



Mid-Atlantic Network Forest Vegetation Monitoring

2007 to 2010

Natural Resource Technical Report NPS/MIDN/NRTR—2011/471



ON THE COVER

American beech (*Fagus grandifolia*) leaves in Fredericksburg and Spotsylvania NMP.
Photograph by: James A. Comiskey, National Park Service

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Natural Resource Technical Report NPS/MIDN/NRTR—2011/471

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Executive Summary

Between 2007 and 2010, 316 forest vegetation monitoring plots were established in 11 parks of the Mid-Atlantic and Northeast Coastal and Barrier networks. Plots were randomly selected using a generalized random-tessellation stratified (GRTS) approach from a 250-m grid that overlays the parks. The monitoring plots consist of a 20 m x 20 m square with three nested microplots and 12 quadrats. All trees and shrubs with a diameter at breast height (DBH) ≥ 10 cm in the main plot were identified, measured, tagged with a unique number, marked with paint at the point of measurement, their locations were mapped using a laser rangefinder, and their condition was assessed. Saplings and shrubs with a DBH ≥ 1 cm and < 10 cm were identified, measured, marked, and tagged in each of the three microplots. The number, height, and cover of tree seedlings, as well as cover of a list of native and invasive exotic indicator plants were measured in the quadrats. Coarse woody debris was measured along three 15-m transects. Soil sampling was incorporated in 2010.

A total of 6,457 tree stems ≥ 10 cm DBH belonging to 64 species, and 3,712 sapling stems ≥ 1 cm and < 10 cm DBH belonging to 56 species were tagged, measured, and identified. The highest species richness of trees and saplings was found at Appomattox Court House NHP. The most common tree species across all parks were loblolly pine (*Pinus taeda*), tulip poplar (*Liriodendron tulipifera*), and white oak (*Quercus alba*). No high priority pests or pathogens were detected. Several plots were designated as being of significant concern due to the high level of leaf loss and chlorosis, most occurring in Fredericksburg and Spotsylvania NMP. Only Gettysburg NMP and Petersburg NB had a healthy proportion of snags to live standing trees. Thirty-two species were identified among the 1,592 shrubs measured; the most common species were northern spicebush (*Lindera benzoin*), highbush blueberry (*Vaccinium corymbosum*), and mountain laurel (*Kalmia latifolia*). Tree seedlings were counted in 12 quadrats and assigned to height class categories that were used to calculate a regeneration stocking index. The greatest seedling species richness and stocking rate was recorded at Booker T. Washington NM. The most common tree seedling species across all parks were white oak (*Quercus alba*), white ash (*Fraxinus americana*), and sweetgum (*Liquidambar styraciflua*). Vines occurred in all parks and Virginia creeper (*Parthenocissus quinquefolia*) was the most common. Among the target list of 29 invasive exotic indicator species, 18 were documented in the plots. The most common species were Japanese honeysuckle (*Lonicera japonica*) and Japanese stiltgrass (*Microstegium vimineum*) occurring in more than 100 plots. Japanese stiltgrass had the highest percent cover (10-25%) in the quadrats where it occurred. Of the target list of 33 native indicator species and taxa, 30 were encountered; Virginia creeper (*Parthenocissus quinquefolia*) occurred in quadrats in 162 plots, while blueberries (*Vaccinium* spp.) had the highest average percent cover per plot (5-10%). Among the indicators of deer browse, Valley Forge NHP had the lowest number of deer-avoided and deer-preferred species. The Five Forks unit of Petersburg NB and Sagamore Hill NHS were the only two units having low levels of coarse woody debris and were categorized as being of significant concern. Soils were sampled only in 2010, with a wide range of results for calcium to aluminum ratios and for carbon to nitrogen ratios.

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Acronyms

APCO: Appomattox Court House National Historical Park
BOWA: Booker T. Washington National Monument
DBH: Diameter at breast height
DRC: Diameter at root crown
EISE: Eisenhower National Historic Site
EPMT: Exotic Plant Management Team
ERMN: Eastern Rivers and Mountains Network
FIA: Forest Inventory and Analysis Program of USFS
FRSP: Fredericksburg and Spotsylvania National Military Park
FRSP-FRED: Fredericksburg Battlefield unit of FRSP
FRSP-SPOT: Spotsylvania Battlefield unit of FRSP
FRSP-CHWILD: Chancellorsville Battlefield and Wilderness Battlefield units of FRSP
GETT: Gettysburg National Military Park
GEWA: George Washington Birthplace National Monument
GRTS: Generalized Random Tessellation Stratified Design
HOFU: Hopewell Furnace National Historic Site
I&M: Inventory and Monitoring Program
IVI: Importance Value Index
MIDN: Mid-Atlantic Network
NB: National Battlefield
NBP: National Battlefield Park
NCBN: Northeast Coastal and Barrier Network
NCRN: National Capital Region Network
NER: NPS Northeast Region
NETN: Northeast Temperate Network
NHP: National Historical Park
NHS: National Historic Site
NM: National Monument
NMP: National Military Park
NP: National Park
NPS: National Park Service
PETE: Petersburg National Battlefield
PETE-EAST: Eastern and Western Front units of PETE
PETE-FIVE: Five Forks unit of PETE
RICH: Richmond National Battlefield Park
SAHI: Sagamore Hill National Historic Site
SHEN: Shenandoah National Park
THST: Thomas Stone National Historic Site
USDA: U.S. Department of Agriculture
USFS: U.S. Forest Service
VAFO: Valley Forge National Historical Park

Introduction

The Mid-Atlantic region is primarily a forested ecoregion and all Mid-Atlantic Network (MIDN) parks have forests that form an essential part of the landscape and provide habitat for a diversity of wildlife. For this reason, the vital signs selection process highlighted forest vegetation and several associated indicators as being a high priority for monitoring (Comiskey et al. 2009). The network thus initiated forest monitoring in 2007, conducting an initial year of pilot plot implementation which helped refine the process for the subsequent establishment of monitoring plots between 2008 and 2010. Three Northeast Coastal and Barrier Network (NCBN) parks were incorporated in 2008. The full forest vegetation monitoring protocol was finalized and published in 2009 (Comiskey et al. 2009).

The overarching goal of the vegetation monitoring program is to provide a framework for monitoring long-term change over broad spatial scales of the forests in the parks.

Specific monitoring objectives include:

- Determine the status and trends in forest structure, composition, and dynamics of canopy and understory woody species.
- Determine the status and trends in the density and composition of tree seedlings and selected herbaceous species that are indicators of deer browse.
- Detect and monitor the presence of invasive exotic plants, exotic plant diseases and pathogens, and forest pests.
- Determine the status and trends in forest coarse woody debris and the availability of snags.
- Determine the status and trends in soil Ca:Al and C:N ratios to assess the extent of base cation depletion, increased aluminum availability and/or nitrogen saturation impacting MIDN forest soils.

The monitoring protocol calls for establishment of a network of vegetation plots across eight of the 10 MIDN parks (Shenandoah NP uses a separate protocol (Cass 2007), and forest cover is low at Eisenhower NH), and three NCBN parks (these were incorporated between 2008 and 2010) (Figure 1).

Inferences are made on a park basis in this report. For Fredericksburg and Spotsylvania NMP and Petersburg NB, analyses and summary statistics are reported for individual units. Table 1 shows the allocation of plots in relation to forest area in the MIDN and NCBN parks. The standardized approach will also facilitate comparisons across networks in future reports and publications.

USFS Bailey's Ecoregion Provinces Mid-Atlantic Network

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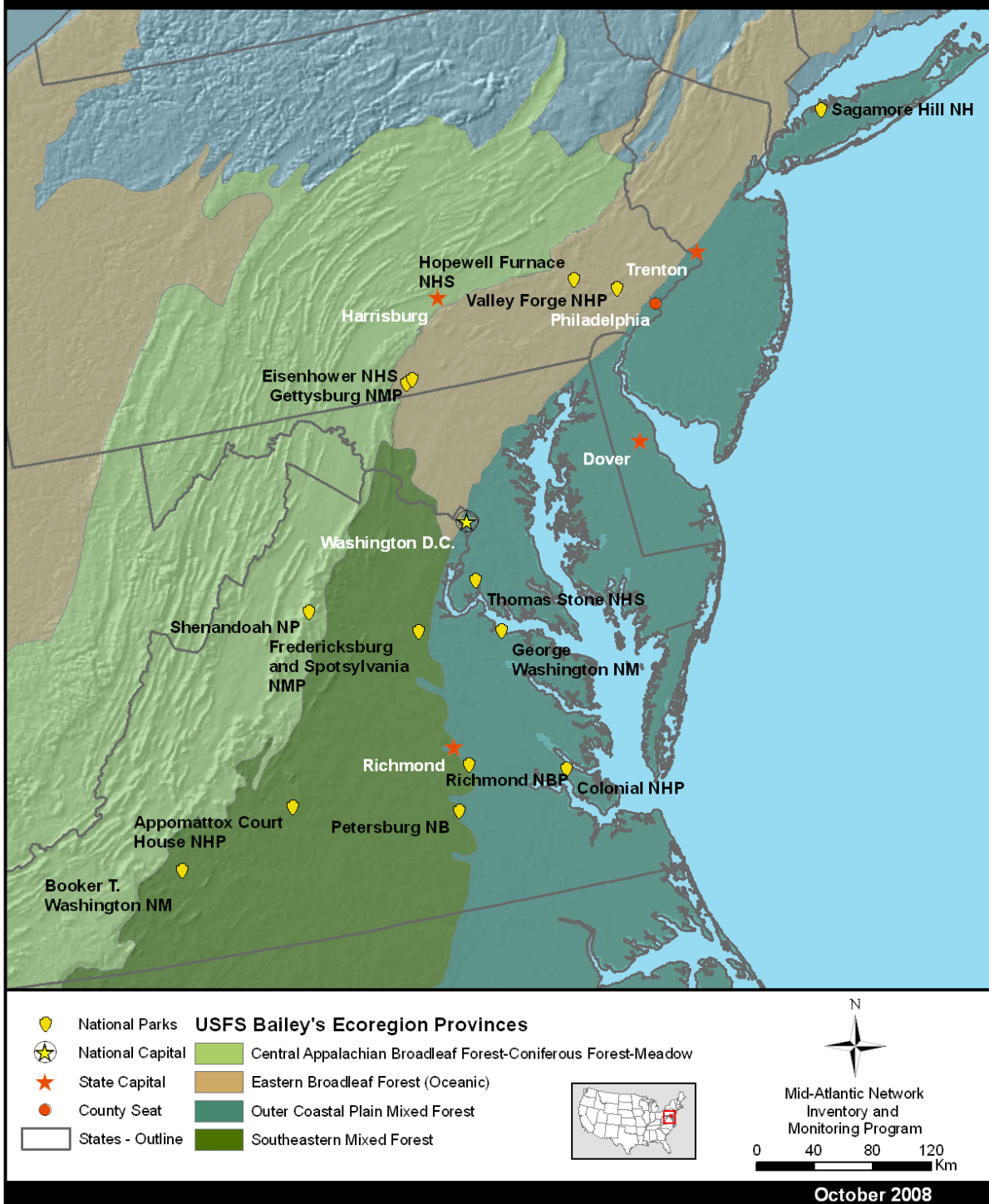


Figure 1. Location of parks included in the Mid-Atlantic Network's Forest Vegetation Monitoring protocol. Three parks from the Northeast Coastal and Barrier Network are also included in the monitoring program.

Table 1. Allocation of plots in Mid-Atlantic and Northeast Coastal and Barrier network parks in relation to forested area.

Park	Park unit	Park code	Established Plots	Forested Area (ha)
Mid-Atlantic Network				
Appomattox Court House National Historical Park (NHP)		APCO	28	442.0
Booker T. Washington National Monument (NM)		BOWA	8	62.4
	Fredericksburg Battlefield	FRSP-FRED	28	459.6
Fredericksburg and Spotsylvania National Military Park (NMP)	Spotsylvania Battlefield	FRSP-SPOT	28	430.0
	Chancellorsville Battlefield and Wilderness Battlefield	FRSP-CHWILD	48	1,397.9
Gettysburg National Military Park (NMP)		GETT	32	587.7
Hopewell Furnace National Historic Site (NHS)		HOFU	16	269.5
Petersburg National Battlefield (NB)	Eastern and Western Front	PETE-EAST	28	525.3
	Five Forks	PETE-FIVE	24	397.4
Richmond National Battlefield Park (NBP)		RICH	32	564.1
Valley Forge National Historical Park (NHP)		VAFO	28	427.3
Northeast Coastal and Barrier Network				
Thomas Stone National Historic Site (NHS)		THST	6 ¹	89.0
George Washington Birthplace National Monument (NM)		GEWA	6 ¹	86.6
Sagamore Hill National Historic Site (NHS)		SAHI	4 ²	16.6
Total			316	5,755.6

¹ Northeast Coastal and Barrier Network plots were incorporated beginning in 2008. Two additional plots will be established in each of THST and GEWA in 2011.

² At SAHI, the sampling design called for a minimum of eight plots, but due to the small size of the forested area in the park, only four plots could be established.

Methods

Field Methods

The target population is restricted to forested areas within each park. Plots were randomly selected using a generalized random-tessellation stratified (GRTS) approach from a 250-m grid that overlays the entire mid-Atlantic region (including all MIDN parks and those NCBN parks included in this protocol). Field crews navigated to the predetermined locations and rejected plot locations only for specific reasons and after having attempted alternate locations as outlined in the Table 5 of the forest vegetation protocol (Comiskey et al. 2009).

In 2007, one-fourth of the allocated plots were established in all eight MIDN parks by a crew of two people between May and September. In 2008 through 2010, the Mid-Atlantic Network shared a crew of four people with the Northeast Temperate Network (NETN). The crew worked in teams of two, starting the field season in NETN, and reaching the MIDN in August. In each of the three years another one-fourth of the allocated plots were established, proceeding along the Pennsylvania parks from Valley Forge NHP to Hopewell Furnace NHS to Gettysburg NMP, followed by the Virginia parks starting with Appomattox Court House NHP and Booker T. Washington NM, and then Petersburg NB and Fredericksburg and Spotsylvania NMP. During the month of September, most of the work was conducted in Fredericksburg and Spotsylvania NMP, Richmond NBP, George Washington Birthplace NM, and Thomas Stone NHS. The latter two parks are part of the NCBN and were incorporated into the protocol in 2008; two additional plots will be established in each of these two parks in 2011. Another NCBN park, Sagamore Hill NHS, was sampled only in 2009, primarily due to the small area of forest located in the park resulting in only four possible plots being established. Sagamore Hill NHS will only be revisited once every four years and all plots will be remeasured. For the remainder of the parks, one-fourth of the plots will be remeasured every four years. Appendix A provides maps showing locations of all plots and the year they were established for each park.

Each plot consists of a 20 m x 20 m square with three nested microplots and 12 quadrats (Figure 2). A laser rangefinder was used to establish the plot boundaries so that the plot is a square in a horizontal plain (irrespective of the slope). PVC posts were used to mark the plot corners and the microplots (rebar was used in 2007); a survey marker attached to rebar was placed at the plot center. Site data were recorded for all plots (except in 2007; this data will be collected in 2011) including slope, aspect, physiographic class, stand structure and height, crown closure, ground cover and disturbance, microtopography, and presence of water. Digital photographs were taken to provide a visual characterization of each plot.

