only include plots sampled in both cycles. An assessment point for Significant Concern has not been defined for MABI, MIMA, SAGA and SARA.

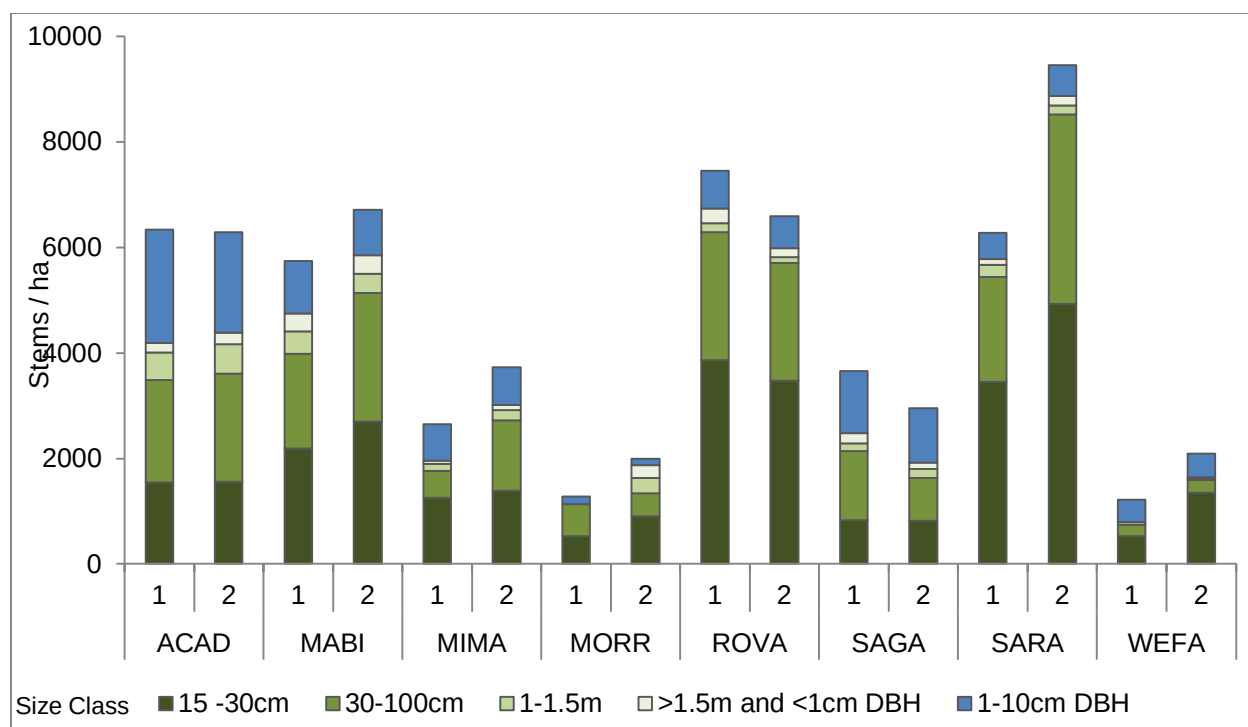


Figure 5. Mean seedling (green) and sapling (blue) densities for cycle 1 (2006-2009) and cycle 2 (2010-2013) by park. Stem densities only include plots sampled in both cycles.

Table 8. Mean stocking index and seedling ratio averaged over three 2-m radius microplots per plot for cycle 1 (2006-2009) and cycle 2 (2010-2013) in the NHP and NHS parks. Data summaries only include plots that were sampled in both cycles. Plots without browse preferred species are not included in the seedling ratio summaries, and t-tests were not conducted on this metric. The deer browse index was not used to rate the regeneration metric and only includes the full set of plots from cycle 2. SE refers to 1 standard error around the mean. There were no significant differences between cycles.

Park	Cycle	# Plots	Stocking Index		Seedling Ratio		Deer Browse Index	
			Mean	SE	Mean	SE	Mean	SE
MABI	1	24	63.38	21.80	-0.75	0.81		
	2	24	58.74	22.70	-0.98	0.73	2.46	0.12
MIMA	1	20	48.80	14.92	-1.98	0.53		
	2	20	43.95	12.49	1.21	0.83	2.60	0.11
MORR	1	28	9.89	2.54	-0.88	0.30		
	2	28	29.27	22.56	-1.44	0.44	4.36	0.17
ROVA	1	40	70.34	13.36	-1.16	0.55		
	2	40	49.38	8.74	-2.64	0.59	3.13	0.15
SAGA	1	20	87.52	26.91	-0.37	0.66		
	2	20	70.03	18.32	-1.34	0.65	2.43	0.11
SARA	1	31	42.29	11.39	-2.00	0.57		
	2	31	48.98	21.73	-2.31	0.61	2.90	0.10
WEFA	1	10	29.13	9.31	-5.53	1.93		
	2	10	31.13	7.98	-5.10	1.49	4.00	0.26

ROVA had high seedling densities, but also had a number of plots that were rated Significant Concern and an average deer browse index of 3. While not statistically significant, the stocking index in ROVA was lower in cycle 2 %, and this was primarily from plots in VAMA (ES = -43.3%; Appendix B: Table 4). Some of the decline in regeneration in VAMA may be the result of crews in cycle 1 misidentifying Norway maple (*Acer platanoides*) as sugar maple (*Acer saccharum*), as crews in the second cycle tended to have stronger plant identification skills, and exotic species are not included in the stocking index. However, the stocking index decline cannot entirely be explained by sample error, as the stocking index in VAMA was still lower in cycle 2 when exotic species were included in the index. We will continue to track regeneration metrics in ROVA to determine if these changes are ongoing or the result of sample bias.

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 the park's 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 old-growth and late-successional stands. There were no significant differences in the stocking index between cycles in ACAD.

Table 9. Regeneration metric summaries for ACAD by cycle. Data summaries only include plots that were sampled in both cycles, and metric ratings are based on the complete set of plots for each cycle. Standard error (SE) for the ratio accounts for the uncertainty in the estimates of sapling and seedling abundance. Mosaic 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. There were no significant differences between cycles.

Unit	Cycle	# Plots	Stocking Index			Sapling: Small Seedling Ratio			
			Mean	SE	Rating	# Plots	Mean	SE	Rating
Overall	1	157	149.70	15.57	Good	125	0.57	0.10	Caution
	2	157	144.54	15.24	Good	125	0.52	0.09	Caution
IAH	1	18	169.76	34.93	Good	13	1.37	0.77	Caution
	2	18	149.59	30.79	Good	13	0.89	0.41	Caution
MDI-East	1	74	114.66	14.21	Good	59	0.69	0.12	Caution
	2	74	114.44	15.51	Good	59	0.82	0.16	Caution
MDI-West	1	59	184.30	35.09	Good	49	0.49	0.13	Caution
	2	59	182.69	33.77	Good	49	0.40	0.11	Caution
Schoodic	1	6	181.39	52.60	Good	4	0.17	0.16	---
	2	6	125.50	38.80	Good	4	0.15	0.08	---

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 and pathogens 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; Appendix D). 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*; WM), a recently introduced pest in the Northeast, we may add this species to one of the priority lists. In addition, we record tree conditions related to native pests and pathogens, such as spruce budworm (*Choristoneura fumiferana*), forest tent caterpillars (*Malacosoma disstria*), and needlecast fungi, but only the damage resulting from these native pests/pathogens (e.g., foliage herbivory) is included in the metric ratings. We also look for signs of white pine blister rust (*Cronartium ribicola*), and may include this on the priority list as we learn more about the recent resurgence of this pathogen in New England (Frederick et al. 2011).

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, and is the assessment point that distinguishes between Caution and Significant Concern. Likewise, evidence that Priority 1 pests have reached NETN forests, which might still be controlled by management action, also warrants a Significant Concern rating.

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 the northern NETN parks. The loss of hemlock due to HWA can result in cascading effects throughout the ecosystem, and is a major threat to these parks (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 was similar between cycles in ACAD, MABI, MORR, and SARA, and few plots in these parks were rated Significant Concern (Figure 6). MIMA, ROVA, and WEFA had the highest proportion of plots with Significant Concern ratings in both cycles, and in ROVA and WEFA this

was primarily due to the presence of HWA in plots. Few plots were rated Good in WEFA, particularly in the second cycle. The Caution ratings in WEFA were primarily the result of elevated necrosis and leaf loss on plots in wet areas. In both cycles, elevated insect herbivory was the most common reason for Caution ratings in ACAD, MIMA, MORR, ROVA, and SARA. BBD was the main reason for Caution ratings in MABI and SAGA.

Pests and pathogens that have been detected in forest plots include BWA in ACAD, BBD in all NETN parks, and HWA and EHS in ROVA and WEFA. Dutch elm disease, which is not on the priority pest/pathogen lists because it has been widespread in the Northeastern US since the 1950s, continues to cause significant mortality in SARA. While not detected in forest plots, HWA and EHS have been identified in MIMA and MORR, and EAB was recently detected by park staff in VAMA. HWA and WM have also recently been detected on MDI, but their presence has not been verified in ACAD forests.

Four out of the 10 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 be the result of WM. WM is a non-native insect that feeds on the leaves of a range of deciduous tree and shrub species, including maples, oaks and blueberries (U.S. Forest Service 2012).