All trees and shrubs¹ with a diameter at breast height (DBH) ≥ 10 cm in the main plot were identified, measured, tagged with a unique number, and marked with paint at the point of measurement, their locations were mapped using the laser rangefinder, and their condition was

¹ Trees and shrubs are perennial woody plants, distinguished primarily by growth form. Trees generally have one main stem or trunk, while shrubs tend to have multiple stems and a shorter stature. However, the distinction between trees and shrubs can be difficult as shrubs may exhibit a variety of growth forms depending on species, location, and environmental conditions. For this reason, we have categorized all perennial woody plants as either being trees or shrubs based primarily on FIA (U.S. Department of Agriculture 2010), Plants Database (U.S. Department of Agriculture 2011), and personal observation. In addition, in the case of shrubs, we define how they should be measured.

assessed. All trees were also assigned to a canopy class based on their position in the canopy in relation to other individuals in the plot; canopy trees are those that are classified as belonging to the dominant, co-dominant, or intermediate crown classes. Trees (saplings²) and shrubs with a $DBH \geq 1$ cm and < 10 cm were identified, measured, marked, and tagged in each of the three microplots. Number, height, and cover of tree seedlings³, as well as cover of a list of native and invasive exotic indicator plants and vines were measured in the quadrats. Coarse woody debris was measured along three transects. Soil sampling was incorporated in 2010.

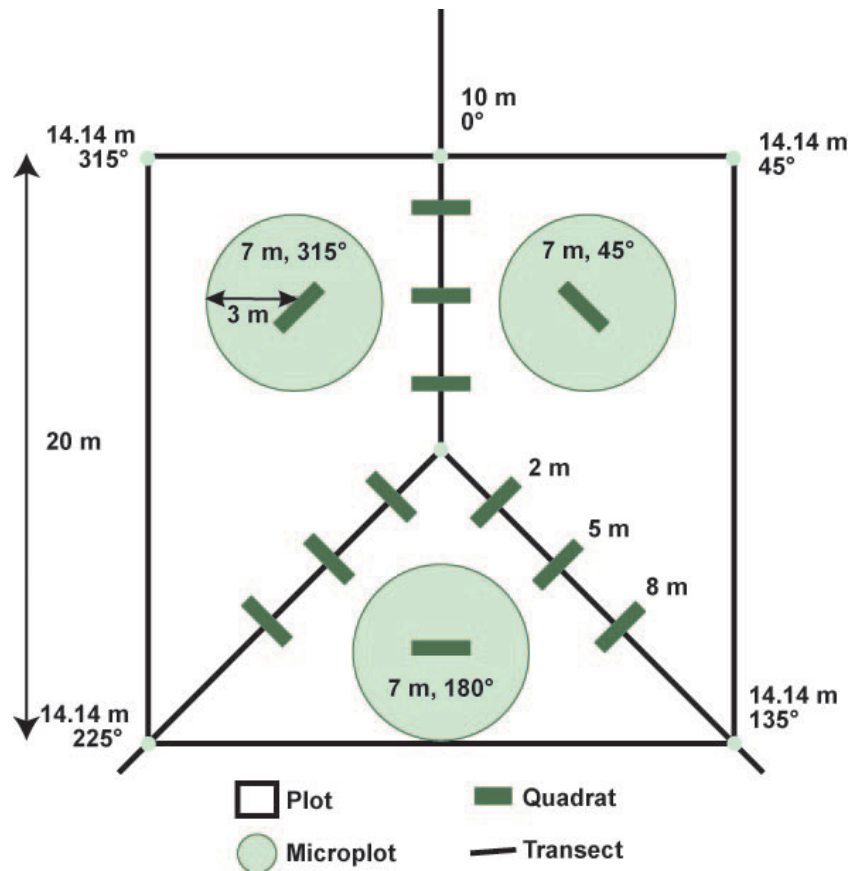


Figure 2. Layout of forest vegetation monitoring plot used in Mid-Atlantic and Northeast Coastal and Barrier network parks from 2007 to 2010.

Shrubs

Shrubs present a substantial challenge for consistent measurement due to their varied growth forms. Some species typically grow like trees, generally having a single stem and reaching heights where DBH can be measured. However, other species tend to sprout multiple stems from the base or branch extensively below DBH, and, if DBH were measured, the individuals would be grossly under-represented as most stems at DBH would be too small to be included. For this reason, between 2007 and 2010, the Mid-Atlantic Network quantified shrub basal area for such

² Trees with a DBH of ≥ 1 cm and < 10 cm are also referred to as saplings.

³ Tree seedlings include all individuals with a $DBH < 1$ cm and a height ≥ 15 cm (5 cm at VAFO). Shrub seedlings are excluded from measurement as this protocol focuses on determining regeneration of tree species that will reach the forest canopy.

species by measuring the Diameter at Root Crown (DRC). For yet other species, not even DRC is a practical measure, and the only option available has been to estimate total cover. A list of shrub species encountered in the plots and how they were measured is listed in Appendix B.

As the program was implemented, adjustments were made to how shrubs were treated:

- Between 2007 and 2010, all shrubs with a tree growth form and a DBH ≥ 10 cm were recorded, measured, marked, tagged, and mapped in the main plot (20 x 20 m area).
- In the microplots, between 2007 and 2008, all shrubs with a tree growth form that had a DBH ≥ 1 cm and < 10 cm were recorded, measured, marked, and tagged (Appendix B). For the appropriate subset of species, DRC was measured for all individuals with a DRC ≥ 1 cm. In 2009 and 2010, the protocol was changed so that only the first five individuals of each species in the above two categories in each microplot were measured, marked and tagged; additional individuals of the species were counted and the density recorded. In the results, we use the mean diameter of individuals that were measured for each species in each microplot to provide an estimate for individuals that were counted, thus enabling us to calculate an estimated total basal area.
- Between 2007 and 2008, shrub cover was only measured in the quadrats for indicator species. From 2009 to 2010, cover was measured in microplots for all shrubs that were not measured or counted.

Indicator Taxa

The Mid-Atlantic Network focuses on indicator species and taxa for monitoring in quadrats. The species have been selected as 1) invasive exotic indicators, 2) indicators of deer-browse effects, or 3) vines that may reach the forest canopy. In most cases, the indicators are ‘species’ (e.g. *Aralia nudicaulis*), while in other cases they are groups of species identified to the genus (e.g. *Rubus* spp. or *Vaccinium* spp.), family (e.g. Poaceae or Cyperaceae), or division (e.g. ferns) level. Throughout this report, the terms species and taxa may be used to indicate the indicator list.

The invasive exotic indicators have been selected in consultation with the NPS Mid-Atlantic Exotic Plant Management Team (EPMT) and park resource managers as being the top priority for parks in the networks (29 taxa; Table 2). A series of native species and taxa either preferred or avoided by deer are monitored as indicators of deer-browse effects (29 taxa; Table 3). Vines can indicate forest disturbance, and, in turn, may also cause disturbance when they reach the canopy by adding weight to and shading the host tree (16 taxa; Table 4). Nine of the indicator vines are invasive exotic and seven are native. In total (including vines), 33 native and 29 invasive exotic indicator taxa are monitored.

The indicators of deer browse are organized into those preferred by deer (18 taxa) and those avoided by deer (11 taxa; Table 3). The presence / absence of these indicators are used to evaluate the impact that deer may be having on the vegetation. When assessing potential deer browse there are a number of challenges, and the following section outlines how we address them in this report:

- Species vary in their distributions and abundance; the presence / absence of one species may reflect a variety of edaphic (e.g. soil chemistry) and biotic (e.g. displacement by invasive

exotic plant species) conditions at a site, not just deer-browse pressure. The indicator data are reviewed as a group, with no single species being an indicator on its own.

- Growth form varies between indicator species and sites. Large values of percent cover at a site may result from a single individual of a species with dense growth, which may skew the results. This is particularly the case if shrubs are included in the analyses, and may not necessarily reflect browse pressure. For this reason we present the data for shrub indicators (one preferred and two avoided taxa) separate from that of the herbaceous indicators (17 preferred and nine avoided taxa).
- Some taxa, such as ferns and grasses, are generally avoided by deer and thus may be indicators of high deer-browse pressure; furthermore, they may also impede seedling regeneration due to heavy growth cover, thus compounding the selective pressure by deer (e.g. Latham et al. 2005, Diefenbach and Fritsky 2007).
- Other species, e.g. *Rubus* spp., are preferred deer-browse, however, they do not tolerate shade, and thus, their absence from a plot may not necessarily indicate heavy deer browse (Diefenbach and Fritsky 2007). Therefore, the absence of *Rubus* is not used as an indicator on its own.
- Lastly, there are some challenges specific to our data, primarily that we have incorporated additional indicator species between 2007 and 2010. Plots established in the first few years were sampling fewer species than in the latter years. This will become more of an issue when comparing temporal changes within the same plots.

Repeated visits to the same plots are the most effective way to overcome many of the issues addressed above. Evaluating temporal changes in the composition and cover of the indicator species at each plot will provide a clearer picture; for example, a decline in deer-preferred versus deer-avoided species will suggest that deer pressure may be increasing at that site. In future analyses we will use a metric that evaluates changes in frequency and cover over time.

Table 2. Invasive exotic indicator species chosen for monitoring in the Mid-Atlantic and Northeast Coastal and Barrier networks.

Species	Common Name	Comments
<i>Akebia quinata</i>	five-leaved akebia	
<i>Alliaria petiolata</i>	garlic mustard	
<i>Ampelopsis brevipedunculata</i>	porcelain berry	
<i>Berberis thunbergii</i>	Japanese barberry	
<i>Cardamine impatiens</i>	narrowleaf bittercress	
<i>Celastrus orbiculatus</i>	Oriental bittersweet	
<i>Centaurea biebersteinii</i>	spotted knapweed	
<i>Cirsium arvense</i>	Canada thistle	
<i>Clematis ternifolia</i>	yam-leaf clematis	
<i>Duchesnea indica</i>	mock strawberry	
<i>Euonymus fortunei</i>	creeping euonymus	
<i>Glechoma hederacea</i>	ground ivy	
<i>Hedera helix</i>	English ivy	
<i>Hemerocallis fulva</i>	common daylily	
<i>Lespedeza cuneata</i>	Chinese lespedeza	<i>Sericea lespedeza</i>
<i>Ligustrum spp.</i> ¹	privet	
<i>Lonicera japonica</i>	Japanese honeysuckle	
<i>Lonicera spp.</i>	bush honeysuckles	
<i>Microstegium vimineum</i>	Japanese stiltgrass	
<i>Oplismenus hirtellus spp. undulatifolius</i> ¹	wavy-leafed basketgrass	
<i>Polygonum caespitosum</i> ¹	Oriental lady's thumb	
<i>Polygonum cuspidatum</i>	Japanese knotweed	
<i>Polygonum perfoliatum</i>	mile-a-minute	
<i>Pueraria montana</i>	kudzu	
<i>Ranunculus ficaria</i>	lesser celandine	
<i>Rosa multiflora</i>	multi-flora rose	
<i>Rubus phoenicolasius</i>	wineberry	
<i>Vinca minor</i>	periwinkle	
<i>Wisteria sinensis</i> ¹	wisteria vine	

¹ Species added in 2009.

Table 3. Deer-browse indicator taxa chosen for monitoring the Mid-Atlantic and Northeast Coastal and Barrier networks.

Latin Name	Common	Deer Preference	Reference
<i>Aralia nudicaulis</i> ¹	wild sarsaparilla	Preferred	Balگووین and Waller (1995)
<i>Arisaema triphyllum</i> ¹	jack in the pulpit	Avoided	Ruhren and Handel (2000), Heckel et al (2010)
<i>Cyperaceae</i> ⁴	sedges	Avoided	Latham et al. (2005), Diefenbach and Fritsky (2007)
<i>Dennstaedtia punctilobula</i> ¹	eastern hayscented fern	Avoided / Impede Regeneration	Horsley et al. (2003), Diefenbach and Fritsky (2007)
<i>Eurybia divaricata</i> ¹	white wood aster	Preferred	Williams et al. (2000)
<i>Ferns</i> ⁴	Ferns	Avoided / Impede Regeneration	Latham et al. (2005), Diefenbach and Fritsky (2007)
<i>Impatiens capensis</i>	jewelweed	Preferred	Williams et al. (2000)
<i>Laportea canadensis</i> ¹	Canadian woodnettle	Preferred	Augustine and Jordan (1998)
<i>Lilium</i> spp. ⁴	Lilies	Preferred	Miller et al. (1992)
<i>Maianthemum racemosum</i>	feathery false lily of the valley	Preferred	Fletcher et al. (2001), Augustine and DeCalesta (2003)
<i>Medeola virginiana</i> ¹	Indian cucumber	Preferred	Diefenbach and Fritsky (2007), Royo et al. (2010)
<i>Orchids</i> ⁴	orchids	Preferred	Miller et al. (1992)
<i>Poaceae</i> ⁴	grasses	Avoided / Impede Regeneration	Latham et al. (2005), Diefenbach and Fritsky (2007)
<i>Podophyllum peltatum</i>	may apple	Avoided	Webster and Parker (2000)
<i>Polygonatum biflorum</i> ¹	smooth Solomon's seal	Preferred	Fletcher et al. (2001), Augustine and DeCalesta (2003), Kraft et al. (2004), Webster et al. (2005)
<i>Polystichum acrostichoides</i>	Christmas fern	Avoided	Diefenbach and Fritsky (2007)
<i>Rubus</i> spp. ⁵	blackberry	Preferred ²	Horsley et al. (2003), Diefenbach and Fritsky (2007)
<i>Sanguinaria canadensis</i> ³	bloodroot	Preferred	Augustine and DeCalesta (2003)
<i>Smilax</i> spp. ⁶	Common greenbrier	Preferred	Maxey (1976), Blair and Brunett (1980), Diefenbach and Fritsky (2007)
<i>Smilax glauca</i> ²	cat greenbrier	Preferred	
<i>Smilax rotundifolia</i> ²	roundleaf greenbrier	Preferred	
<i>Thelypteris noveboracensis</i>	New York fern	Avoided / Impede Regeneration	Williams et al. 2000, Horsley et al. (2003)
<i>Trillium cernuum</i>	nodding trillium	Preferred	Anderson (1994), Augustine and Frelich (1998), Rooney (2001), Augustine and DeCalesta (2003), Webster et al. (2005)
<i>Trillium erectum</i>	red trillium	Preferred	
<i>Uvularia perfoliata</i> ¹	perfoliate bellwort	Preferred	Fletcher et al. (2001), Augustine and DeCalesta (2003), Webster et al. (2005)
<i>Uvularia sessilifolia</i> ¹	sessileleaf bellwort	Preferred	
<i>Vaccinium</i> ⁷	blueberries	Avoided / Impede Regeneration	Diefenbach and Fritsky (2007)
<i>Vaccinium corymbosum</i>	highbush blueberry		
<i>Vaccinium stamineum</i>	deer berry		

¹ Species added in 2008. ² Species added in 2009. ³ Species added in 2010. ⁴ All species grouped.

⁵ *Rubus* is preferred deer browse but it may be absent from the understory as it does not tolerate shade, and thus may not be a good indicator (Diefenbach and Fritsky 2007). ⁶ Excluding *S. glauca* and *S. rotundifolia* that are identified to species. ⁷ Includes *Gaylussacia* spp but excludes *V. corymbosum* and *V. stamineum*.

Table 4. Vine indicator species chosen for monitoring the Mid-Atlantic and Northeast Coastal and Barrier networks.

Species	Common Name	Comments
<i>Akebia quinata</i> ³	five-leaved akebia	
<i>Ampelopsis brevipedunculata</i> ³	porcelain berry	
<i>Campsis radicans</i>	common trumpet creeper	
<i>Celastrus orbiculatus</i> ³	oriental bittersweet	
<i>Clematis ternifolia</i> ³	yam-leaf clematis	
<i>Euonymus fortunei</i> ³	climbing euonymus, winter creeper	
<i>Hedera helix</i> ^{1,3}	English ivy	
<i>Lonicera japonica</i> ³	Japanese honeysuckle	
<i>Parthenocissus quinquefolia</i>	Virginia creeper	
<i>Pueraria montana</i> ³	kudzu	
<i>Smilax glauca</i> ²	cat greenbrier	
<i>Smilax rotundifolia</i> ²	common greenbrier	
<i>Smilax</i> spp. ¹	greenbrier	
<i>Toxicodendron radicans</i>	poison ivy	
<i>Vitis</i> spp.	grape vine	
<i>Wisteria sinensis</i> ^{2,3}	wisteria vine	

¹ Species added in 2008. ² Species added in 2009. ³ Invasive exotic species.

Analyses

This report focuses primarily on descriptive statistics for the various vegetative components including mature trees, snags, saplings, tree seedlings, shrubs, vines, and native and invasive exotic indicator taxa. Data are first presented for the entire network, summarizing results by parks or park units, with a subsequent section providing details on forest composition and regeneration for each park. A final section provides park based summaries for all metrics.

Ecological Integrity

In some instances, ecological integrity metrics are used (Tierney et al. 2009a, Tierney et al. 2009b). These include structural stage distribution, tree condition, snag proportion, Coarse Woody Debris (CWD) volume, and soil condition. Details on the calculation of the integrity metrics are provided with the results. All the calculations for ecological integrity metrics were conducted with the Forest Scorecard Database developed by Brian Mitchell (2011).

Forest Regeneration

Having sustainable regeneration of tree seedlings is an important metric to monitor. Stocking rates established by McWilliams et al. (2005) for Pennsylvania are used throughout the Mid-Atlantic Network. Tree seedlings are measured in quadrats and a score applied that is weighted according to the height class (see regeneration results for more details). An average stocking index is used to assign a regeneration ranking for plots in a park.

Knowing the current and potential future composition of the forest is also important for managing forest resources. For this reason, we also present data for canopy species showing the current composition of mature trees, saplings, and seedlings. The values are shown as relative values (a proportion of the total number for that category) in order to compare across these different size classes. For mature trees and saplings, we evaluate the density (number of individuals) and dominance (basal area) and aggregate the relative values into a combined index

(Importance Value Index or IVI). For tree seedlings, we use density and dominance (based on the weighted scores from the stocking index calculations). The three values (IVIs for mature trees, saplings, and seedlings) are plotted for the most common species.

Basal Area (BA) = area occupied at breast height (m²)

$$\text{Relative Density} = \frac{\text{\# of individuals of species}}{\text{Total \# of individuals in the plot}} \times 100$$

The number of individuals refers to the number of mature trees, saplings or seedlings.

$$\text{Relative Dominance} = \frac{\text{BA of a species}}{\text{Total BA of individuals in the plot}} \times 100$$

For the seedling data, basal area is replaced with the seedling weighted score which is based on height class categories of seedlings.

$$\text{Importance Value Index (IVI)} = \text{Relative Density} + \text{Relative Dominance}$$

The data are plotted using bar charts that illustrate present (mature trees) and potential future (seedlings and saplings) composition of the forest canopy.

Results and Discussion

Mature Trees

Live tree stems ≥ 10 cm DBH that occur within the 20 x 20 m plots represent mature individuals that may be present in the canopy. Between 2007 and 2010, 316 plots were established in the 14 park sampling units. A total of 6,457 stems ≥ 10 cm DBH belonging to 64 species of trees have been tagged, measured, mapped, and identified. The average number of stems per plot varied from 10.25 at Sagamore Hill NHS to 40.50 at Petersburg NB's Five Forks unit. The high density at Petersburg NB is primarily due to the extensive regenerating pine plantations that occur in that unit. The largest basal area (representing large individuals) occurred in George Washington Birthplace NM (Table 5). Species richness varied from 10 in Sagamore Hill NHS to 37 in Appomattox Court House NHP; however, Booker T. Washington NM had the highest average number of species per plot. It should be noted that only four plots were established in Sagamore Hill NHS due to the small area of forest in the park.

Table 5. Summary of trees ≥ 10 cm DBH in forest vegetation monitoring plots established between 2007 and 2010 in the Mid-Atlantic and Northeast Coastal and Barrier networks.

Park	# of plots	Mean # of stems / plot	Stems / ha	Mean BA (m ²) / plot	BA (m ²) / ha	# of species	Mean # of species / plot
APCO	28	22.04	550.89	0.91	22.63	37	6.1
BOWA	8	21.88	546.88	0.96	24.11	23	6.5
FRSP_CHWILD	48	18.79	469.79	1.11	27.72	30	5.8
FRSP_FRED	28	16.68	416.96	0.99	24.75	25	5.3
FRSP_SPOT	28	20.54	513.39	1.33	33.27	24	6.1
GETT	32	12.81	320.31	0.96	24.05	33	5.5
GEWA	6	23.67	591.67	1.82	45.47	17	5.3
HOFU	16	14.25	356.25	1.21	30.29	22	5.4
PETE_EAST	28	21.00	525.00	1.25	31.18	29	5.3
PETE_FIVE	24	40.50	1,012.50	1.43	35.67	21	5.8
RICH	32	24.94	623.44	1.15	28.83	35	6.3
SAHI	4	10.25	256.25	1.70	42.41	10	4.0
THST	6	15.00	375.00	1.29	32.21	13	5.2
VAFO	28	16.14	403.57	1.26	31.43	31	4.6

Structural Stage

A range of forest structural stages enhances species diversity by providing multiple habitats within park units. As multiple stressors including global climate change and exotic pest and pathogen outbreaks alter disturbance regimes (Dale et al. 2001), structural stage distributions are likely to shift. This metric assesses the structural stage distribution of forest plots in relation to the expected distribution under natural disturbance regimes. It provides an indicator of altered disturbance regimes, and habitat availability for species dependent on specific structural stages (Tierney et al. 2009a).

Structural stage distribution is assessed for each park based on calculations from canopy trees (trees with a DBH ≥ 10 cm that are categorized as belonging to the dominant, co-dominant, or intermediate crown classes based on their relative position in the canopy) in forested plots using methods similar to that of Frelich and Lorimer (1991) but substituting basal area for exposed crown area (Goodell and Faber-Langendoen 2007). The canopy trees are assigned into the following size classes: 10-25.9 cm DBH (pole), 26-45.9 cm DBH (mature), and ≥ 46 cm DBH

(large). Plots are then classified as pole, mature, late-successional stage, or mosaic based on relative basal area of live canopy trees within pole, mature, and large size classes as follows:

Pole stage: $\geq 67\%$ of total plot BA of canopy trees in pole plus mature sizes, with more basal area in pole than mature size.

Mature stage: $\geq 67\%$ of total plot BA of canopy trees in pole plus mature sizes, with more basal area in mature than pole size or $\geq 67\%$ in mature plus large size, with more basal area in mature than large size.

Late-successional stage: $\geq 67\%$ of total plot BA of canopy trees in mature plus large sizes, with more basal area in large than mature size.

Mosaic: Any plot not meeting the above criteria.

Ratings based on expected percentage of late-successional forest stages across the landscape are then assigned according to Frelich and Lorimer (1991) and Lorimer and White (2003) as follows:

Good: At least 25% late-successional structure across the park.

Caution: Less than 25% late-successional structure across the park.

Significant Concern: Less than 25% combined mature and late-successional structure across the park

The distribution of structural stages in Mid-Atlantic and Northeast Coastal and Barrier network forests is generally classified as “Good” with only Appomattox Court House NHP, Five Forks unit of Petersburg NB, and Richmond NBP rated as “Caution”. It is important to note that this metric is only taking into consideration the size of trees and not the species composition. For example, George Washington Birthplace NM and Sagamore Hill NHS are shown to have 100% combined mature and late-successional forests, but in both cases the forest plots are dominated by tulip poplar (*Liriodendron tulipifera*), a species that is primarily considered to be early-successional though it can persist in the canopy for many years. Lack of regeneration at both parks is of concern as these early-successional species will likely reach maturity and die, with no individuals to replace them in the canopy (Busing 1995).

Table 6. Structural stage of forest vegetation monitoring plots established between 2007 and 2010 in the Mid-Atlantic and Northeast Coastal and Barrier networks.

Park	% Late Succession	% Mature and Late Succession	Rating
APCO	21.0%	50.0%	Caution
BOWA	25.0%	75.0%	Good
FRSP_CHWILD	26.0%	87.0%	Good
FRSP_FRED	43.0%	89.0%	Good
FRSP_SPOT	29.0%	89.0%	Good
GETT	61.0%	85.0%	Good
GEWA	50.0%	100.0%	Good
HOFU	73.0%	93.0%	Good
PETE_EAST	46.0%	83.0%	Good
PETE_FIVE	0.0%	33.0%	Caution
RICH	19.0%	77.0%	Caution
SAHI	100.0%	100.0%	Good
THST	50.0%	83.0%	Good
VAFO	58.0%	92.0%	Good

Canopy Tree Condition

The Mid-Atlantic Network uses a tree condition ecological integrity metric to assess foliage condition in canopy trees (DBH $\geq$ 10 cm and in a dominant, co-dominant, or intermediate crown class). As the season progresses, most trees develop minor foliage problems (e.g., insect damage, chlorosis, etc.) and this is visible in MIDN plots as they are sampled between August 1 and September 30. More extensive damage, however, can indicate a wide variety of stressors ranging from forest pests and pathogens, to air quality and climatic change impacts. Pests and pathogens in particular pose a significant threat to forest communities, and several, such as beech bark disease (BBD) or hemlock woolly adelgid (HWA), affect individual species. Some species are considered a high priority due to the severity of their threat, including Asian longhorned beetle (ALB), emerald ash borer (EAB), and sudden oak death (SOD). Other pests are low priority, including BBD, butternut canker (BC), elongate hemlock scale (EHS), and HWA. In this metric, any plot that had a high priority pest was ranked as “Significant Concern”, and plots with low priority pests or high severity of BBD were ranked as “Caution”. Rankings are assigned to each plot as follows:

Good: Average foliage problem with < 10% of canopy stems in plot, and no HWA, BC, EHS, ALB, EAB or SOD, and average BBD severity $\leq$ 2 among any stems in plot.

Caution: Average foliage problem with 10-50 % of canopy stems or species (species with at least two stems) in plot, or evidence of HWA, EHS or BC , or average BBD severity > 2 among any stems in plot.

Significant Concern: Average foliage problem with > 50% of canopy stems or species (species with at least two stems) in plot, or evidence of ALB, EAB or SOD among any stems in plot.

No high priority pests were encountered in any of the MIDN or NCBN parks. For the most part, those plots that were assigned as being of “Significant Concern” were mainly due to a high proportion canopy trees with leaves that were chlorotic or had extensive leaf loss (Table 7).

Chancellorsville and Wilderness unit of Fredericksburg and Spotsylvania NMP had the greatest number of plots in the “Significant Concern” category, mostly due to leaf damage — holes in leaves and leaf necrosis — to canopy trees in three plots. One plot in each of Appomattox Court House NHP, Booker T. Washington NM, Hopewell Furnace NHS, and Richmond NBP were also identified as being in the “Significant Concern” category due to holes in leaves and necrosis. Subsequent visits to all these plots will determine if there is a long-lasting impact on forest health.

Table 7. Canopy tree condition in forest vegetation monitoring plots established between 2007 and 2010 in the Mid-Atlantic and Northeast Coastal and Barrier networks.

Park	# of Plots in a Good Condition	# of Plots in a Caution Condition	# of Plots in a Significant Concern Condition
APCO	18	9	1
BOWA	4	3	1
FRSP_CHWILD	33	12	3
FRSP_FRED	20	8	0
FRSP_SPOT	22	6	0
GETT	23	10	0
GEWA	4	2	0
HOFU	7	7	1
PETE_EAST	23	5	0
PETE_FIVE	20	4	0
RICH	23	8	1
SAHI	2	2	0
THST	2	4	0
VAFO	20	8	0

Snags

Standing dead biomass (snags) is an important element of eastern forests, contributing nesting and feeding habitat for birds and other vertebrates (Conner et al. 1979, Rosenberg et al. 1988, Petranksa et al. 1994). In addition, snags are an important indicator of the structural age and health of the forest (Keddy and Drummond 1996). The proportion of snags in relation to live standing trees and shrubs with DBH ≥ 10 cm can indicate a higher or a lower mortality than expected for a given community.

The Mid-Atlantic Network considers snags to include all dead standing trees and shrubs ≥ 10 cm DBH (those that are leaning beyond 45° are classified as coarse woody debris). Forests are considered healthy (“Good”) if snags constitute 10% or more of the standing trees and shrubs ≥ 10 cm DBH, and, for stems ≥ 30 cm DBH, snags make up 10% or more of the composition (Nilsson et al. 2002).

Good: At least 10% of all standing trees and shrubs ≥ 10 cm DBH in a park or group of plots are snags and at least 10% of all medium-large (≥ 30 cm DBH) standing trees in a park or group of plots are snags.

Caution: Less than 10% of standing trees and shrubs ≥ 10 cm DBH in a park or group of plots are snags or less than 10% of all medium-large (≥ 30 cm DBH) standing trees in a park or group of plots are snags

Significant Concern: Fewer than five medium-large snags (≥ 30 cm DBH) per hectare, calculated for the park or a group of plots.

Table 8. Snags in forest vegetation monitoring plots established between 2007 and 2010 in the Mid-Atlantic and Northeast Coastal and Barrier networks.

Plot	# of plots	Mean # of snags/plot	Snags / ha	BA (m ²) / ha	# of snag Species ¹	Snags / ha ≥ 30 cm	% snags	% snags ≥ 30 cm
APCO	28	2.25	56.25	1.45	7	3.57	9.09%	5.06%
BOWA	8	3.88	96.88	2.72	3	6.25	14.98%	6.90%
FRSP_CHWILD	48	1.83	45.83	1.63	10	5.21	8.78%	3.73%
FRSP_FRED	28	1.46	36.61	1.38	9	8.04	7.99%	6.57%
FRSP_SPOT	28	2.32	58.04	2.46	7	8.04	9.97%	4.84%
GETT	32	2.16	53.91	2.36	16	11.36	14.00%	10.49%
GEWA	6	2.50	62.50	9.09	4	29.17	9.49%	11.11%
HOFU	16	1.06	26.56	1.19	7	4.69	6.91%	3.49%
PETE_EAST	28	2.43	60.71	4.71	6	22.32	10.35%	14.53%
PETE_FIVE	24	2.21	55.21	1.01	5	0.00	5.10%	0.00%
RICH	32	1.38	34.38	1.40	10	5.47	5.00%	4.83%
SAHI	4	0.50	12.50	0.72	1	6.25	4.55%	4.00%
THST	6	1.33	33.33	0.57	3	0.00	8.16%	0.00%
VAFO	28	1.61	40.18	1.98	9	7.14	9.16%	5.56%

¹ Species richness of snags only includes trees and shrubs ≥ 10 cm DBH identified to species. Not all snags could be identified.

Gettysburg NMP and Eastern Front unit of Petersburg NB have a healthy composition of snags (Table 8). In contrast, Appomattox Court House NHP, Hopewell Furnace NHS, Five Forks unit of Petersburg NB, and Thomas Stone NHS are categorized as “Significant Concern”, having fewer than five medium-large snags per hectare. All remaining parks are ranked as “Caution”. Booker T. Washington NM had the highest density of snags per hectare; however George Washington Birthplace NM had significantly larger snags than any other park. For those snags that could be identified to species, Gettysburg NMP had the highest species richness.

Tree Saplings

Tree saplings were measured in three 3-m radius microplots and included all tree species with a DBH ≥ 1 cm and < 10 cm and generally represent immature individuals that can become part of the forest canopy. A total of 3,712 saplings were measured. The average number of saplings per plot varied from as low as 3.0 in Valley Forge NHP to over 20 in Five Forks unit of Petersburg NB and Appomattox Court House NHP (Table 9). The largest basal area of saplings was found in Five Forks, the smallest in Sagamore Hill NHS. The Five Forks unit of Petersburg NB is undergoing significant regeneration of hardwoods as the pine plantations mature. A total of 56 species of saplings were recorded across all parks. Appomattox Court House NHP had the highest number of species represented among saplings whereas George Washington Birthplace NM had the lowest species richness. Hopewell Furnace NHS had the lowest average number of species per plot.

Table 9. Tree saplings in forest vegetation monitoring plots established between 2007 and 2010 in the Mid-Atlantic and Northeast Coastal and Barrier networks.