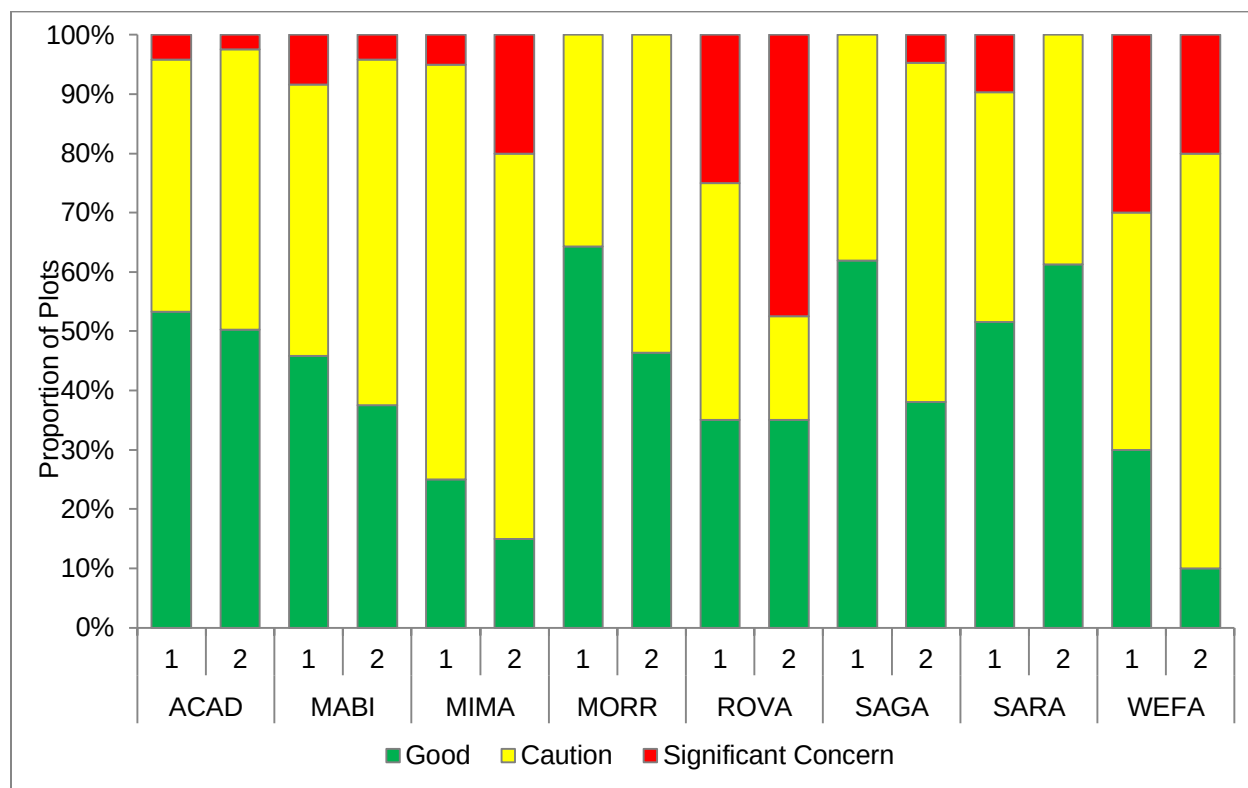


Figure 6. Proportion of plots receiving Good (green), Caution (yellow), and Significant Concern (red) ratings for tree condition for each park by cycle 1 (2006-2009) and cycle 2 (2010-2013), and including only plots that were sampled in both cycles.

WM was first detected in New England in 2003 in eastern Massachusetts, and has since spread throughout Coastal New England. Repeated defoliation by WM can increase tree mortality either directly, or through increased susceptibility to other stressors (e.g., drought, secondary defoliators, and fungal pathogens). This species is 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 WM from the native Bruce spanworm (*Operophtera bruceata*). Larvae of the WM 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 WM 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 WM infestations in MIMA and ACAD.

The known range of the emerald ash borer (EAB) continues to expand in the eastern US, and now includes parts of New Hampshire, Massachusetts, and Connecticut (Figure 7). 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 40 miles south of SARA, a park where EAB poses a significant threat.

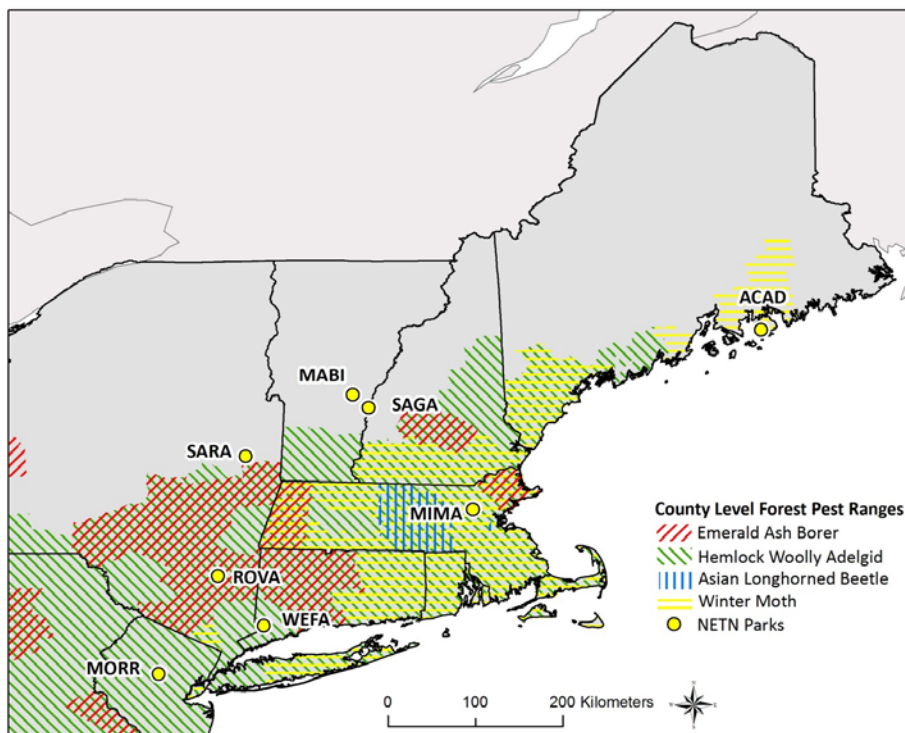


Figure 7. Exotic forest pest detections near NETN parks. Pest ranges were mapped at the county level and were downloaded from the Alien Forest Pest Explorer (<http://www.nrs.fs.fed.us/tools/afpe/maps/>), and the Collaborative EAB Project (<http://www.emeraldashborer.info>). Asian Longhorned Beetle range only reflects the most recent detection that has not yet been eradicated.

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. 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. 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 E). 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 have not been found to suppress forest succession or to 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.

Results and Discussion

ACAD continues to have the lowest incidence of invasive exotic species, and in both cycles, indicator invasive species occurred in only three plots (Table 10). MABI and SAGA had low levels of indicator invasive species, and were both rated Caution in the second cycle. Indicator invasive species were more widespread in the remaining parks, and may be increasing in MIMA, ELRO/HOFR, VAMA, SARA, and WEFA (Table 10 and Appendix B: Table 4). In MIMA, the average number of indicator species in the plot (ES = 12.9%, $q = 0.04$, $df = 19$) was significantly higher in cycle 2. In WEFA, the average number of indicator species per plot (ES = 54.8%, $q = 0.08$, $df = 9$) and per quadrat (ES = 43.4%, $q = 0.03$, $df = 9$) were significantly higher in cycle 2. Average number of indicator invasive species per plot was significantly higher in ROVA overall (ES = 20.6%, $q = 0.08$, $df = 39$), in ELRO/HOFR (ES = 7.9%, $q = 0.09$, $df = 23$) and in VAMA (ES = 35.4%, $q = 0.07$, $df = 15$). These results may be an early indication of invasive species expansion, or could be the result of phenological differences between cycles or better plant identification skills of field crews in

the second cycle. We expect patterns in invasive species abundance and richness to become clearer as more cycles of data are collected.

SARA showed the greatest increase in indicator invasive species, with significant increases in number of indicator invasive species per quadrat ($ES = 21.4\%$, $q = 0.003$, $df = 30$), and an increase in average percent cover of indicator species in cycle 2 ($ES = 96.5\%$, $q = 0.01$, $df = 30$). The increases in number and cover of indicator invasive species were primarily driven by increases in the Field category (Appendix B: Table 4). It is important to note that the first panel in SARA was sampled in August 2006 and has been sampled in early June since. Panel 1 plots in MABI, MIMA and SAGA were also sampled in a different order in 2006 than 2010 and beyond, but the timing differences were less extreme. Forest characteristics that can change over the growing season (e.g., quadrat percent cover and foliage condition) are not directly comparable in Panel 1 between 2006 and 2010. Therefore the results, particularly in SARA, should be considered preliminary. Given that two of the three indicator invasive metrics in SARA were significantly higher in cycle 2, this is rather strong evidence for invasive species expansion and is of management concern. As more data are available, it will be important to track these metrics across cycles.

Table 10. Indicator invasive exotic plant species ratings for NETN parks by cycle. Data summaries only include plots that were sampled in both cycles, and metric ratings are based on the complete set of plots for each cycle. Metric ratings are based on the mean number of indicator species found per plot. 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. Significance levels are indicated by *, where * is significant at q-value < 0.1, ** is significant at q-value < 0.05, and *** is significant at q-value < 0.01, and are denoted at the higher mean.

Park	Cycle	# Plots	# Species/ Plot		% Cover/ Quad		# Species/ Quad		Rating
			Mean	SE	Mean	SE	Mean	SE	
ACAD	1	167	0.02	0.02	<0.01	<0.01	<0.01	<0.01	Good
	2	167	0.01	0.01	<0.01	<0.01	<0.01	<0.01	Good
MABI	1	24	0.54	0.15	0.02	0.02	0.01	<0.01	Caution
	2	24	0.71	0.16	<0.01	<0.01	0.02	<0.01	Caution
MIMA	1	20	4.10	0.41	11.66	2.91	1.13	0.11	Sign. Conc.
	2	20	4.75**	0.43	13.99	2.83	1.32	0.14	Sign. Conc.
MORR	1	28	5.71	0.64	28.57	5.62	2.06	0.31	Sign. Conc.
	2	28	6.18	0.58	26.83	5.67	2.08	0.31	Sign. Conc.
ROVA	1	40	3.55	0.31	4.00	1.05	0.75	0.09	Sign. Conc.
	2	40	4.28*	0.34	3.51	0.96	0.78	0.11	Sign. Conc.
SAGA	1	21	0.43	0.15	0.65	0.64	0.04	0.03	Good
	2	21	0.67	0.23	1.06	1.06	0.05	0.03	Caution
SARA	1	31	2.94	0.20	7.54	2.33	0.84	0.09	Caution
	2	31	3.32	0.23	14.81***	3.51	1.02***	0.10	Caution
WEFA	1	10	3.10	0.66	2.61	2.10	0.66	0.38	Caution
	2	10	4.80*	0.89	2.86	1.76	0.95**	0.43	Sign. Conc.

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). Japanese barberry (*Berberis thunbergii*) and exotic bush honeysuckles (*Lonicera* spp.) are the most frequent indicator invasive species across NETN parks. Common buckthorn (*Rhamnus cathartica*), glossy buckthorn (*Rhamnus frangula*), oriental bittersweet (*Celastrus orbiculatus*), and multiflora rose (*Rosa multiflora*) are also relatively common. 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.