Park	# of plots	Mean # of saplings / plot	Saplings / ha	Mean BA (m ²) / plot	BA (m ²) / ha	Total # of species ¹	Mean # of species / plot ¹
APCO	28	24.8	2,917.8	0.03	3.24	42	7.0
BOWA	8	16.0	1,886.3	0.02	2.79	18	5.1
FRSP_CHWILD	48	11.6	1,368.0	0.02	2.08	27	3.8
FRSP_FRED	28	10.8	1,267.3	0.02	2.10	21	3.8
FRSP_SPOT	28	11.2	1,322.1	0.02	1.97	18	3.8
GETT	32	8.9	1,046.3	0.01	1.19	23	2.6
GEWA	6	7.5	884.2	0.01	1.44	5	1.5
HOFU	16	2.3	272.6	0.01	0.68	9	0.9
PETE_EAST	28	7.3	863.1	0.02	1.89	25	3.1
PETE_FIVE	24	23.3	2,741.0	0.04	4.64	21	6.3
RICH	32	14.0	1,650.5	0.02	2.60	31	4.1
SAHI	4	5.0	589.5	0.01	0.64	6	2.5
THST	6	5.7	668.1	0.01	1.44	9	2.2
VAFO	28	3.0	353.7	0.01	0.96	13	1.6

¹ Species richness of tree saplings only includes saplings identified to species.

Shrubs

Shrubs are classified as perennial woody plants that tend to have multiple stems and a shorter stature than trees. Defining a particular species as a shrub or a small tree can be a challenge, therefore the Mid-Atlantic Network has developed a list of shrubs based on classifications used by the USDA Forest Inventory and Analysis Program (U.S. Department of Agriculture 2010), Plants Database (U.S. Department of Agriculture 2011), and personal observation.

A total of 1,592 shrubs belonging to 32 species or genera were documented in the plots, eight being exotic species. The highest density of shrubs was documented in Sagamore Hill NHS and Thomas Stone NHS. The shrub density was in the mid-range at Appomattox Court House NHP, but the average size per stem was large, resulting in high basal areas per hectare. Species richness was highest in Appomattox Court House NHP and Gettysburg NMP, and lowest at George Washington Birthplace NM and Sagamore Hill NHS.

Table 10. Shrubs in forest vegetation monitoring plots established between 2007 and 2010 in the Mid-Atlantic and Northeast Coastal and Barrier networks.

Park	# of plots	Mean # of shrubs / plot	Shrubs / ha	Mean BA (m²) / plot	BA (m²) / ha	Total # of species¹
APCO	28	5.21	614.73	0.01	1.31	10(6)
BOWA	8	1.63	191.58	0.00	0.05	1(2)
FRSP_CHWILD	48	5.38	633.67	0.00	0.38	5(3)
FRSP_FRED	28	3.46	408.41	0.00	0.27	4(3)
FRSP_SPOT	28	0.25	29.47	0.00	0.01	4(2)
GETT	32	12.31	1,451.55	0.01	1.05	9(6)
GEWA	6	1.50	176.84	0.00	0.03	1(0)
HOFU	16	10.38	1,223.14	0.00	0.26	4(7)
PETE_EAST	28	1.86	218.94	0.00	0.07	3(3)
PETE_FIVE	24	4.38	515.78	0.00	0.14	7(1)
RICH	32	2.03	239.47	0.00	0.16	8(2)
SAHI	4	22.00	2,593.64	0.01	1.44	4(2)
THST	6	17.83	2,102.42	0.01	0.76	1(1)
VAFO	28	3.04	357.89	0.01	0.87	7(0)

¹ Species richness only includes shrubs identified to species. Values in parentheses are additional species encountered in the quadrats but no DBH or DRC was taken.

Tree Seedlings

Tree seedlings ≥ 15 cm in height and less than 1 cm in DBH are identified, counted, and assigned to a height class category in twelve 1-m² quadrats. A weighted score is assigned to each seedling and combined for all seedlings in a plot to provide a stocking index (McWilliams et al. 2005). In addition, seedlings of each species are assigned to a cover class, including germinants (seedlings smaller than the smallest height class category). In Valley Forge NHP, an additional height class category (5-15 cm) was included due to the low density of seedlings as a result of high deer browse pressure.

Booker T. Washington NM had the highest average number of seedlings ≥ 15 cm in height per plot, with George Washington Birthplace NM and Richmond NBP having the lowest (Table 11). The stocking index correlated closely with seedling density in most parks though there were some notable differences. For example, stocking index was similar for George Washington Birthplace NM and Hopewell Furnace NHS, but seedling density was three times higher in Hopewell Furnace NHS, suggesting that there are many more, smaller seedlings than in George Washington Birthplace NM (Table 11). Total species richness among seedlings ≥ 15 cm in height was highest in Appomattox Court House NHP and lowest in George Washington Birthplace NM. Including species that were present but too small for a height measurement (values in parentheses in Table 11) did not change the results. Valley Forge NHP had the lowest average number of seedling species per plot even though a smaller height class category was included at this park, while Booker T. Washington NM had the highest.

Table 11. Tree seedlings in forest vegetation monitoring plots established between 2007 and 2010 in the Mid-Atlantic and Northeast Coastal and Barrier networks.

Park	# of plots	Mean # seedlings / plot	Mean stocking index / ha	# of species ^{1,2}	Mean # of species / plot ^{1,2}
APCO	28	17.7	50,922.6	33 (8)	4.3 (5.1)
BOWA	8	38.3	80,729.2	21 (2)	5.9 (3.6)
FRSP_CHWILD	48	16.6	38,697.9	27 (4)	3.7 (3.9)
FRSP_FRED	28	7.3	14,047.6	19 (7)	2.6 (4.8)
FRSP_SPOT	28	16.7	46,964.3	19 (7)	3.6 (4.3)
GETT	32	23.5	75,911.5	32 (9)	4.1 (2.1)
GEWA	6	3.3	9,027.8	4 (3)	1.7 (2.2)
HOFU	16	9.6	9,322.9	14 (2)	2.4 (3.0)
PETE_EAST	28	11.5	31,517.9	20 (6)	2.2 (3.2)
PETE_FIVE	24	7.9	21,805.6	19 (7)	2.6 (4.3)
RICH	32	5.3	32,291.7	25 (4)	2.3 (2.9)
SAHI	4	5.8	20,833.3	7 (4)	2.2 (2.2)
THST	6	6.0	38,194.4	5 (11)	2.0 (5.0)
VAFO ³	28	8.7	7,410.7	15 (2)	1.4 (0.6)

¹ Species richness only includes seedlings identified to species. Not all seedlings could be identified.

² Values in parentheses are for additional species identified in quadrats but that were below the minimum height of the smallest height class category.

³ Seedlings between 5 and 15 cm are included as a separate height class category at VAFO.

Vines

Vines are common throughout the Mid-Atlantic and Northeast Coastal and Barrier networks. Vines can indicate disturbance and may result in increased tree mortality (Mohan et al. 2006). Twelve of the 16 indicator vine species were encountered, with nine of these reaching the tree canopy (Table 12). Three of the 12 species are exotics. The most common species was Virginia creeper (*Parthenocissus quinquefolia*) which was found in 166 plots. The next most common species across the network was grape (*Vitis* spp.). Among the exotic species, Japanese honeysuckle (*Lonicera japonica*) was encountered most frequently. For trees that had vines in their canopy, over 50% of the vines were grape with poison ivy (*Toxicodendron radicans*) accounting for just under 20%.

George Washington Birthplace NM had the highest proportion of trees with indicator vines per plot, and Chancellorsville and Wilderness unit in Fredericksburg and Spotsylvania NMP had the lowest. Richmond NBP had the most indicator vine species, both in tree canopies and in the quadrats (Table 13).

Table 12. Vine indicator species in forest vegetation monitoring plots established between 2007 and 2010 in the Mid-Atlantic and Northeast Coastal and Barrier networks.

Latin Name	Common Name	# of plots with vines	# of trees with vines in canopy
<i>Campsis radicans</i>	common trumpet creeper, cow-itch, trumpet	19	8
<i>Celastrus orbiculatus</i> ¹	oriental bittersweet	17	18
<i>Euonymus fortunei</i> ¹	climbing euonymus, winter creeper	4	0
<i>Hedera helix</i> ¹	English ivy	5	0
<i>Lonicera</i> spp.	honeysuckle	2	32
<i>Lonicera japonica</i> ¹	Japanese honeysuckle	112	3
<i>Parthenocissus quinquefolia</i>	Virginia creeper	166	29
<i>Smilax</i> spp.	Common greenbrier	125	13
<i>Smilax glauca</i>	cat greenbrier	84	0
<i>Smilax rotundifolia</i>	roundleaf greenbrier	78	7
<i>Toxicodendron radicans</i>	eastern poison ivy	107	69
<i>Vitis</i> spp.	grape	160	192

¹ Invasive exotic species.

Table 13. Indicator vines in forest vegetation monitoring plots established between 2007 and 2010 in the Mid-Atlantic and Northeast Coastal and Barrier networks.

Park	# of plots	# species in trees ¹	# species in quadrats ¹	# trees with vines	Mean # of trees with vines	# tree species with vines
APCO	28	2	9	47	1.68	15
BOWA	8	1	7	2	0.25	2
FRSP_CHWILD	48	3	9	7	0.15	6
FRSP_FRED	28	3	8	12	0.43	5
FRSP_SPOT	28	2	7	9	0.32	3
GETT	32	3	8	34	1.06	16
GEWA	6	4	8	29	4.83	7
HOFU	16	4	9	11	0.69	5
PETE_EAST	28	6	9	43	1.54	9
PETE_FIVE	24	1	9	4	0.17	3
RICH	32	8	10	92	2.88	18
SAHI	4	3	6	15	3.75	5
THST	6	3	7	5	0.83	3
VAFO	28	5	8	56	2.00	16

¹ Species richness only includes vine indicator taxa.

Exotic Species

A list of 29 indicator exotic species is targeted for monitoring by the Mid-Atlantic Network. The cover of these exotic indicators is recorded in each of the 12 quadrats, and additional species of indicator exotics present in the plot are noted. Exotic indicator species occurred in all parks with the frequency (number of plots with exotics) being highest at Gettysburg NMP where all plots registered exotic indicators (Table 14). Gettysburg also had the highest percentage of quadrats within each plot registering indicator exotics, with an average of 10.34 quadrats per plot. The

Five Forks unit of Petersburg NB had the lowest number of plots and the lowest percentage of quadrats per plot with indicator exotics. Valley Forge NHP had the highest richness of exotic indicator species in the network, but again Gettysburg NMP had the highest average number of species per plot, while the Five Forks unit of Petersburg NB had the lowest average number per plot.

Across the Mid-Atlantic and Northeast Coastal and Barrier networks, 18 of the 29 invasive exotic indicator species were encountered (Table 15). The most common indicator species were Japanese honeysuckle (*Lonicera japonica*) and Japanese stiltgrass (*Microstegium vimineum*) occurring in more than 100 plots. Japanese stiltgrass had the highest percent cover (10-25%) in the quadrats where it occurred.

Table 14. Exotic indicator species and taxa in forest vegetation monitoring plots established between 2007 and 2010 in the Mid-Atlantic and Northeast Coastal and Barrier networks.

Park	# of plots	# plots with exotics ¹	% quads with exotics	Mean # quads / plot with exotics	Total # exotic species ²	Mean # Exotic Species ²
APCO	28	26 (0)	53.87	6.46	8 (1)	1.79 (0.21)
BOWA	8	7 (0)	64.58	7.75	4 (0)	1.38 (0.12)
FRSP_CHWILD	48	8 (1)	9.55	1.15	5 (2)	0.23 (0.08)
FRSP_FRED	28	7 (2)	5.06	0.61	5 (4)	0.36 (0.14)
FRSP_SPOT	28	4 (3)	2.98	0.36	4 (1)	0.18 (0.11)
GETT	32	32 (0)	86.2	10.34	12 (0)	4.00 (0.31)
GEWA	6	3 (1)	31.94	3.83	3 (1)	0.83 (0.33)
HOFU	16	13 (1)	61.46	7.38	10 (0)	2.88 (0.62)
PETE_EAST	28	19 (1)	32.44	3.89	3 (0)	1.00 (0.07)
PETE_FIVE	24	3 (1)	1.74	0.21	3 (0)	0.12 (0.08)
RICH	32	17 (2)	35.94	4.31	8 (1)	1.19 (0.22)
SAHI	4	4 (0)	58.33	7.00	4 (3)	2.00 (1.00)
THST	6	4 (0)	50.00	6.00	4 (0)	1.50 (0.33)
VAFO	28	22 (1)	61.61	7.39	13 (0)	2.14 (0.25)

¹ Number of plots with exotic indicator species in quadrats. Values in parentheses are additional number of plots with indicator exotics recorded only outside quadrats.

² Number of indicator exotic species in quadrats. Values in parentheses are additional indicator exotic species counted outside quadrats.

Table 15. Indicator exotic taxa in forest vegetation monitoring plots established between 2007 and 2010 in the Mid-Atlantic and Northeast Coastal and Barrier networks.

Latin Name	Common Name	# of plots ¹	Mean cover class / plot ²
<i>Alliaria petiolata</i>	garlic mustard	32 (1)	0-1%
<i>Berberis thunbergii</i>	Japanese barberry	28 (9)	5-10%
<i>Cardamine impatiens</i>	narrowleaf bittercress	2 (0)	0-1%
<i>Celastrus orbiculatus</i>	oriental bittersweet	15 (3)	1-2%
<i>Cirsium arvense</i>	Californian thistle, Canada thistle,	1 (0)	0-1%
<i>Clematis terniflora</i>	leatherleaf clematis, sweet autumn	1 (0)	0-1%
<i>Duchesnea indica</i>	India mockstrawberry	28 (4)	0-1%
<i>Euonymus fortunei</i>	climbing euonymus, winter creeper	4 (4)	0-1%
<i>Hedera helix</i>	English ivy	5 (1)	0-1%
<i>Lespedeza cuneata</i>	Chinese lespedeza, sericea lespedeza	1 (1)	0-1%
<i>Lonicera - Exotic</i>	honeysuckle - exotic	7 (1)	1-2%
<i>Lonicera japonica</i>	Japanese honeysuckle	111 (5)	2-5%
<i>Microstegium vimineum</i>	Japanese stiltgrass	104 (10)	10-25%
<i>Polygonum caespitosum</i>	bristled knotweed	18 (5)	0-1%
<i>Polygonum perfoliatum</i>	Asiatic tearthumb, mile-a-minute weed	3 (0)	0-1%
<i>Ranunculus ficaria</i>	fig buttercup	1 (0)	0-1%
<i>Rosa multiflora</i>	multiflora rose	38 (13)	2-5%
<i>Rubus phoenicolasius</i>	Japanese wineberry	13 (8)	1-2%
Total Species:	18		

¹ Number of plots with indicator exotics in quadrats. Values in parentheses are additional number of plots with indicator exotics recorded only outside quadrats.

² Mean cover class was derived using mid-points of each cover class and averaging across quadrats. Averaged mid-point was then converted back to cover class category.

Native Species

A list of 33 native indicator taxa (including vines) is targeted for measurement in the 12 quadrats in each plot, and their presence is noted if they occur in the plot only but outside the quadrats. All plots had native indicator species present in the quadrats with the exception of four plots at Valley Forge NHP; three plots had no indicators present, and one plot had indicators present but not in the quadrats. Appomattox Court House NHP had the highest proportion of quadrats per plot with native indicator species, followed by Hopewell Furnace NHS (Table 16). Chancellorsville and Wilderness units of Fredericksburg and Spotsylvania NMP had the highest total number of native indicator species, and Thomas Stone NHS had the highest average number per plot. Valley Forge NHP had the lowest number of quadrats per plot with native indicators and the lowest average number of indicator species per quadrat.

The most common native indicator species was Virginia creeper (*Parthenocissus quinquefolia*) which occurred in quadrats in 162 plots (with an additional 16 plots where it was not found in the quadrats but was present in the plot) (Table 17). Blueberries (*Vaccinium* spp. excluding *V. corymbosum* and *V. stamineum*) were encountered in quadrats in 148 plots and had the highest average percent cover per plot (5-10%). Lilies (*Lilium* spp.) and trillium (*Trillium* spp.) were the least common indicator species, occurring in quadrats in only one plot.

Table 16. Native indicator species and taxa in forest vegetation monitoring plots established between 2007 and 2010 in the Mid-Atlantic and Northeast Coastal and Barrier networks.

Park	# of plots	Plots with native spp.¹	% quads / plot with native spp.	Mean # quads / plot with native spp.	Total # native spp.²	Mean # native spp. / plot²
APCO	28	28 (0)	85.12	10.21	22 (3)	6.57 (0.89)
BOWA	8	8 (0)	76.04	9.12	18 (1)	5.50 (1.75)
FRSP_CHWILD	48	48 (0)	79.34	9.52	26 (0)	4.29 (0.94)
FRSP_FRED	28	28 (0)	71.43	8.57	18 (4)	4.36 (1.25)
FRSP_SPOT	28	28 (0)	67.86	8.14	20 (3)	4.71 (0.86)
GETT	32	32 (0)	81.77	9.81	20 (3)	5.38 (0.81)
GEWA	6	6 (0)	72.22	8.67	12 (4)	4.83 (2.17)
HOFU	16	16 (0)	82.29	9.88	24 (0)	5.62 (1.12)
PETE_EAST	28	28 (0)	70.83	8.50	19 (1)	4.96 (0.79)
PETE_FIVE	24	24 (0)	70.49	8.46	21 (3)	4.92 (1.21)
RICH	32	32 (0)	79.43	9.53	24 (0)	6.16 (0.88)
SAHI	4	4 (0)	81.25	9.75	7 (2)	4.00 (1.25)
THST	6	6 (0)	81.94	9.83	20 (1)	9.50 (0.83)
VAFO	28	24 (1)	31.55	3.79	13 (8)	2.04 (1.00)

¹ Number of plots with native indicators in quadrats. Values in parentheses are additional number of plots with native indicators only outside quadrats.

² Number/Mean of native indicator species occurring in quadrats. Values in parentheses are additional number/mean of native indicator species found only outside quadrats.

Table 17. Native indicator species and taxa in forest vegetation monitoring plots established between 2007 and 2010 in the Mid-Atlantic and Northeast Coastal and Barrier networks.

Latin Name	Common Name	Plots ¹	Mean % Cover / Plot
<i>Arisaema triphyllum</i>	Indian jack in the pulpit	42 (10)	0-1%
<i>Campsis radicans</i>	common trumpet creeper	15 (4)	0-1%
<i>Cyperaceae</i> spp.	sedges	112 (25)	0-1%
<i>Dennstaedtia punctilobula</i>	eastern hayscented fern	15 (2)	2-5%
<i>Eurybia divaricata</i>	white wood aster	3 (3)	2-5%
Ferns (all families)	Ferns	59 (24)	2-5%
<i>Impatiens capensis</i>	jewelweed	13 (4)	0-1%
<i>Laportea canadensis</i>	Canada lettuce	1 (2)	0-1%
<i>Lilium</i> spp.	Lilies	1 (1)	0-1%
<i>Maianthemum racemosum</i>	No Solomon's-seal	25 (7)	0-1%
<i>Medeola virginiana</i>	Indian cucumber	5 (2)	0-1%
Orchid spp.	Orchids	5 (9)	0-1%
<i>Parthenocissus quinquefolia</i>	Virginia creeper	162 (16)	0-1%
<i>Poaceae</i> spp.	grasses	149 (24)	1-2%
<i>Podophyllum peltatum</i>	may apple	1 (5)	0-1%
<i>Polygonatum biflorum</i>	Solomon's seal	23 (11)	0-1%
<i>Polystichum acrostichoides</i>	Christmas fern	36 (26)	1-2%
<i>Rubus</i> spp.	blackberry	87 (12)	0-1%
<i>Smilax</i> spp.	Common greenbrier	122 (10)	0-1%
<i>Smilax glauca</i>	cat greenbrier	85 (24)	0-1%
<i>Smilax rotundifolia</i>	roundleaf greenbrier	78 (24)	0-1%
<i>Thelypteris noveboracensis</i>	New York fern	15 (4)	2-5%
<i>Toxicodendron radicans</i>	eastern poison ivy	100 (25)	0-1%
<i>Trillium</i> spp.	trillium	1 (0)	0-1%
<i>Uvularia perfoliata</i>	perfoliate bellwort	7 (3)	0-1%
<i>Uvularia sessilifolia</i>	sessileleaf bellwort	6 (2)	0-1%
<i>Vaccinium</i> spp. ³	blueberries	148 (13)	5-10%
<i>Vaccinium corymbosum</i>	highbush blueberry	36 (11)	1-2%
<i>Vaccinium stamineum</i>	deerberry	49 (5)	1-2%
<i>Vitis</i> spp.	grape	145 (13)	1-2%
Total Species:	30		

¹ Number of plots with native indicators in quadrats. Values in parentheses are additional number of plots with native indicator species recorded only outside quadrats.

² Mean cover class was derived using mid-points of cover class and averaging across quadrats. Averaged mid-point values were then converted back to cover class.

³ Includes *Gaylussacia* spp.

Deer-Browse Indicators

The deer-browse indicator data were collected in the 12 quadrats in each plot. The indicator species are a subset of the species listed in the previous section. The data are presented as the mean number and percent cover of deer-avoided and deer-preferred herbaceous and shrub indicators per plot in each park. Only George Washington Birthplace NM had a higher mean number of deer-preferred than avoided herbaceous and shrub indicators per plot. Thomas Stone NHS and Booker T. Washington NM had the highest average number of preferred herbaceous indicators while Valley Forge NHP had the lowest. Valley Forge NHP also had the lowest percent cover of deer-preferred herbaceous species followed by Gettysburg NMP and Five Forks

unit of Petersburg NB. Chancellorsville and Wilderness unit of Fredericksburg and Spotsylvania NMP had the highest cover of deer avoided shrubs, primarily due to the dominance of *Vaccinium* spp. at the unit.

Table 18. Deer-browse indicator herbaceous and shrub species and taxa in forest vegetation monitoring plots established between 2007 and 2010 in the Mid-Atlantic and Northeast Coastal and Barrier networks.

Park	# of plots	Mean # of indicators / plot				Mean % cover / plot			
		Herbaceous		Shrubs		Herbaceous		Shrubs	
		Avoided	Preferred	Avoided	Preferred	Avoided	Preferred	Avoided	Preferred
APCO	28	2.18	1.50	0.39	0.43	1.99	1.25	0.81	0.14
BOWA	8	1.13	1.75	0.38	0.25	1.94	0.35	0.24	0.04
FRSP_CHWILD	48	0.96	1.25	1.40	0.17	2.27	0.42	10.38	0.03
FRSP_FRED	28	1.07	1.00	0.96	0.11	0.78	0.27	2.50	0.02
FRSP_SPOT	28	0.89	1.46	1.46	0.18	0.38	0.27	2.96	0.03
GETT	32	1.81	0.69	0.16	0.69	1.72	0.12	0.29	0.66
GEWA	6	0.83	1.50	0.00	0.17	0.29	0.34	0.00	0.03
HOFU	16	1.88	1.25	0.50	0.44	4.56	0.77	1.27	0.24
PETE_EAST	28	1.36	1.25	0.50	0.14	1.20	0.26	3.17	0.01
PETE_FIVE	24	0.88	1.33	1.33	0.25	0.25	0.21	3.77	0.03
RICH	32	1.88	1.41	0.66	0.31	5.18	1.39	1.85	0.06
SAHI	4	0.50	1.25	0.00	0.00	1.96	0.23	0.00	0.00
THST	6	3.50	2.50	0.17	0.67	7.15	0.53	0.01	0.04
VAFO	28	0.93	0.11	0.11	0.11	0.42	0.01	0.00	0.74

Coarse Woody Debris

Coarse woody debris (CWD) volume is calculated from the transect data (Marshall et al. 2000) and corrected for slope (Van Wagner 1982). Tree volume is calculated for all live mature trees. All calculations are provided in the monitoring protocol SOP and performed using the ecological integrity database (Mitchell 2011). Not all Mid-Atlantic and Northeast Coastal and Barrier networks plots are included in this calculation due to missing or incomplete data (tree heights and slope corrections were not collected in 2007).

Good: CWD volume > 15% of live tree volume.

Caution: CWD volume is 5-15% of live tree volume.

Significant Concern: CWD volume < 5% of live tree volume.

The Eastern Front unit of Petersburg NB and the Fredericksburg unit of Fredericksburg and Spotsylvania NMP had the highest proportion of CWD in relation to standing live tree volume (Table 19). The Eastern Front of Petersburg NB in particular was heavily affected by Hurricane Isabel which resulted in high levels of CWD in the understory (Shedd 2006). Five Forks unit of Petersburg NB and Sagamore Hill NHS were the only two parks with proportions considered as “Significant Concern”, that is, CWD were < 5% of standing live tree volume. In the case of Five Forks, the forests are composed of maturing plantations of loblolly pine (*Pinus taeda*) which will likely show increasing mortality in the coming years, with a subsequent increase in CWD.

‘Caution’ ratings are given to Booker T. Washington NM, Spotsylvania unit of Fredericksburg

and Spotsylvania NMP, George Washington Birthplace NM, Hopewell Furnace NHS, Richmond NBP, and Thomas Stone NHS.

Table 19. Coarse woody debris in forest vegetation monitoring plots established between 2008 and 2010 in the Mid-Atlantic and Northeast Coastal and Barrier networks¹.

Park	# of plots	Mean volume CWD (m ³ / ha)	Mean volume live trees (m ³ / ha)	Mean ratio CWD to live trees / Plot	Rating
APCO	20	16.83	261.49	20%	Good
BOWA	6	30.35	278.01	14%	Caution
FRSP_CHWILD	36	31.00	330.32	20%	Good
FRSP_FRED	21	44.36	354.15	27%	Good
FRSP_SPOT	21	44.18	499.50	10%	Caution
GETT	22	49.77	326.27	21%	Good
GEWA	6	44.53	643.78	7%	Caution
HOFU	11	33.72	430.29	8%	Caution
PETE_EAST	21	106.43	367.16	37%	Good
PETE_FIVE	17	11.80	430.16	3%	Significant Concern
RICH	24	28.12	296.90	10%	Caution
SAHI	4	10.05	769.97	2%	Significant Concern
THST	5	29.47	498.03	12%	Caution
VAFO	21	48.76	401.89	19%	Good

¹ Not all plot data are included due to missing tree heights and slope corrections (mostly 2007 data).

Forest Regeneration

Forest regeneration in the Mid-Atlantic and Northeast Coastal and Barrier networks is primarily affected by deer browse as is seen across the region (Rooney and Waller 2003, Randall and Walters 2011). Impacts on forest regeneration occur at densities as low as 8.5 deer per km² or about 22 per square mile (Augustine and DeCalesta 2003). However, a dense understory growth of invasive exotic species can also suppress seedling regeneration and alter natural succession (Meiners 2007, Flory and Clay 2010).

Stocking rates established by McWilliams et al. (2005) for Pennsylvania are used throughout the Mid-Atlantic Network. Tree seedlings are measured in quadrats and a score applied that is weighted according to the height class – e.g. one seedling that is >1.5 m in height is equivalent to 50 seedlings that are 0.15 to 0.3 m in height (Table 20). Exotic tree species and species that do not reach the canopy are excluded from the seedling index score. In areas with low deer densities, the forest will be considered adequately stocked (i.e. having sustainable regeneration) if there is an average weighted score or stocking index of 24 seedlings per twelve 1m² quadrats, or about 2 seedlings per 1m². In high deer density areas, an average stocking index of 8 seedlings per 1m² is required. For this reason, we consider regeneration to be “Good” if the stocking index is above 8 seedlings per m² averaged across all plots, “Caution” if less than 8 but greater than 2 per m², and “Significant Concern” if stocking index is below 2 per m². It is important to note that this is a conservative ranking as in areas with low deer densities a stocking index above 2 per m² would be considered “Good”.

Another metric that can be used to evaluate regeneration is to determine the proportion of plots meeting minimum average weighted scores (>2 per m^2 in areas with low deer densities and >8 per m^2 in areas with high deer densities); if 70% of plots meet these criteria, then regeneration is deemed to be adequate.

Table 20. Height class categories for enumeration of seedlings and the associated weighted score to estimate stocking index (modified from McWilliams et al. 2005).

Seedling height class	Weighted score
0.15 – 0.3 m	1
0.3 – 1 m	2
1 – 1.5 m	20
>1.5	50

Figure 3 shows the average weighted seedling score per plot in each of the parks. The two lines show the lower and upper limits established for different deer densities. Each bar also shows the 95% confidence limits; any value within that limit is not significantly different from the mean (i.e. the difference is due to chance). The graph shows that Booker T. Washington NM and Gettysburg NMP have the highest seedling regeneration, with means that are not significantly different from the “Good” level. Fredericksburg unit of Fredericksburg and Spotsylvania NMP and Thomas Stone NHS have mean seedling scores that lie in the “Significant Concern” range but that are not significantly different from the “Caution” level. George Washington Birthplace NM, Hopewell Furnace NHS, Sagamore Hill NHS, and Valley Forge NHP have means that are within the “Significant Concern” level. Some of the lower regeneration levels may be attributed to the type of forest communities where plots were located and this will be explored in more detail for each park in the next sections. No parks had stocking rates that exceeded an average of 8 per m^2 (96 per plot).

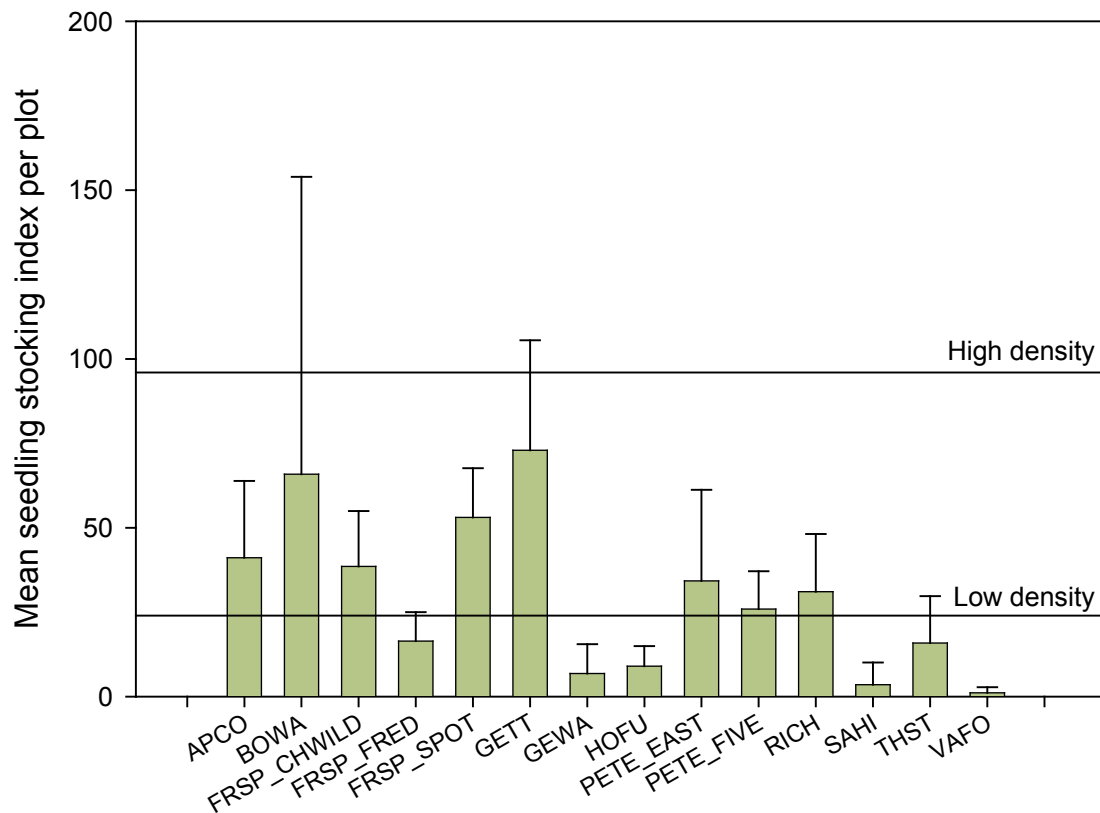


Figure 3. Regeneration of canopy tree species across Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established between 2007 and 2010. Exotic tree species and species that do not reach the canopy are excluded from the seedling index score. Bars show the 95% confidence interval.