In addition to ecosystem impacts, recent studies have suggested 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, such as Lyme disease (*Borrelia burgdorferi*), 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 (Williams et al. 2009).

Table 11. Most frequent indicator invasive exotic species in each park by cycle. Number of occurrences only includes plots sampled in both cycles. Number of plots per park is listed below the park name in column 1.

Park	Latin Name	Common Name	# Plot Occurrences	
			Cycle 1	Cycle 2
ACAD n=168	<i>Berberis thunbergii</i>	Japanese barberry	1	1
	<i>Lonicera</i> spp.	exotic bush honeysuckle	1	1
	<i>Rhamnus frangula</i>	glossy buckthorn	1	2
MABI n=24	<i>Berberis vulgaris</i>	common barberry	4	6
	<i>Celastrus orbiculatus</i>	oriental bittersweet	0	1
	<i>Lonicera</i> spp.	exotic bush honeysuckle	5	6
	<i>Rhamnus cathartica</i>	common buckthorn	2	4
MIMA n=20	<i>Acer platanoides</i>	Norway maple	10	9
	<i>Celastrus orbiculatus</i>	oriental bittersweet	10	16
	<i>Lonicera</i> spp.	exotic bush honeysuckle	10	13
	<i>Rhamnus frangula</i>	glossy buckthorn	19	18
	<i>Rosa multiflora</i>	multiflora rose	14	17
MORR n=28	<i>Berberis thunbergii</i>	Japanese barberry	24	24
	<i>Cardamine impatiens</i>	narrowleaf bittercress	18	20
	<i>Celastrus orbiculatus</i>	oriental bittersweet	19	23
	<i>Microstegium vimineum</i>	Japanese stiltgrass	20	19
	<i>Rosa multiflora</i>	multiflora rose	12	15
	<i>Rubus phoenicolasius</i>	wine raspberry	15	19
ROVA n=40	<i>Acer platanoides</i>	Norway maple	13	18
	<i>Ailanthus altissima</i>	Tree of heaven	24	18
	<i>Alliaria petiolata</i>	garlic mustard	29	29
	<i>Berberis thunbergii</i>	Japanese barberry	14	19
	<i>Celastrus orbiculatus</i>	oriental bittersweet	19	25
	<i>Rosa multiflora</i>	multiflora rose	10	14
SAGA n=21	<i>Berberis thunbergii</i>	Japanese barberry	4	3
	<i>Celastrus orbiculatus</i>	oriental bittersweet	0	2
	<i>Euonymus</i> spp.	burningbush	0	2
	<i>Lonicera</i> spp.	exotic bush honeysuckle	5	6
SARA n=31	<i>Alliaria petiolata</i>	garlic mustard	8	11
	<i>Lonicera</i> spp.	exotic bush honeysuckle	29	29
	<i>Rhamnus cathartica</i>	common buckthorn	29	27
	<i>Rosa multiflora</i>	multiflora rose	20	20
WEFA n=10	<i>Alliaria petiolata</i>	garlic mustard	1	5
	<i>Berberis thunbergii</i>	Japanese barberry	8	9
	<i>Celastrus orbiculatus</i>	oriental bittersweet	8	7
	<i>Euonymus alatus</i>	burningbush	5	6
	<i>Lonicera japonica</i>	Japanese honeysuckle	1	4
	<i>Rosa multiflora</i>	multiflora rose	5	6

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, Wiegmann and Waller 2006, 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, 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 for this metric are listed in Appendix F. 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. Due to quadrat sampling inconsistencies between 2006 and 2010 (i.e., parks were sampled in reverse order in 2006 from all following years), which may bias analyses due to phenological differences, analyses are based on panels 2 through 4. This metric is very sensitive to small changes in quadrat frequency, which may be due to sample variability (e.g., different quadrat placements) rather than actual changes. Therefore, until more cycles can be used for comparisons, the results should be considered preliminary.

Results and Discussion

ACAD, MABI, MIMA, and SAGA only showed slight changes in browse-preferred and browse-avoided species and were rated Good for this metric (Table 12). More than half of the browse preferred species in ROVA and SARA decreased in quadrat frequency between cycles, and over half of the deer-avoided species increased in frequency MORR, SARA, and WEFA, and all of these parks were rated Caution. Based on the original assessment points for this metric, SARA should be rated Significant Concern. However, the frequency changes between cycles only represented a few quadrats, which could also be due to sample variability. We will not assign a Significant Concern rating until we have more cycles of data. We will also examine change in other metrics, such as average percent cover of browse-preferred and browse-avoided species, to assess deer impacts to forest understories.

Table 12. Deer browse indicator species ratings for plots resampled from 2011-2013. % 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	130	0.0	33.3	Good
MABI	12	40.0	33.3	Good
MIMA	10	0.0	25.0	Good
MORR	28	50.0	66.7	Caution
ROVA	40	83.3	25.0	Caution
SAGA	11	50.0	33.3	Good
SARA	16	66.7	66.7	Caution
WEFA	10	50.0	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 growth and mortality 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 (Frelich and Reich 1995, Lutz and Halpern 2006).

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. The average growth rate of each plot, or species within a plot, is then averaged by park or group of plots. Metric ratings are based on regional growth rates and derived from U.S. Forest Service Forest Inventory and Analysis (FIA) data collected from plots in the same Ecological Subsection as each NETN park. FIA growth and mortality rates are calculated using the same metric calculations and subset of plots (mature and late-successional) and trees (e.g., only canopy trees) from each plot. We determined the subset of plots by calculating the same structural stage metric with the FIA plot data as we calculate for NETN plots in the Ecological Integrity scorecard. As more cycles are sampled, we will examine growth rates within plots and across NETN parks in more detail.

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 mature and late-successional plots that were sampled in both cycles. 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. Trees with large vines on the bole were also excluded from growth rate calculations, because DBH in cycle 1 was often measured over the vine with a diameter tape, and DBH in cycle 2 was often measured using calipers. This resulted in artificially negative growth rates on several plots, and especially influenced growth rates in WEFA, where poison ivy vines were common.

Results and Discussion

Average growth rates were lower for NETN parks than FIA average growth rates, and only ACAD, MIMA, and SARA had an overall growth rate within 60% of the FIA growth rate (Table 13). Growth rates in NETN parks were based on a higher proportion of late-successional stands (Miller et al. 2013b). 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.

Growth rates of tree species in WEFA were consistently lower than regional FIA growth rates. Half of the plots in WEFA are in areas with a seasonally (e.g., vernal pool) or consistently high water table (forested swamp). Growth rates are expected to be slower in areas where tree roots experience periods of inundation, and this may at least partially explain the low growth rates in WEFA. Trees in WEFA also commonly had poison ivy (*Toxicodendron radicans*) climbing up the bole and measuring diameter at breast height (DBH) on trees with vines was difficult and was not always measured the same way between cycles. As previously mentioned, we removed trees that were measured differently between cycles (e.g., DBH tape over vines in cycle 1 and calipers in cycle 2) where we could identify these trees from field notes, but we may not have accounted for all of the trees in this situation. Therefore, differences in DBH measurement methods may also explain the low tree growth rates in WEFA.

In all parks but SARA, average mortality rates were within expected levels and rated Good (Table 14). SARA was rated Caution for this metric, and American elm and white pine (*Pinus strobus*) mortality were the main drivers behind the elevated mortality rate. The high mortality rate for white pine in SARA was likely due to successional white pine stands that are undergoing stem exclusion.

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 G. --- indicates less than five individuals of the species on the plots.

Species	ACAD		MABI		MIMA		MORR		ROVA		SAGA		SARA		WEFA	
	Park	FIA	Park	FIA	Park	FIA	Park	FIA	Park	FIA	Park	FIA	Park	FIA	Park	FIA
<i>Abies balsamea</i>	3.77	4.91	---	---	---	---	---	---	---	---	---	---	---	---	---	---
<i>Acer pensylvanicum</i>	8.33	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
<i>Acer platanoides</i>	---	---	---	---	0.00	---	---	---	0.00	---	---	---	---	---	---	---
<i>Acer rubrum</i>	0.29	0.68	0.00	0.56	0.00	0.80	0.00	1.60	1.00	0.13	1.14	0.56	0.00	1.16	1.70	0.97
<i>A. saccharum/ A. nigrum</i>	---	---	1.12	0.14	---	---	---	3.90	0.14	0.00	0.00	0.14	0.00	0.00	1.79	0.00
<i>Ailanthus altissima</i>	---	---	---	---	---	---	---	---	0.00	---	---	---	---	---	---	---
<i>Betula alleghaniensis</i>	0.00	---	0.00	0.31	---	---	0.00	---	---	---	0.00	0.31	---	---	0.00	0.23
<i>Betula lenta</i>	---	---	---	0.00	0.00	0.00	1.32	0.60	0.00	0.00	0.00	0.00	---	---	0.00	0.66
<i>Betula papyrifera</i>	1.56	2.75	---	5.87	---	0.88	---	---	---	---	---	5.87	---	---	---	---
<i>Carya cordiformis</i>	---	---	---	---	---	---	---	---	---	---	---	---	0.00	0.00	---	---
<i>Carya ovata</i>	---	---	---	---	---	---	---	---	---	---	---	---	0.00	---	---	---
<i>Carya tomentosa</i>	---	---	---	---	---	---	3.13	---	0.00	---	---	---	---	---	---	---
<i>Fagus grandifolia</i>	0.00	---	2.94	4.71	---	0.33	0.00	---	0.00	---	1.85	4.71	---	---	---	0.93
<i>Fraxinus americana</i>	0.00	---	0.86	0.06	2.50	1.15	2.00	0.42	4.17	1.28	0.00	0.06	0.00	2.78	---	3.29
<i>Fraxinus pennsylvanica</i>	---	---	---	---	---	---	---	---	0.00	---	---	---	---	---	---	---
<i>Juglans nigra</i>	---	---	---	---	0.00	---	---	0.00	---	---	---	---	---	---	---	---
<i>Larix decidua</i>	---	---	0.00	---	---	---	---	---	---	---	---	---	---	---	---	---
<i>Larix laricina</i>	1.56	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
<i>Liriodendron tulipifera</i>	---	---	---	---	---	---	0.64	0.12	0.00	---	---	---	---	---	---	---
<i>Ostrya virginiana</i>	---	---	4.55	---	---	---	---	---	0.00	---	---	---	---	---	---	---
<i>Picea abies</i>	---	---	0.00	---	---	---	---	---	4.17	---	---	---	---	---	---	---
<i>Picea mariana</i>	1.48	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
<i>Picea rubens</i>	0.97	0.54	---	---	---	---	---	---	---	---	---	---	---	---	---	---
<i>Pinus resinosa</i>	0.00	---	3.00	---	---	---	---	---	2.63	---	---	---	---	---	---	---
<i>Pinus strobus</i>	0.00	---	2.88	3.13	0.00	1.14	---	---	---	0.00	1.64	3.13	3.65	0.00	---	0.13
<i>Pinus sylvestris</i>	---	---	3.57	---	---	---	---	---	---	---	---	---	---	---	---	---
<i>Populus grandidentata</i>	5.11	0.95	---	---	---	---	---	---	---	---	---	---	---	---	---	---
<i>Populus tremuloides</i>	---	0.36	---	---	---	---	---	---	---	---	---	---	2.73	2.08	---	---
<i>Prunus serotina</i>	---	---	---	---	---	---	---	4.29	---	0.00	---	---	0.00	2.78	---	---
<i>Quercus alba</i>	---	---	---	---	0.00	0.00	0.00	---	0.00	---	---	---	---	---	---	---
<i>Quercus montana</i>	---	---	---	---	0.00	0.00	0.00	0.00	0.00	---	---	---	---	---	---	0.38

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 G. --- indicates less than five individuals of the species on the plots (continued).