Table 21. Number of plots in each of the regeneration integrity ranking categories (assuming a high deer density) for plots established in Mid-Atlantic and Northeast Coastal and Barrier networks between 2007 and 2010.

Park	Good	Caution	Significant Concern	% plots with adequate Regeneration
APCO	4	7	17	39%
BOWA	2	2	4	50%
FRSP_CHWILD	5	15	28	42%
FRSP_FRED	0	8	20	29%
FRSP_SPOT	4	15	9	68%
GETT	9	10	13	59%
GEWA	0	0	6	0%
HOFU	0	2	14	13%
PETE_EAST	2	8	18	36%
PETE_FIVE	0	9	15	38%
RICH	3	7	22	31%
SAHI	0	0	4	0%
THST	0	3	3	50%
VAFO	0	0	28	0%

In terms of the proportion of plots in different regeneration categories, close to 70% of plots in the Spotsylvania unit of Fredericksburg and Spotsylvania NMP were rated as “Good” or “Caution” (Table 21). The next highest proportions were in Gettysburg NMP, Booker T. Washington NM, and Thomas Stone NHS. George Washington Birthplace NM, Sagamore Hill NHS, and Valley Forge NHP had no plots with adequate regeneration; all plots were ranked as “Significant Concern”.

Forest Succession

Knowing the current stocking rate present in each park is only part of the regeneration picture. Adequate seedling stocking rates do not guarantee that park forests will be maintained in their current state; the species composition of seedlings and saplings provides a snapshot of the potential future composition of the forest canopy. Likewise, low regeneration may also be explained by factors other than high-browse intensity, and may be characteristic of the types of forest communities sampled in the parks. In addition, attention should be paid to the species composition of the canopy as well as the sapling and seedling layers as differences may be attributed to natural succession as the forests mature.

Typically in the coastal plain and piedmont, pine species and other non-coniferous softwoods such as eastern cedar (*Juniperus virginiana*) represent the early colonizers. They are followed closely by hardwoods that are shade intolerant including red maple (*Acer rubrum*), American elm (*Ulmus american*), ash (*Fraxinus* spp.), sweetgum (*Liquidambar styraciflua*), and tulip poplar (*Liriodendron tulipifera*), the latter being one of the first to reach the canopy as the softwoods mature (Godfrey 1997). Examples of these types of forests are most common in the Five Forks unit of Petersburg NB where the canopy is dominated by pine species, primarily loblolly pine (*Pinus taeda*), with an understory of hardwood saplings.

As the first hardwoods reach the canopy, a second wave of hardwoods develops in the understory, primarily composed of species such as the oaks (*Quercus* spp.) and hickories (*Carya* spp.) which are destined to become the species of the mature canopy. Much of the forests of the Eastern Front of Petersburg NB are at this successional stage. As the first wave of hardwoods mature and die out, the oaks reach the canopy followed by the hickories; the early successional hardwoods decline in overall importance. Such a successional stage is seen in the various units of Fredericksburg and Spotsylvania NMP where the canopy is primarily dominated by oak species. American beech (*Fagus grandifolia*) will reach the canopy last, mostly in more mesic surroundings — these may develop as soils deepen and moisture conditions change. As the forests mature, shade tolerant, slow to moderate growing, sub-canopy species start to increase in importance as can be seen for Fredericksburg and Spotsylvania NMP units where American holly (*Ilex opaca*), flowering dogwood (*Cornus florida*), and black gum (*Nyssa sylvatica*) are increasing in importance.

Several authors have noted that beech, holly, and red maple are becoming more prevalent in the understory of oak-hickory forests and attribute this to the exclusion of disturbance that may promote oak regeneration, such as fire and logging (Orwig and Abrams 1994, Abrams and Copenheaver 1999). There is evidence to suggest that white oak (*Quercus alba*) is being replaced as the dominant species by red oak (*Quercus rubra*) in other areas as the red oak is more sensitive to fire and may be more shade-tolerant (Abrams 2003). Thus, in the absence of fire, red oaks may benefit over white oaks. However, in general, oaks have seedlings that do not

regenerate well in shade and therefore require disturbance to successfully grow into the canopy (Abrams 1992). Some authors have therefore suggested that oaks are not necessarily a climax feature of the forest, and are largely maintained through disturbance. There is some evidence to suggest that over time, an old-growth oak-hickory forest may give way to a forest with a higher dominance of beech and maple (Abrams and Downs 1990). From a wildlife perspective this may be a less desirable outcome as bears (Clark 2004), deer (Johnson et al. 1995), squirrels (Short 1976), birds (Servello and Kirkpatrick 1989), and rodents (Wolff 1996) are heavily dependent on acorns.

In the following sections, we review in more detail the regeneration data for each park. The approach we are using is to evaluate the present structure and composition of the trees, saplings, and seedlings. Because each of these vegetative strata are sampled differently, we have used relative values based on density and size (basal area for trees and saplings; height for seedlings) combined into an index (Importance Value Index or IVI) to allow comparison (see methods section for more details). The data are plotted using bar charts that illustrate present (trees) and potential future (seedlings and saplings) composition of the forest canopy. When interpreting the graphs, it is important to note that equal size bars across trees, saplings, and seedlings do not indicate similar density or dominance as these values are relative, that is, they are based on the proportion of individuals of each species in relation to the total number for that category.

Appomattox Court House NHP

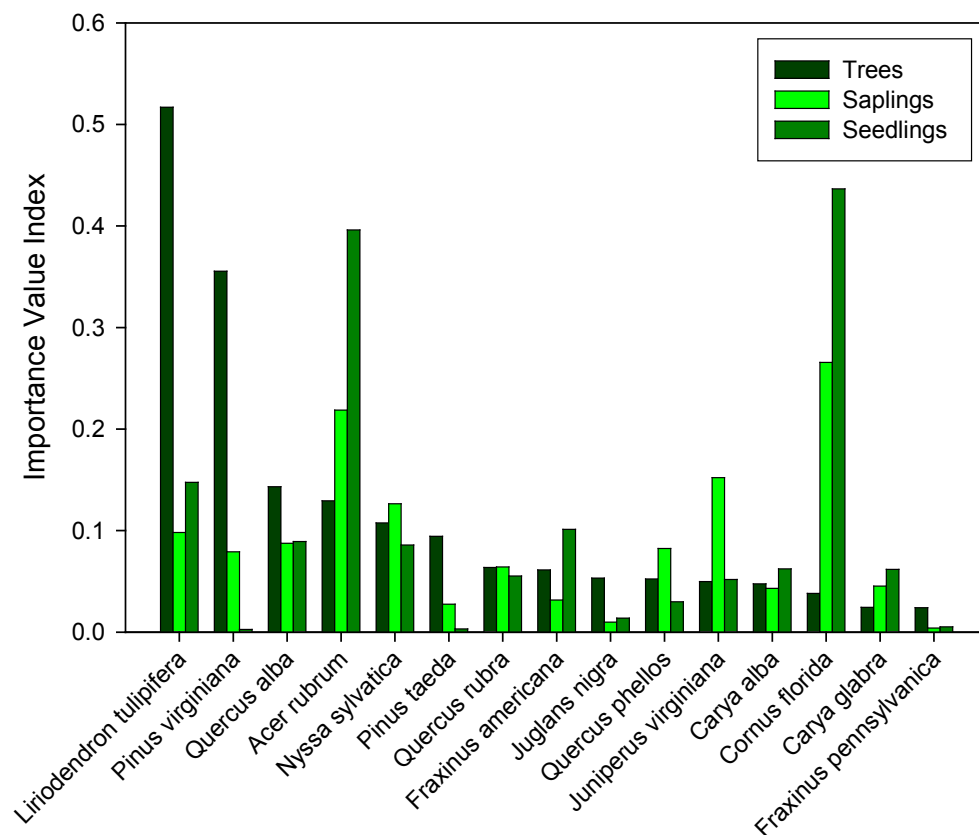


Figure 4. Composition of seedlings, saplings, and trees in forest vegetation plots at Appomattox Court House NHP.

The forests of Appomattox Court House NHP are still maturing. Tulip poplar (*Liriodendron tulipifera*) dominated the canopy and were relatively common in the seedling and sapling layers, followed closely by Virginia pine (*Pinus virginiana*) which was found very infrequently in the seedling layer (Figure 4). Both these species are considered successional species. In contrast, white oak (*Quercus alba*) is a later successional species and is present in the understory. As observed in most of the MIDN parks, red maple (*Acer rubrum*) is represented by high numbers in seedling and sapling. Likewise, flowering dogwood (*Cornus florida*) has adequate regeneration, having the highest importance value among seedlings and saplings. The mean seedling score at Appomattox Court House NHP was 58.5 per plot (“Caution”), with 39% of the plots having adequate regeneration under low deer densities and 14% under high deer density (Figure 3 and Table 21).

Patteson (2008b) observed that many of the oak-hickory forests are succeeding to a more mesic composition, primarily beech (*Fagus grandifolia*). We did not observe this trend, with beech not being present among the top species in the plots that we sampled in the park. Nevertheless, as observed across the network, red maple is commonly appearing as a seedling.

Booker T. Washington NM

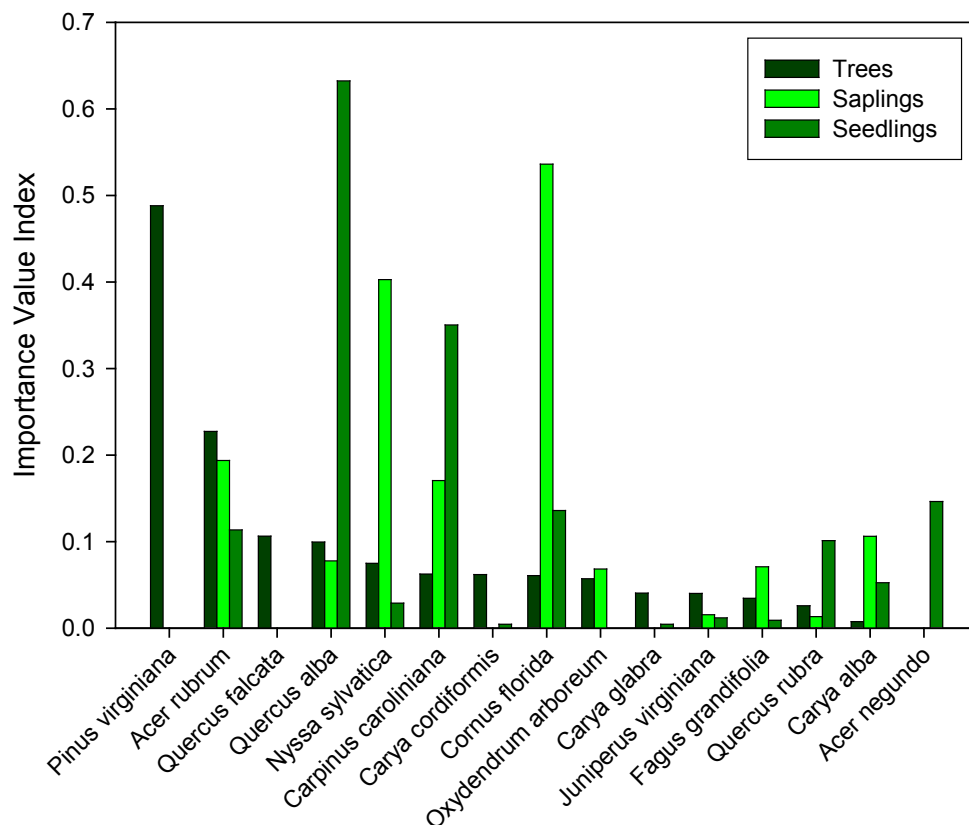


Figure 5. Composition of seedlings, saplings, and trees in forest vegetation plots at Booker T. Washington NM.

Among the plots sampled at Booker T. Washington NM, the species with the highest importance value was Virginia pine (*Pinus virginiana*); however, no regeneration of this species was observed (Figure 5). Instead, the sapling layer was dominated by the canopy species red maple (*Acer rubrum*), black gum (*Nyssa sylvatica*), mockernut hickory (*Carya alba*), and white oak (*Quercus alba*). Flowering dogwood (*Cornus florida*) was the most common understory species in the sapling layer. Among the seedlings, the species with the highest importance value was white oak, a clear indication that the forests of Booker T. Washington are maturing, with the dominant Virginia pines being replaced by white oaks. The mean seedling score at Booker T. Washington NM was 65.9 per plot (“Caution”), with 50% of the plots having adequate regeneration under low deer densities and 25% under high deer density (Figure 3 and Table 21).

Patterson (2008a) observed that some stands in the park are being invaded by red maple, American beech (*Fagus grandifolia*), and American holly (*Ilex opaca*), creating more mesic forest. Certainly red maple is an important element of the seedling and sapling layer, but the other two species were not observed in high numbers in any strata of the plots sampled.

Fredericksburg and Spotsylvania NMP

Across the three units of Fredericksburg and Spotsylvania NMP, regeneration of canopy and understory tree species appears to be adequate to sustain long-term forest composition. In all three units, white oak (*Quercus alba*) was the dominant species, with adequate levels of seedling regeneration, but generally under-represented in the sapling layer. It is not clear whether the lack of white oak saplings is due to high seedling mortality or whether this is an artifact of prior conditions that did not favor regeneration of the species. In all units, more than 99% of the seedlings were below 1 m tall and over 70% were below 30 cm. This may suggest low survival rate as they grow. Data collected during the first recensus will provide additional insights.

Chancellorsville and Wilderness Battlefields units of Fredericksburg and Spotsylvania NMP

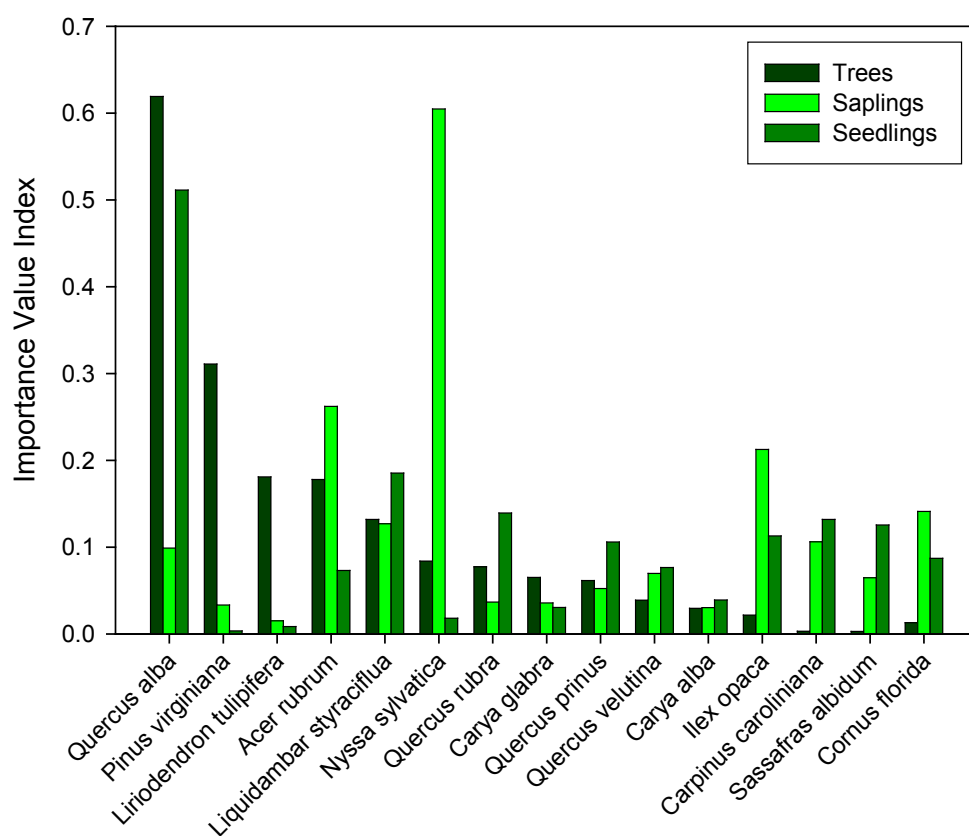


Figure 6. Composition of seedlings, saplings, and trees in forest vegetation plots at Chancellorsville and Wilderness unit of Fredericksburg and Spotsylvania NMP.