Species	ACAD		MABI		MIMA		MORR		ROVA		SAGA		SARA		WEFA	
	Park	FIA	Park	FIA	Park	FIA	Park	FIA	Park	FIA	Park	FIA	Park	FIA	Park	FIA
<i>Quercus rubra</i>	0.35	---	0.00	0.00	1.67	0.51	0.00	---	0.00	0.00	0.00	0.00	---	0.00	---	0.13
<i>Quercus velutina</i>	---	---	---	---	1.43	0.57	2.08	---	2.08	---	---	---	0.00	---	---	---
<i>Robinia pseudoacacia</i>	---	---	---	---	0.00	---	2.78	---	---	---	---	---	---	---	---	---
<i>Thuja occidentalis</i>	0.00	0.58	---	---	---	---	---	---	---	---	---	---	---	---	---	---
<i>Tilia americana</i>	---	---	---	---	---	---	---	---	---	---	0.00	---	---	---	---	---
<i>Tsuga canadensis</i>	---	---	0.00	0.00	---	0.72	---	---	1.16	0.00	1.61	0.00	---	0.00	---	0.12
<i>Ulmus americana</i>	---	---	---	---	---	---	---	---	---	18.47	---	---	7.35	8.33	---	---
Overall	1.05	1.16	1.40	0.99	0.66	0.61	1.23	0.81	0.57	0.69	0.97	0.99	2.00	0.51	1.04	0.67
Park Rating	Good		Good		Good		Good		Good		Good		Caution		Good	

American elm in SARA had the highest mortality rate of NETN parks, and was also high in FIA plots in the same ecological subsection as SARA. The high mortality rate of American elm is likely due to Dutch elm disease (*Ophiostoma ulmi*). Elevated mortality rates for balsam fir (*Abies balsamea*) in ACAD and American beech (*Fagus grandifolia*) in MABI may also be the result of exotic pests, with balsam woolly adelgid affecting balsam fir, and beech bark disease affecting American beech. The elevated mortality rate of white ash in ROVA could be the result of emerald ash borer, although we have yet to detect this species in forest plots in ROVA.

At the time of sampling in 2013, tree growth and mortality rates had not yet responded to the effects of Hurricane Sandy in MORR. As forests respond in the next cycle, we expect to see a temporary spike in tree growth and mortality rates in MORR. 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 2 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).

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). Prior to calculating the Ca:Al and C:N metrics, soil samples 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. Soil metrics were 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. Because this metric uses the sample (O or A horizon) with the minimum ratio for each plot, paired t-tests were not appropriate for this metric. More detailed analyses of soil chemistry and forest health indicators will be included in periodic trend reports.

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		

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 in ACAD, ELRO/HOFR, MIMA, and WEFA. All parks but ACAD and VAMA were rated Significant Concern in cycle 2 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 an earlier 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 earlier 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, and may even facilitate invasion of exotic species, such as common buckthorn (Knight et al. 2007). Efforts to avoid further introduction of earthworms, such as cleaning tires on heavy equipment before moving into uninvaded areas, are important for maintaining understory diversity, particularly in the richer hardwood stands.

Table 16. Soil chemistry ratings for NETN parks by cycle. % 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	Cycle	% of Plots with Earthworms	Median Ca:Al	Ca:Al Rating	Median C:N	C:N Rating
ACAD	1	3.2%	2.74	Caution	32.61	Good
	2	5.7%	3.16	Caution	32.04	Good
MABI	1	18.2%	14.16	Good	15.97	Sign.Conc.
	2	41.7%	22.06	Good	15.31	Sign.Conc.
MIMA	1	11.1%	0.74	Sign.Conc.	14.51	Sign.Conc.
	2	30.0%	1.38	Caution	14.92	Sign.Conc.
MORR	1	78.6%	7.47	Good	14.81	Sign.Conc.
	2	96.6%	7.62	Good	16.29	Sign.Conc.
ROVA	1	69.4%	7.44	Good	19.15	Sign.Conc.
	2	60.0%	4.98	Good	16.29	Sign.Conc.
ELRO/HOFR	1	71.4%	6.41	Good	17.22	Sign.Conc.
	2	50.0%	3.31	Caution	16.99	Sign.Conc.
VAMA	1	66.7%	7.44	Good	20.49	Caution
	2	75.0%	13.74	Good	21.68	Caution
SAGA	1	21.1%	2.50	Caution	21.14	Caution
	2	38.1%	1.28	Caution	19.74	Sign.Conc.
SARA	1	34.6%	22.68	Good	14.18	Sign.Conc.
	2	76.7%	31.85	Good	12.93	Sign.Conc.
WEFA	1	100.0%	5.48	Good	15.55	Sign.Conc.
	2	90.0%	1.87	Caution	15.72	Sign.Conc.

Management Implications

Ecological Integrity Scorecard: 2010-2013

Park	Structural Stage Distribution	CWD Ratio	Snag Abundance	Invasive Exotic Plants	Tree Condition/ ¹ Forest Pests	Tree ² Regeneration	Deer Browse Indicator Species	Tree Growth and Mortality	Soil Ca:Al	Soi C:N
ACAD	Caution	Caution	Caution	Good			Good	Good	Caution	Good
MABI	Caution	Caution	Sign. Conc.	Caution			Good	Caution	Good	Sign. Conc.
MIMA	Good	Sign. Conc.	Caution	Sign. Conc.			Good	Good	Caution	Sign. Conc.
MORR	Good	Caution	Sign. Conc.	Sign. Conc.			Caution	Caution	Good	Sign. Conc.
ROVA ELRO/HOFR	Good	Good	Caution	Caution			Caution	Caution	Good	Sign. Conc.
VAMA	Good	Good	Caution	Sign. Conc.			Caution	Caution	Good	Caution
SAGA	Caution	Caution	Caution	Caution			Good	Caution	Sign. Conc.	Sign. Conc.
SARA	Caution	Caution	Caution	Caution			Caution	Caution	Good	Sign. Conc.
WEFA	Good	Caution	Caution	Sign. Conc.			Caution	Caution	Caution	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

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 and ongoing exotic plant management is vitally important to maintaining forest health there. 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

As is common in managed forests, coarse woody debris and snag abundance are lower than expected in the park's late-successional hardwood stands. MABI also has the lowest density of trees with cavities in the network. Adapting forest management approaches to encourage more snag and CWD retention and to identify trees with cavities may be necessary to improve these important structural components.

Continued efforts to eradicate invasive species, particularly in plantation stands slated for harvesting, are important for maintaining forest health in MABI. Eradication of exotic shrub species is especially important, as they have caused significant impacts to forest condition in other network parks, and once established eradication is costly and labor intensive. Continued vigilance and outreach are important for preventing the spread of forest pests such as hemlock woolly adelgid, winter moth, and emerald ash borer. Efforts to slow the spread of earthworms, such as cleaning tires on logging equipment before moving into uninvaded areas, are recommended, particularly in hardwood stands

dominated by sugar maple (*Acer saccharum*). Continuing to monitor deer densities in the park is also helpful to determine how deer may be impacting forest health.

Minute Man National Historical Park

Invasive species, particularly thickets of exotic shrubs, are negatively impacting forest condition and may be increasing in MIMA. Without management efforts, these exotic shrub thickets are expected to persist and spread into new areas, especially recently disturbed areas. Forest pests also pose a significant threat to forest health in MIMA. Asian longhorned beetle, emerald ash borer, and winter moth are of particular concern, as all are found in isolated areas of Massachusetts. Early detection and rapid response to detections of Asian longhorned beetle and emerald ash borer are particularly important, not just for the health of forests in MIMA, but for hardwood forests throughout the northeastern US.

Morristown National Historic Park

A high density of white-tailed deer and invasive exotic species are significantly impacting forest health in MORR and management action will be necessary to improve forest condition. Regeneration densities are well below levels required to restock the future forest and are suppressed by a combination of deer browse pressure and competition from invasive species.

While the damage from Hurricane Sandy was widespread in MORR and the blowdown areas may appear devastating, we advise against removing or cutting logs where possible. Leaving the CWD intact will, in the long run, benefit forest health in MORR. In addition, the tip-up mounds created by windthrow are an important soil cycling process that generally only happens in older forests. Management efforts should focus on encouraging tree regeneration in the newly created canopy gaps by controlling invasive species and reducing deer browse pressure.

Roosevelt-Vanderbilt National Historic Sites

Forest condition, composition, and structure vary considerably between ELRO/HOFR and VAMA. VAMA has the highest average density of seedlings in NETN and deer browse impacts were minimal. In contrast, the majority of plots in ELRO/HOFR were rated as Significant Concern for regeneration, and moderate deer browse impacts were observed. The deer browse indicator species metric tentatively detected browse impacts for both ELRO/HOFR and VAMA. If these trends worsen in ELRO/HOFR, managers may want to consider deer management. Invasive exotic species and forest pests are a concern in both ELRO/HOFR and VAMA, and control and early detection should be a high priority for all ROVA units. Considering the moderate deer impacts observed, this is especially important in ELRO/HOFR, as high densities of deer tend to promote the spread of invasive exotic species.