In the Chancellorsville and Wilderness unit of Fredericksburg and Spotsylvania NMP, the tree species with the highest importance value was white oak (*Quercus alba*) which dominated the canopy and had the highest level of regeneration among seedlings (Figure 6). Virginia pine (*Pinus virginiana*), as seen in other parks, is a transitional species and is currently being displaced as seedling regeneration is low and hardwood species take over the seedling and sapling layers. Sweetgum (*Liquidambar styraciflua*), an early successional hardwood species,

had the second highest level of seedling regeneration in the unit. American holly (*Ilex opaca*) is another species that is doing well in this unit. This species is very shade tolerant and fire intolerant (Burns and Honkala 1990). The mean seedling score at the Chancellorsville and Wilderness unit was 38.6 per plot (“Caution”), with 42% of the plots having adequate regeneration under low deer densities and 10% under high deer density (Figure 3 and Table 21).

Fredericksburg Battlefield Unit of Fredericksburg and Spotsylvania NMP

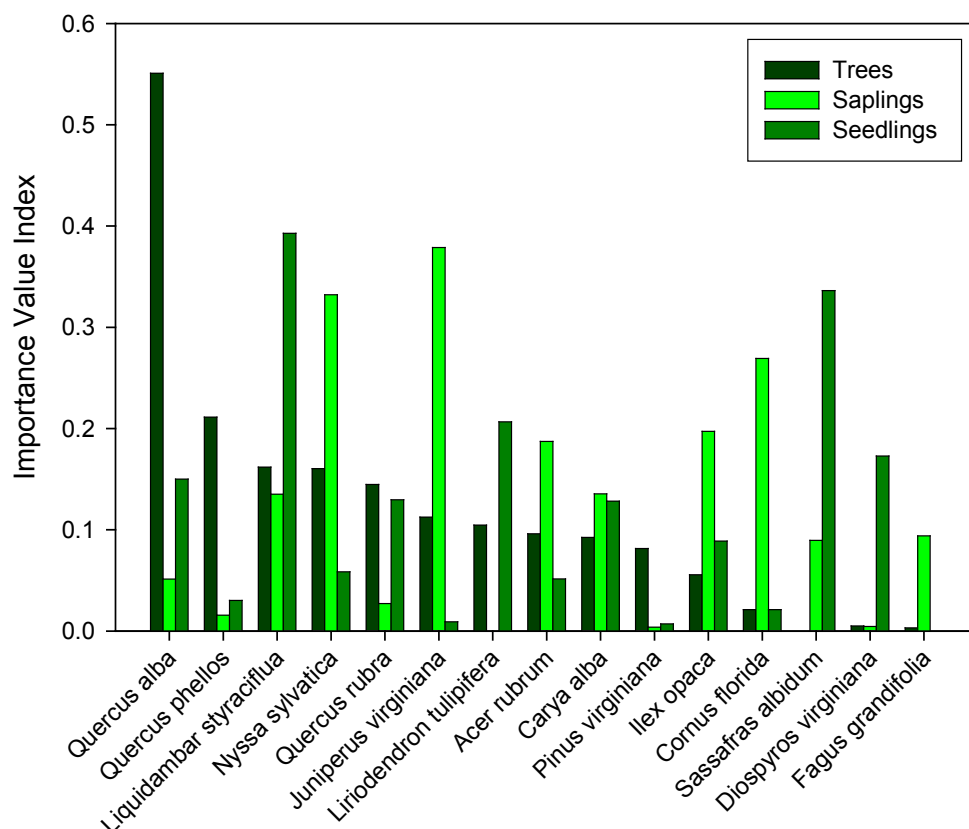


Figure 7. Composition of seedlings, saplings, and trees in forest vegetation plots at Fredericksburg unit of Fredericksburg and Spotsylvania NMP.

As observed in the Chancellorsville and Wilderness unit of Fredericksburg and Spotsylvania NMP, white oak (*Quercus alba*) was the species with the highest importance value in the unit, with a good level of regeneration (Figure 7). In contrast, Virginia pine (*Pinus virginiana*) was a much less significant species, possibly due to a more mature state of forest regeneration across the unit. However, as seen in Chancellorsville and Wilderness unit, sweetgum (*Liquidambar styraciflua*), which is an early pioneer and usually one of the first hardwoods to regenerate in coniferous stands, was showing high levels of regeneration in the unit. The mean seedling score at the Fredericksburg unit was 16.4 per plot (“Significant Concern”), with 29% of the plots having adequate regeneration under low deer densities and 0% under high deer density (Figure 3 and Table 21).

Spotsylvania Battlefield Unit

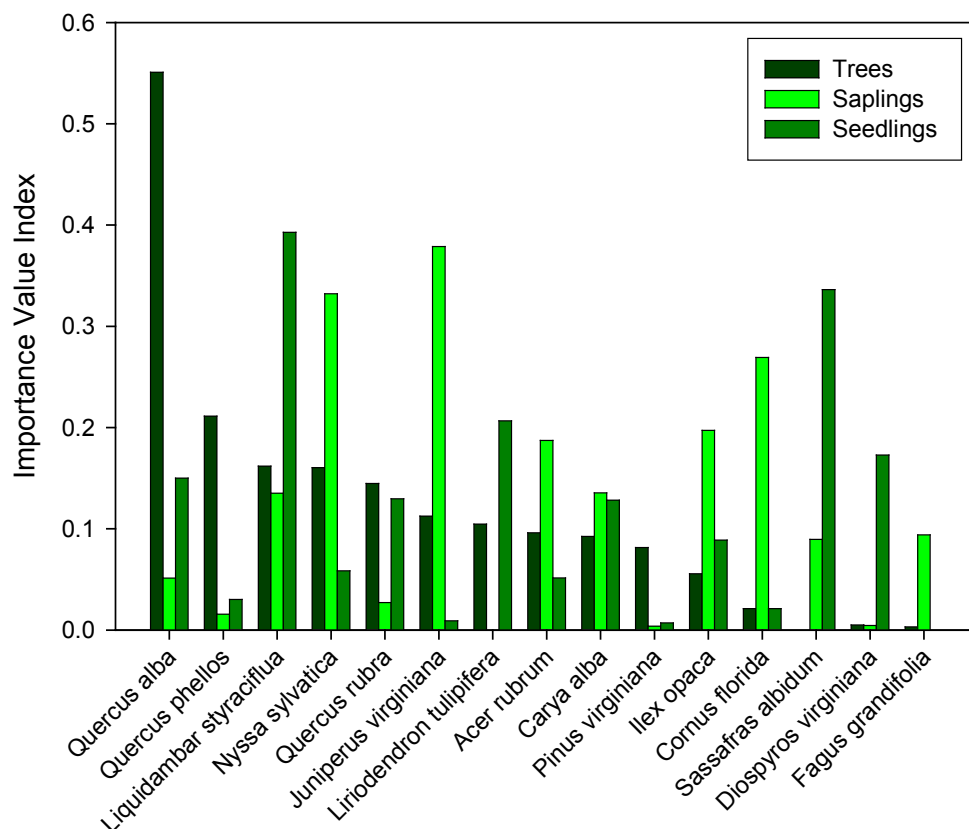


Figure 8. Composition of seedlings, saplings, and trees in forest vegetation plots at Spotsylvania unit of Fredericksburg and Spotsylvania NMP.

As in the other two units of Fredericksburg and Spotsylvania NMP, white oak (*Quercus alba*) is the tree species with the highest importance value, with an excellent level of regeneration, but with few individuals represented in the sapling layer (Figure 8). As observed elsewhere, sweetgum (*Liquidambar styraciflua*) dominated the seedling regeneration with sassafras (*Sassafras albidum*) and persimmon (*Diospyros virginiana*), two lower-canopy species, also showed healthy regeneration. Blackgum (*Nyssa sylvatica*), eastern redcedar (*Juniperus virginiana*), American holly (*Ilex opaca*), and flowering dogwood (*Cornus florida*) were all well represented among saplings. The mean seedling score at the Spotsylvania unit was 55.0 per plot (“Caution”), with 68% of the plots having adequate regeneration under low deer densities and 14% under high deer density (Figure 3 and Table 21).

Gettysburg NMP

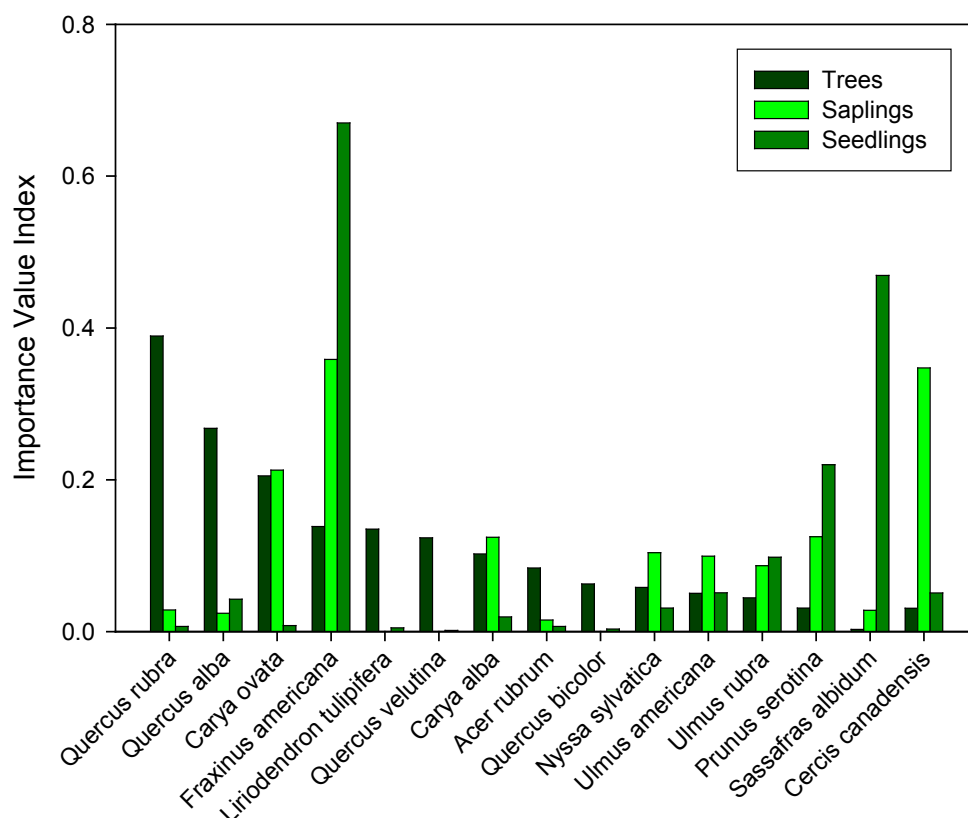


Figure 9. Composition of seedlings, saplings, and trees in forest vegetation plots at Gettysburg NMP.

Oak and hickory species dominated the canopy in Gettysburg NMP, but most of the sapling and seedling layer were dominated by white ash (*Fraxinus americana*), sassafras (*Sassafras albidum*), black cherry (*Prunus serotina*), and eastern redbud (*Cercis canadensis*), the latter species not reaching the canopy (Figure 9). Mockernut hickory (*Carya alba*) and shagbark hickory (*Carya ovata*) formed important elements of the saplings but were both under-represented in the seedling layer. Under current conditions, the canopy is not being replaced by the oak and hickory species and is likely to be replaced by white ash. The mean seedling score at Gettysburg NMP was 72.9 per plot (“Caution”), with 59% of the plots having adequate regeneration under low deer densities and 28% under high deer density (Figure 3 and Table 21).

Perles et al. (2006) noted that many of the Dry Oak – Mixed Hardwood Forest plots they sampled were very disturbed having a high abundance of invasive exotics, vines, with many ‘weedy tree species’ including eastern redcedar (*Juniperus virginiana*), white ash, and black cherry. Invasive exotic species density and cover was higher at Gettysburg NMP than any other park in the network. It is likely that the increased cover is having a detrimental effect on the regeneration of the more shade tolerant oak and hickory species. However, since 2000 the park has implemented a series of health cuts to assist in regeneration based on the findings of

experimental cuts conducted in 1992 (Bowersox et al. 2004, Niewinski et al. 2006). Our data suggests that areas that have undergone health cuts do not have significantly more regeneration than areas that have been cut. However, we also observed high cover of invasive exotics, especially in plots that were cut five or more years prior to the establishment of our forest monitoring plots (Comiskey and Burkart 2011). This may be having the opposite effect to what was desired of the health cuts, but we interpret our data with caution given that our sampling design was not set to address this specific question.

George Washington Birthplace NM

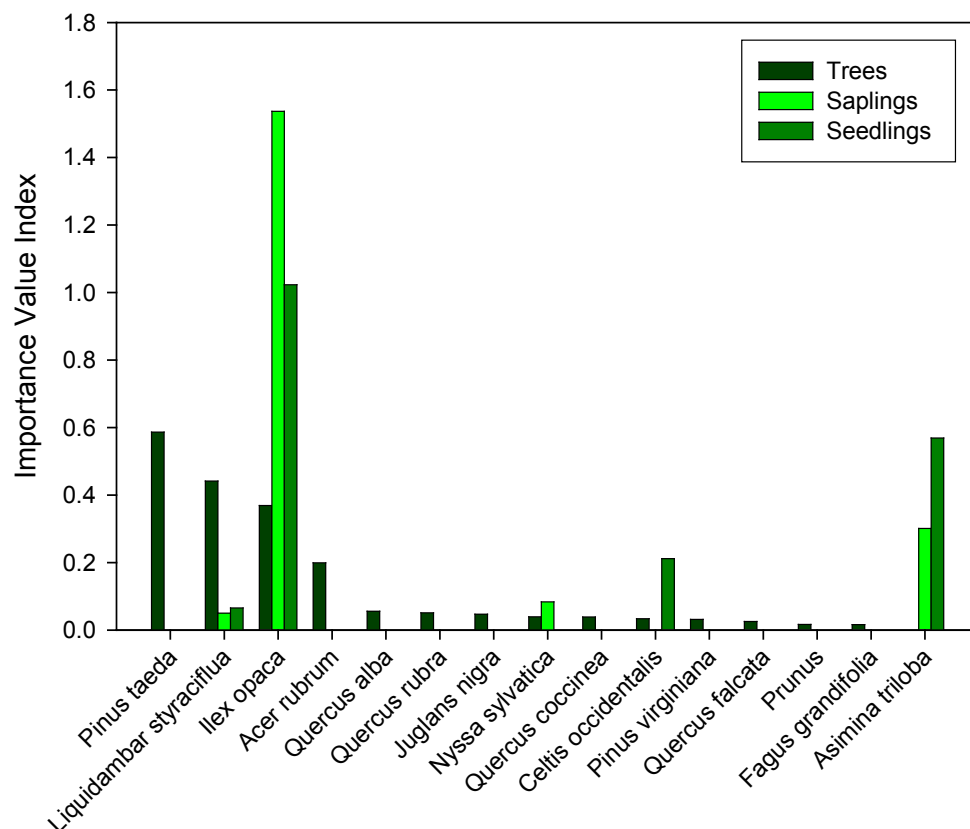


Figure 10. Composition of seedlings, saplings, and trees in forest vegetation plots at George Washington Birthplace NM.