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 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, and invasive species may be increasing in abundance and diversity. 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 poses a significant threat to forests in SARA. Early detection and outreach efforts to prevent spread of emerald ash borer into SARA are extremely important, especially considering its continued spread in NY. Eradication efforts focused on managing and slowing the spread of exotic shrub species are equally important to create and maintain conditions where tree species can regenerate.

Weir Farm National Historic Site

Forest health appears to be impacted by a number of factors, including white-tailed deer herbivory, forest pests, invasive exotic species, and lack of snags and coarse woody debris. Coarse woody debris and snag abundance are expected to increase over time as WEFA's second-growth forests mature. Management efforts to improve forest health in WEFA should focus on controlling invasive species and reducing deer densities. Early detection of new invasive species and forest pests should also be a priority in the park.

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Appendix A. Protocol implementation for the 2013 field season.

2013 Data Quality

Overall data quality for the 2013 field season was excellent. While an exceptional forest crew was no doubt a major reason for the high quality data, continued enhancements to the data checker function in the forest database were also important contributions. The forest crew was able to use the database for data entry for the vast majority of plots, and at the end of every week, we were able to merge the two crew backend databases. This allowed us to begin analyzing the data and to check for inconsistencies or issues within days of the crew sampling a plot.

One major data issue that was detected involved diameter at breast height (DBH) measurements on trees with vines. Vines, particularly poison ivy (*Toxicodendron radicans*), are most common on trees in WEFA, but also occur regularly in MIMA, and ROVA. Measuring DBH on a tree with vines along the bole is difficult, as the diameter tape must be under the vines for an accurate diameter measurement. For the majority of cycle 2, we used tree calipers to measure DBH, as the calipers make it possible to avoid vines for the diameter measurement. After looking through notes from the first cycle of sampling, and after finding a number of negative growth rates between cycles, we realized that cycle 1 crews measured DBH over the vines, and this resulted in artificially negative growth rates between cycles. Now that we are aware of the issue, we can identify most of the trees where this occurred, and remove them from tree growth rate calculations. We will also stress the importance of using calipers to measure DBH in these situations to ensure that tree growth rates are more accurate from now on.

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. WEFA plots 008 and 009, and ACAD plots 139 and 155 were sampled for QA/QC in 2013.

Data comparisons between the forest crew and the QA/QC crew were very close for most stand level assessments, photopoint scenes, regeneration microplot tallies, CWD pieces, tree condition and tree diameter at breast height (DBH) measurements. DBH measurements were most variable on trees with vines in WEFA, as calipers are not as accurate as diameter tapes (though better than DBH tapes when vines are present). Stand height measurements continue to show improvement in accuracy from past years, but this remains one of the more variable measurements in our protocol. Given the high diversity of the QA/QC plots in WEFA, which makes sampling quadrats more challenging, the quadrat species and plot lists were pretty close. Most of the variability in the quadrat and plot search species lists related to species identification of graminoids.

Resampling and Protocol Revision

Few changes were made to existing procedures in the protocol, but we did adopt two new Standard Operating Procedures (SOPs), and significantly revised an existing SOP in response to an equipment change. We began coring trees in plots sampled in 2013 on western MDI in ACAD to better understand stand age dynamics in that section of the park, and one of the new SOPs covers

techniques for tree coring and counting tree rings. This SOP was written by Patrick Curtin, NETN's Student Conservation Association Intern in 2013, and we plan to continue coring trees near plots on western MDI until we have stand ages for each plot. We will expand this effort a little at a time to eventually cover all plots in interested parks. The second new SOP covers best practices for ensuring that forest crews do not act as vectors for invasive plants, pests or pathogens, and was taken from the newly revised Invasive Species Early Detection protocol. Finally, we replaced our MDL Laser Rangefinder (LAR) equipment with a cheaper, more field hardy and reliable TruPulse rangefinder, and revised the LAR SOP to cover the TruPulse instead.

Appendix B. Ecological Integrity metric summaries for groups within parks

Table B-1. Structural stage distribution of plots in NETN parks by group and cycle. Data summaries only include plots sampled in both cycles.

Park	Group	Cycle	# Plots	% Late-succ.	Diff.	% Mature and Late-succ.	Diff.	Rating
ACAD	IAH	1	13	15.4	-7.7	53.8	15.4	Caution
		2	13	7.7		69.2		Caution
	MDI East	1	66	15.2	-4.5	42.4	0.0	Sign. Conc.
		2	66	10.6		42.4		Sign. Conc.
	MDI West	1	55	16.4	5.5	72.7	5.5	Caution
		2	55	21.8		78.2		Caution
	Schoodic	1	5	0.0	0.0	100.0	0.0	Caution
		2	5	0.0		100.0		Caution
	MABI	1	13	46.2	15.4	84.6	7.7	Caution
		2	13	61.5		92.3		Caution
		1	11	36.4	18.1	100.0	0.0	Caution
		2	11	54.5		100.0		Caution
MORR	Mature	1	19	78.9	0.0	100.0	0.0	Good
		2	19	78.9		100.0		Good
	Successional	1	9	44.4	11.1	100.0	0.0	Good
		2	9	55.6		100.0		Good
ROVA	ELRO/HOFR	1	24	33.3	4.2	83.3	4.2	Good
		2	24	37.5		87.5		Good
	VAMA	1	16	68.8	0.0	93.8	0.0	Good
		2	16	68.8		93.8		Good
SARA	Field	1	24	16.7	0.0	37.5	12.5	Caution
		2	24	16.7		50.0		Caution
	Forest	1	7	42.9	0.0	71.4	14.3	Good
		2	7	42.9		85.7		Good

Appendix B. Ecological Integrity metric summaries for groups within parks (continued).

Table B-2. Coarse woody debris (CWD) metric ratings, ratios, and volume calculations for groups within parks by cycle. Data summaries only include plots that were sampled in both cycles, and metric ratings are based on the complete set of plots for each cycle. 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 park 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). Plots with missing stand heights due to sampling error were corrected using stand heights from the other cycle, if available. 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. There were no significant q-values.

Park	Group	Cycle	# 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	IAH	1	13	Good	12.02%	3.63%	22.78	6.71	325.60	95.83	185.92	34.63
		2	13	Good	10.46%	2.40%	21.55	5.32	307.94	80.03	183.92	31.21
	MDI-East	1	66	Good	11.24%	2.04%	17.21	3.27	245.91	46.68	197.23	18.25
		2	66	Good	9.45%	1.68%	16.44	2.93	234.96	43.40	188.52	15.73
	MDI-West	1	55	Good	25.01%	10.21%	36.97	5.46	528.41	78.07	291.80	23.37
		2	55	Good	15.12%	2.15%	35.07	4.40	501.16	62.85	247.63	12.63
	Schoodic	1	5	---	7.06%	2.14%	17.76	8.81	253.79	111.90	220.28	70.83
		2	5	---	10.24%	3.87%	17.96	7.31	256.63	112.95	195.14	61.45
MABI	Natural	1	13	Caution	8.74%	3.03%	32.89	11.52	470.08	164.68	418.08	51.33
		2	13	Caution	8.37%	3.09%	32.44	13.04	463.57	172.16	437.70	43.34
	Plantation	1	11	Caution	5.68%	2.04%	34.65	8.95	495.22	127.87	694.94	87.01
		2	11	Caution	7.41%	2.34%	39.22	9.11	560.51	130.19	614.52	70.78
MORR	Mature	1	19	Caution	8.05%	2.15%	28.35	8.07	405.19	111.39	437.75	32.96
		2	19	Caution	6.60%	1.77%	26.73	7.37	381.97	105.28	467.84	40.10
	Successional	1	9	Caution	7.92%	3.40%	23.47	10.24	335.48	133.42	360.81	64.72
		2	9	Caution	10.64%	6.63%	22.78	9.92	325.52	126.64	359.65	69.02
ROVA	ELRO/HOFR	1	24	Good	26.24%	13.11%	46.61	13.92	666.11	191.33	372.97	37.59
		2	24	Good	24.11%	12.92%	41.56	12.82	594.01	183.17	352.66	33.71
	VAMA	1	16	Good	25.93%	5.61%	75.18	20.08	1,074.38	286.93	369.95	56.56
		2	16	Good	22.89%	8.01%	68.08	25.15	972.94	359.42	366.57	43.58
SARA	Field	1	16	Caution	11.62%	4.24%	21.23	6.06	303.40	92.21	317.85	53.83
		2	16	Good	16.97%	6.35%	23.24	6.33	332.08	90.51	276.54	38.39
	Forest	1	7	Caution	11.43%	5.88%	32.94	11.17	470.80	159.66	381.20	68.34
		2	7	Caution	9.75%	5.22%	24.11	9.97	344.62	142.50	339.99	64.28

Appendix B. Ecological Integrity metric summaries for groups within parks (continued).

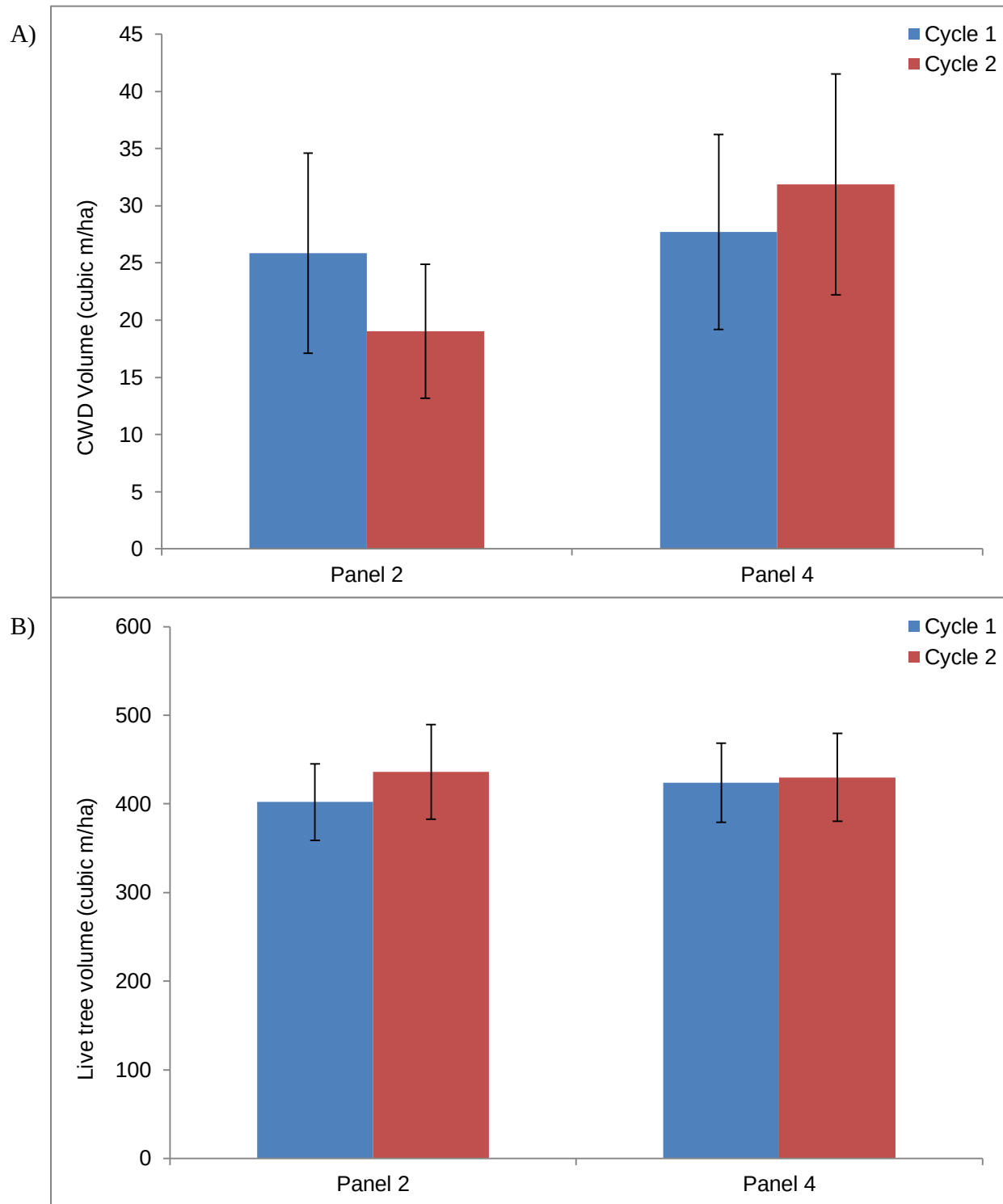


Figure B-1. Average volume of A) coarse woody debris (m^3/ha) and B) live trees (m^3/ha) by panel in MORR. Panel 2 was sampled in 2007 and 2011; panel 4 was sampled in 2009 and 2013. Figures only include plots sampled in both cycles. Error bars are ± 1 standard error around the mean.

Appendix B. Ecological Integrity metric summaries for groups within parks (continued).

Table B-3. Snag abundance ratings and calculations for groups within parks by cycle. Data summaries include plots that were sampled in both cycles, and metric ratings are based on the complete set of plots for each cycle. 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. Significance levels are indicated by *, where * is significant at q-value < 0.1 , ** is significant at q-value < 0.05 , and *** is significant at q-value < 0.01 , and are denoted at the higher mean.

Park	Group	Cycle	# Plots	Rating	# of Snags/ha		# of M-L Snags/ha		% of Trees as Snags	
					Mean	SE	Mean	SE	All Sizes	M-L Snags
ACAD	IAH	1	18	Good	108.64	17.68	9.88	5.74	12.54%	13.33%
		2	18	Good	111.11	15.35	9.88	5.74	12.36%	13.33%
	MDI-East	1	79	Caution	169.34*	19.32	5.63	1.67	17.15%***	8.70%
		2	79	Caution	144.58	14.36	5.63	1.85	14.59%	7.69%
	MDI-West	1	61	Good	222.95*	22.44	10.20	3.18	19.01%	10.53%
		2	61	Good	203.28	20.05	11.66	3.27	17.19%	10.74%
	Schoodic	1	9	---	291.36	58.38	4.94	4.94	25.99%	10.00%
		2	9	---	276.54	53.30	0.00	0.00	25.81%	0.00%
MABI	Natural	1	13	Sign. Conc.	36.54	12.21	3.85	2.60	7.04%	2.82%
		2	13	Caution	38.46	13.46	7.69	3.33	7.38%	5.56%
	Plantation	1	11	Sign. Conc.	50.00	13.06	2.27	2.27	9.65%	1.04%
		2	11	Sign. Conc.	47.73	12.82	0.00	0.00	9.91%	0.00%
MORR	Mature	1	19	Sign. Conc.	22.37	5.02	1.32	1.32	7.66%	1.02%
		2	19	Sign. Conc.	21.05	7.22	2.63	1.81	7.24%	1.96%
	Successional	1	9	---	52.78	9.72	8.33	5.89	17.59%	6.67%
		2	9	---	41.67	8.33	5.56	3.67	16.48%	4.55%
ROVA	ELRO/HOFR	1	24	Caution	45.83	8.06	11.46	4.75	9.54%	8.03%
		2	24	Caution	42.71	10.69	11.46	4.99	9.03%	7.59%
	VAMA	1	16	Good	46.88	16.59	10.94	3.20	11.54%	10.29%
		2	16	Caution	35.94	12.28	9.38	3.87	9.02%	8.45%
SARA	Field	1	24	Sign. Conc.	79.17	19.54	4.17	2.46	18.75%	4.76%
		2	24	Good	93.75	21.24	9.38	3.93	21.63%	10.11%
	Forest	1	7	---	67.86	33.50	0.00	0.00	13.48%	0.00%
		2	7	---	89.29	38.13	7.14	4.61	17.24%	5.13%

Appendix B. Ecological Integrity metric summaries for groups within parks (continued).

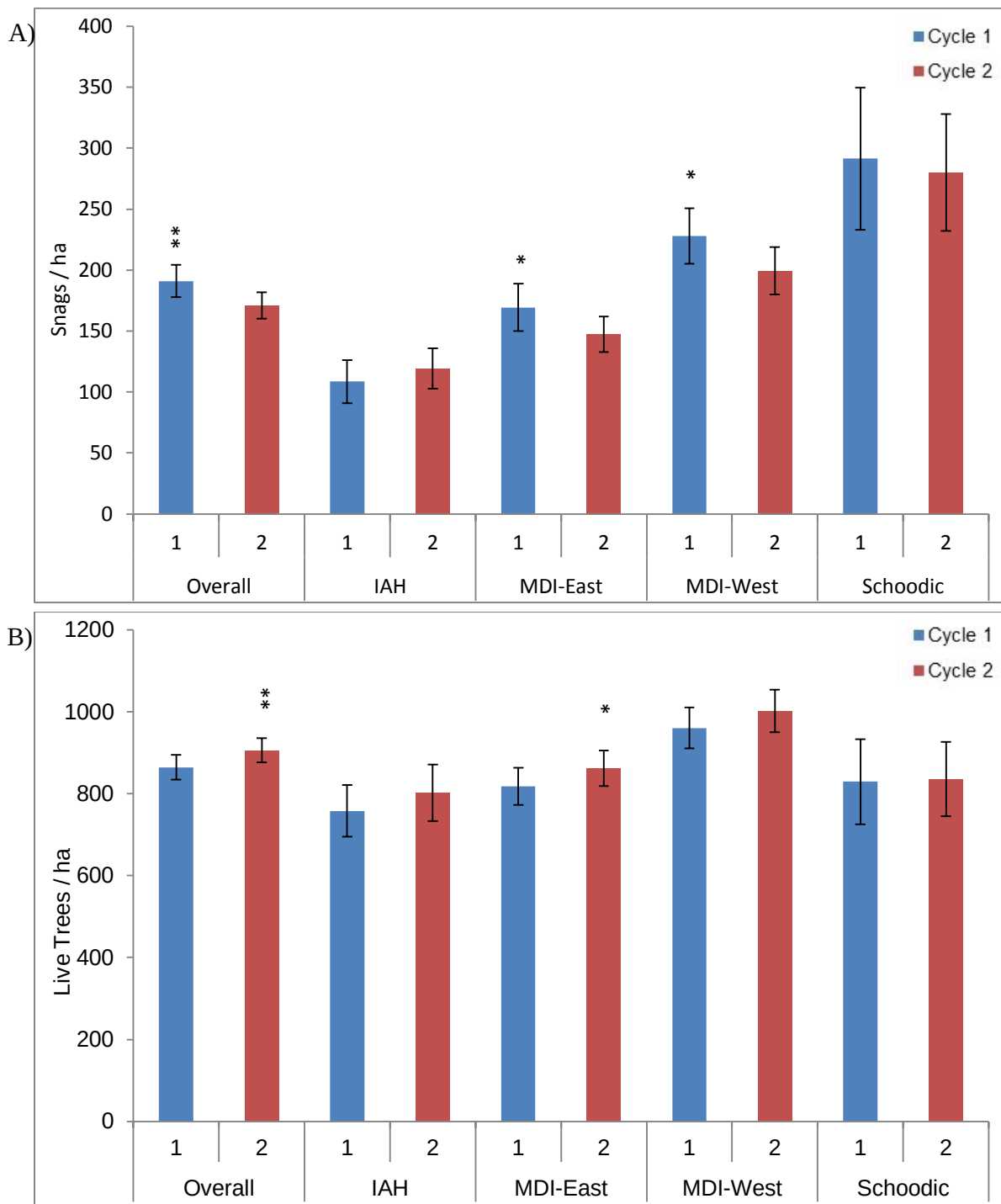


Figure B-2. Average density of A) snags/ha and B) live trees/ha, by park unit for cycle 1 (2006-2009) and cycle 2 (2010-2013) in ACAD. Figures only include plots sampled in both cycles. Error bars are ± 1 standard error around the mean. Significance levels are indicated by *, where * is significant at q-value < 0.1, ** is significant at q-value < 0.05, and *** is significant at q-value < 0.01, and are denoted on the higher mean.

Appendix B. Ecological Integrity metric summaries for groups within parks (continued).

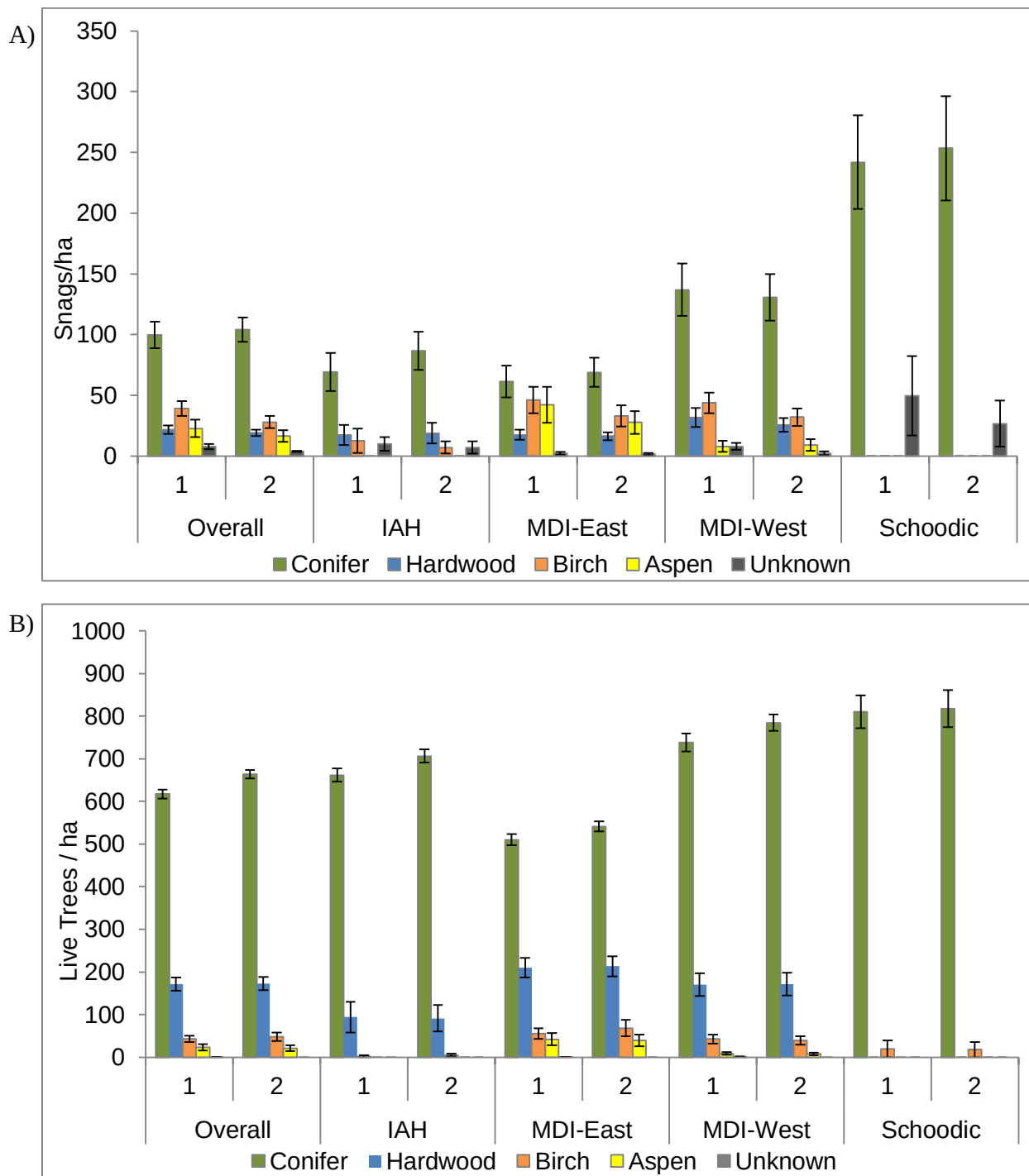


Figure B-3. Average density of A) snags/ ha and B) live trees/ ha, by species group and park unit for cycle 1 (2006-2009) and cycle 2 (2010-2013) in ACAD. Figures only include plots sampled in both cycles. Error bars are ± 1 standard error around the mean. Birch contains white birch species (*Betula papyrifera*, *B. cordifolia*, *B. populifolia*, and *B. x cerulea*). Aspen contains aspen species (*Populus grandidentata* and *P. tremuloides*).

Appendix B. Ecological Integrity metric summaries for groups within parks (continued).

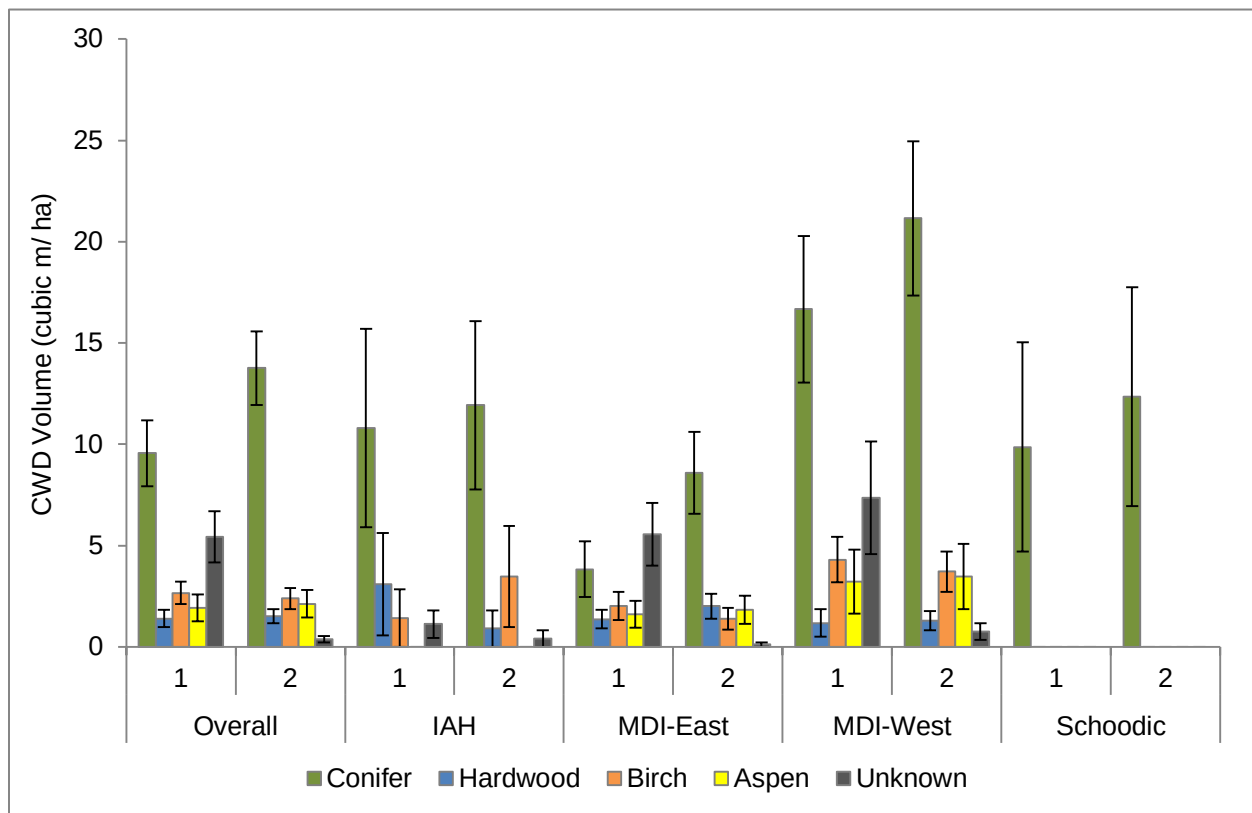


Figure B-4. Coarse woody debris volume (m^3/ha), by species group and park unit for cycle 1 (2006-2009) and cycle 2 (2010-2013) in ACAD. Figures only include plots sampled in both cycles. Error bars are ± 1 standard error around the mean. Birch contains white birch species (*Betula papyrifera*, *B. cordifolia*, *B. populifolia*, and *B. x cerulea*). Aspen contains aspen species (*Populus grandidentata* and *P. tremuloides*).

Appendix B. Ecological Integrity metric summaries for groups within parks (continued).

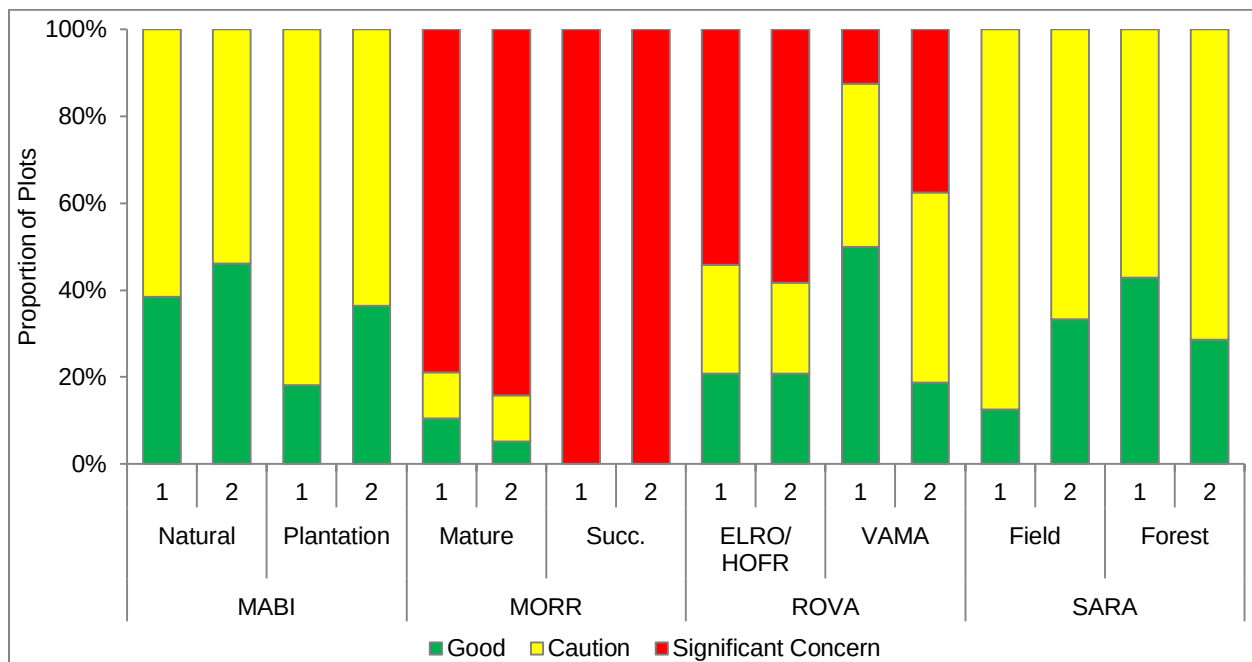


Figure B-5. Proportion of plots by group within parks receiving Good (green), Caution (yellow), and Significant Concern (red) ratings for tree regeneration in cycle 1 (2006-2009) and cycle 2 (2010-2013). Metric ratings are only include plots sampled in both cycles. An assessment point for Significant Concern has not been defined for MABI and SARA.

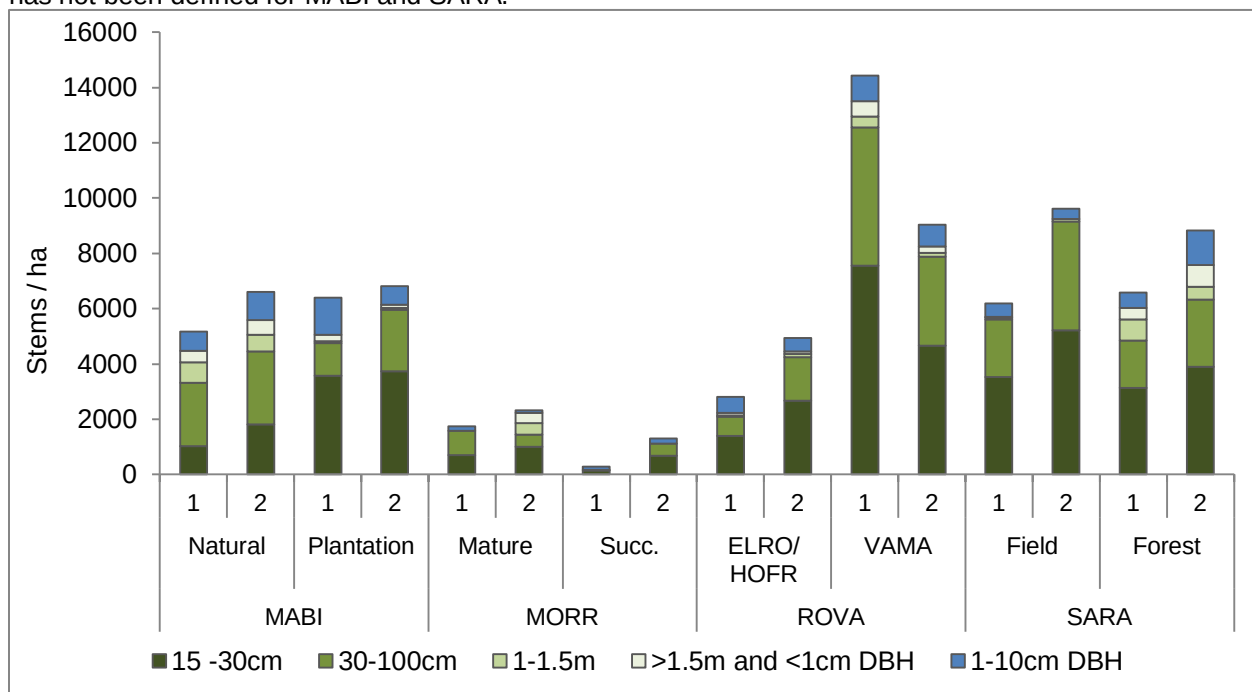


Figure B-6. Mean seedling (green) and sapling (blue) densities for cycle 1 (2006-2009) and cycle 2 (2010-2013) by group within park. Stem densities only include plots sampled in both cycles.

Appendix B. Ecological Integrity metric summaries for groups within parks (continued).

Table B-4. Mean stocking index and seedling ratio averaged over three 2-m radius microplots per plot for cycle 1 (2006-2009) and cycle 2 (2010-2013) in the NHP and NHS parks. Data summaries only include plots that were sampled in both cycles. Plots without browse preferred species are not included in the seedling ratio summaries, and t-tests were not conducted on this metric. The deer browse index was not used to rate the regeneration metric and only includes the full set of plots from cycle 2. SE refers to 1 standard error around the mean. There were no significant differences between cycles.

	Group	Cycle	Stocking Index		Seedling Ratio		Deer Browse Index	
			Mean	SE	Mean	SE	Mean	SE
MABI	Natural	1	64.38	32.76	0.54	1.33		
		2	87.77	40.52	-0.39	1.00	2.46	0.14
	Plantation	1	62.18	29.38	-2.05	0.77		
		2	24.42	6.35	-1.62	1.08	2.45	0.21
MORR	Mature	1	11.84	3.46	-0.76	0.36		
		2	41.30	33.14	-1.58	0.59	4.37	0.23
	Successional	1	5.78	2.83	-1.33	0.33		
		2	3.89	2.42	-1.08	0.34	4.33	0.24
ROVA	ELRO/ HOFR	1	41.44	8.69	-1.29	0.76		
		2	39.33	8.92	-2.27	0.51	3.38	0.18
	VAMA	1	113.69	27.89	-0.99	0.82		
		2	64.44	16.98	-3.16	1.24	2.75	0.23
SARA	Field	1	39.33	7.53	-1.91	0.49		
		2	30.97	9.44	-2.59	0.79	2.96	0.11
	Forest	1	69.29	44.42	-2.25	1.47		
		2	110.71	92.00	-1.40	0.45	2.71	0.18

Appendix B. Ecological Integrity metric summaries for groups within parks (continued).

Table B-5. Indicator invasive exotic plant species ratings for park groups by cycle. Data summaries only include plots that were sampled in both cycles, and metric ratings are based on the complete set of plots for each cycle. Metric ratings are based on the mean number of indicator species found per plot. 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. Significance levels are indicated by *, where * is significant at q-value < 0.1, ** is significant at q-value < 0.05, and *** is significant at q-value < 0.01, and are denoted at the higher mean.

Park	Group	Cycle	# Plots	# Species/ Plot		% Cover/Quad		# Species/ Quad		Rating
				Mean	SE	Mean	SE	Mean	SE	
ACAD	IAH	1	18	0.00	0.00	0.00	0.00	0.00	0.00	Good
		2	18	0.00	0.00	0.00	0.00	0.00	0.00	Good
	MDI-East	1	79	0.04	0.04	0.01	0.01	<0.01	<0.01	Good
		2	79	0.03	0.03	<0.01	<0.01	<0.01	<0.01	Good
	MDI-West	1	61	0.00	0.00	0.00	0.00	0.00	0.00	Good
		2	61	0.00	0.00	0.00	0.00	0.00	0.00	Good
	Schoodic	1	10	0.00	0.00	0.00	0.00	0.00	0.00	Good
		2	10	0.00	0.00	0.00	0.00	0.00	0.00	Good
MABI	Natural	1	13	0.31	0.17	0.00	0.00	0.00	0.00	Good
		2	13	0.38	0.18	0.00	0.00	0.00	0.00	Good
	Plantation	1	11	0.73	0.19	0.04	0.04	0.01	0.01	Caution
		2	11	1.00	0.27	<0.01	<0.01	0.03	0.02	Caution
MORR	Mature	1	19	3.21	0.52	13.44	3.71	1.27	0.28	Caution
		2	19	3.84*	0.61	11.83	3.50	1.34	0.29	Sign. Conc.
	Successional	1	9	7.56	0.60	60.51	8.85	3.72	0.34	Sign. Conc.
		2	9	7.33	0.24	58.48	9.76	3.67	0.43	Sign. Conc.
ROVA	ELRO/HOFR	1	24	2.63	0.34	3.17	1.38	0.57	0.12	Caution
		2	24	2.83*	0.35	3.48	1.53	0.51	0.12	Caution
	VAMA	1	16	3.00	0.40	5.25	1.61	1.02	0.14	Caution
		2	16	4.06*	0.30	3.54	0.76	1.20	0.15	Sign. Conc.
SARA	Field	1	24	3.13	0.18	9.18	2.92	0.95	0.09	Caution
		2	24	3.63	0.18	18.09***	4.29	1.15**	0.11	Sign. Conc.
	Forest	1	7	2.29	0.61	1.90	0.95	0.46	0.17	Caution
		2	7	2.14	0.59	3.57	1.86	0.57**	0.18	Caution

Appendix C. 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 C. 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>	common 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 D. Priority pest and pathogen species.

Common Name	Latin Name	Code	Priority
Asian longhorned beetle	<i>Anoplophora glabripennis</i>	ALB	1
Emerald ash borer	<i>Agrilus planipennis</i>	EAB	1
Hemlock woolly adelgid	<i>Adelges tsugae</i>	HWA	1
Sudden oak death	<i>Phytophthora ramorum</i>	SOD	1
Balsam woolly adelgid	<i>Adelges piceae</i>	BWA	2
Beech bark disease	<i>Cryptococcus fagisuga/Nectria</i> spp.	BBD	2
Butternut canker	<i>Sirococcus clavignenti-juglandacearum</i>	BC	2
Elongate hemlock scale	<i>Fiorinia externa</i>	EHS	2

Appendix E. 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>Euonymus alatus</i>	winged burning bush	Open, successional & wooded habitats
<i>Ligustrum spp. (obtusifolium, vulgare)</i>	privet	Successional & forest habitats
<i>Lonicera japonica</i>	Japanese honeysuckle	Edges & successional habitats
<i>Lonicera spp. (morrowii, tatarica, x 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>Rhamnus frangula (=Frangula alnus)</i>	glossy buckthorn	Wetland & 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
<i>Vincetoxicum spp.</i>	swallow-wort species	Open, successional and wooded habitats

Appendix F. 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>cernuum</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 G. 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 nigrum</i>	black maple
<i>Acer platanoides</i>	Norway maple
<i>Acer rubrum</i>	red maple
<i>Acer saccharum</i>	sugar maple
<i>Ailanthus altissima</i>	tree of heaven
<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>Carya tomentosa</i>	mockernut hickory
<i>Fagus grandifolia</i>	American beech
<i>Fraxinus americana</i>	white ash
<i>Fraxinus pennsylvanica</i>	green ash
<i>Juglans nigra</i>	black walnut
<i>Larix decidua</i>	European larch
<i>Larix laricina</i>	tamarack
<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

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