Regeneration was generally low in George Washington Birthplace NM even though a substantial portion of the park is regenerating from old pine plantations (Patterson 2008c). The dominant canopy species were loblolly pine (*Pinus taeda*) and sweetgum (*Liquidambar styraciflua*), the former showing no regeneration in seedling or sapling layers (Figure 10). Most of the regeneration was dominated by American holly (*Ilex opaca*) and pawpaw (*Asimina triloba*), species that are seldom important elements of the forest canopy. The successional loblolly pine and sweetgum are not being replaced by later successional species, such as oaks and hickories, an issue that should be of concern to the long-term sustainability of the forest canopy. The mean seedling score at George Washington Birthplace NM was 6.8 per plot (“Significant Concern”), with 0% of the plots having adequate regeneration under low deer densities and 0% under high deer density (Figure 3 and Table 21).

Hopewell Furnace NHS

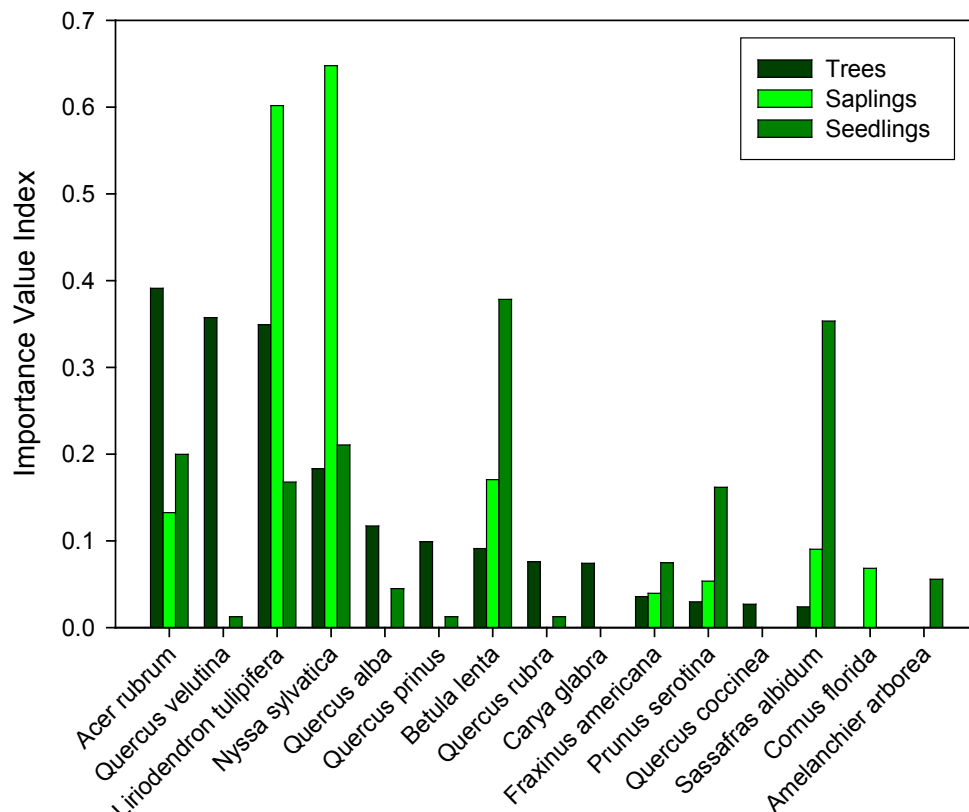


Figure 11. Composition of seedlings, saplings, and trees in forest vegetation plots at Hopewell Furnace NHS.

Forests in Hopewell Furnace NHS also showed relatively low levels of regeneration, however unlike George Washington Birthplace NM, most of the seedlings and saplings belonged to the species that currently dominate the canopy (Figure 11). The highest levels of regeneration were among sweet birch (*Betula lenta*), sassafras (*Sassafras albidum*), red maple (*Acer rubrum*), and sweetgum (*Liquidambar styraciflua*). The latter species along with blackgum (*Nyssa sylvatica*) dominated the sapling layer. The mean seedling score at Hopewell Furnace NHS was 9.0 per plot (“Significant Concern”), with 13% of the plots having adequate regeneration under low deer densities and 0% under high deer density (Figure 3 and Table 21).

Podniesinski et al. (2005) found few tree seedlings below 2 m in height during vegetation mapping in the park, attributing this primarily to white-tailed deer impacts. While deer pressure appears to be high, like most parts of Pennsylvania, our data suggests that regeneration is variable across different areas of the park. Plots in the *Quercus prinus* - (*Quercus coccinea*, *Quercus velutina*) forest alliance varied in their stocking rates from being in the “Caution” level to being of “Significant Concern”. Other associations such as the *Acer rubrum* - *Fraxinus pennsylvanica* seasonally flooded forest alliance occur in low-lying areas that are seasonally flooded, possibly causing reduce regeneration. We also found that the *Quercus alba* - (*Quercus*

rubra, *Carya* spp.) forest alliance showed variable regeneration with no detectable pattern associated with their proximity to the village. Sapling densities were generally low across the entire park.

Eastern Front Unit of Petersburg NB

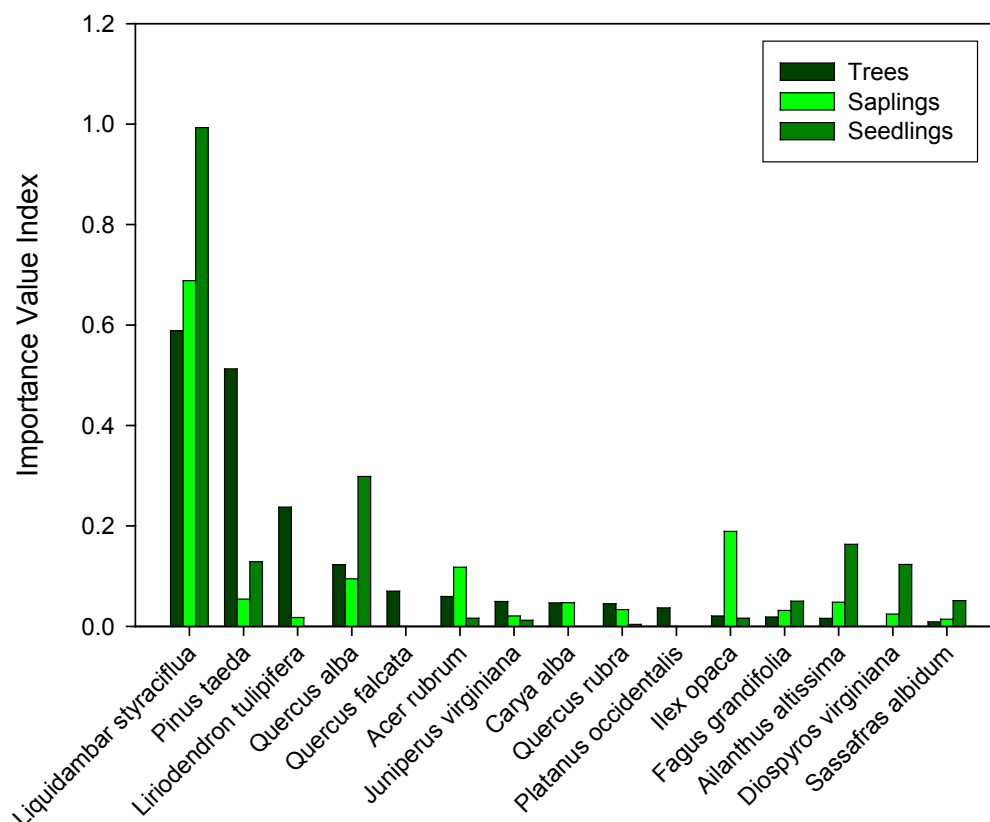


Figure 12. Composition of seedlings, saplings, and trees in forest vegetation plots at Eastern Front unit of Petersburg NB.

Much of the Eastern Front unit consists of maturing successional forests with loblolly pine (*Pinus taeda*) giving way to successional hardwoods including sweetgum (*Liquidambar styraciflua*) and tulip poplar (*Liriodendron tulipifera*) (Figure 12). Sweetgum dominated both the seedling and the sapling layers, with American holly (*Ilex opaca*) and red maple (*Acer rubrum*) as common saplings, and white oak (*Quercus alba*) dominating the seedling layer. Tree of heaven (*Ailanthus altissima*) also registered as an important component of the seedling and sapling layers. The mean seedling score at Eastern Front unit was 34.3 per plot (“Caution”), with 36% of the plots having adequate regeneration under low deer densities and 7% under high deer density (Figure 3 and Table 21).

Patterson (2008d) observed that throughout the mid-Atlantic region forests are being invaded by red maple, American beech (*Fagus grandifolia*), and American holly, creating more mesic forests. All are present in Eastern Front unit but in relatively low numbers.

Five Forks Unit of Petersburg NB

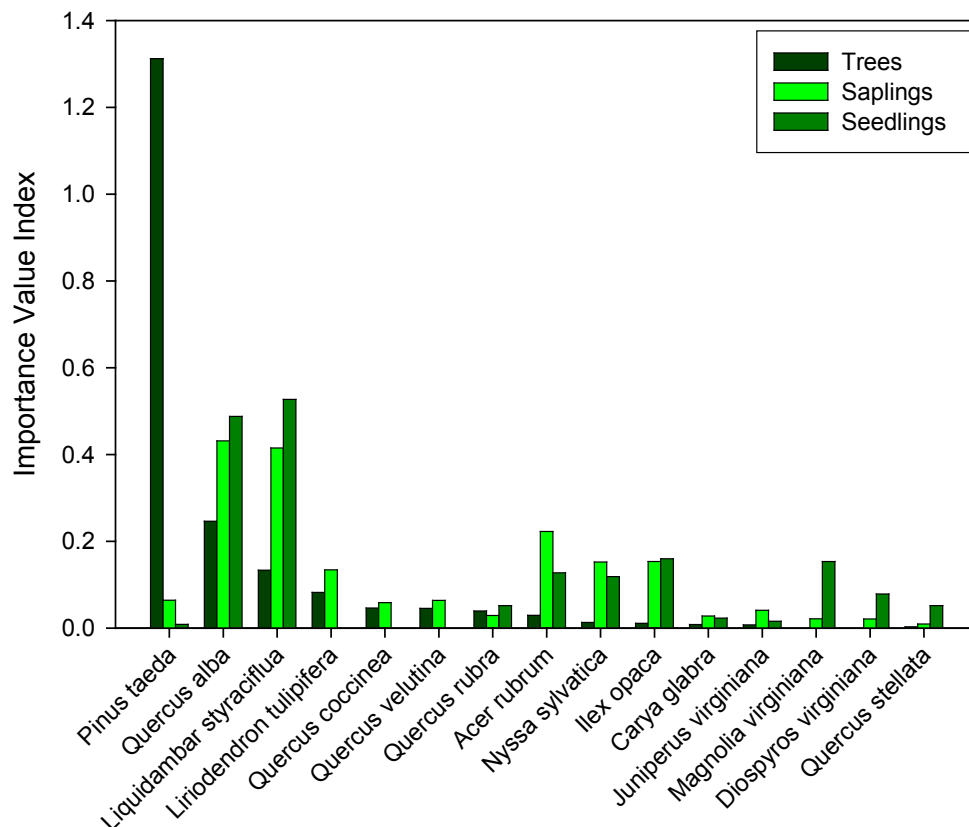


Figure 13. Composition of seedlings, saplings, and trees in forest vegetation plots at Five Forks unit of Petersburg NB.

Five Forks unit of Petersburg NB was predominantly dominated by various stages of loblolly pine (*Pinus taeda*) plantations (Figure 13). This is clearly seen by the dominance of this species in the canopy followed by white oak (*Quercus alba*) and sweetgum (*Liquidambar styraciflua*) as occasional components of the forest community. However, these hardwood species are showing healthy regeneration and are well represented in the seedling and sapling layers. As the more mature loblolly pines die out, the hardwoods have favorable densities to grow into the canopy. The mean seedling score at Five Forks unit was 25.9 per plot (“Caution”), with 39% of the plots having adequate regeneration under low deer densities and 14% under high deer density (Figure 3 and Table 21).

Richmond NBP

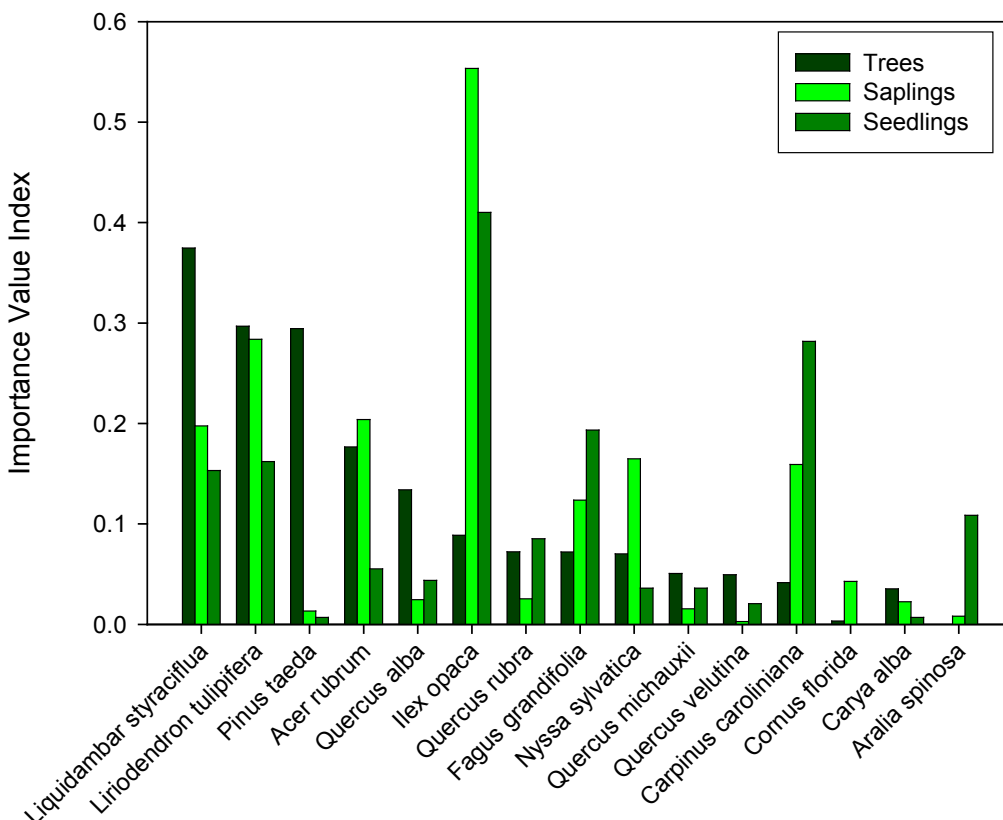


Figure 14. Composition of seedlings, saplings, and trees in forest vegetation plots at Richmond NBP.

Richmond NBP also has a gradually maturing forest composition, with loblolly pine (*Pinus taeda*) gradually being replaced by hardwood species such as sweetgum (*Liquidambar styraciflua*) and tulip poplar (*Liriodendron tulipifera*) (Figure 14). American beech (*Fagus grandifolia*), was showing increasing levels of regeneration as the forests are becoming more mesic. As observed throughout the region (Patterson 2008e), red maple (*Acer rubrum*) was regenerating very well as are some of the lower canopy species including American holly (*Ilex opaca*), musclewood (*Carpinus caroliniana*), and blackgum (*Nyssa sylvatica*). The mean seedling score at Richmond NBP was 31.1 per plot (“Caution”), with 31% of the plots having adequate regeneration under low deer densities and 9% under high deer density (Figure 3 and Table 21).

Sagamore Hill NHS

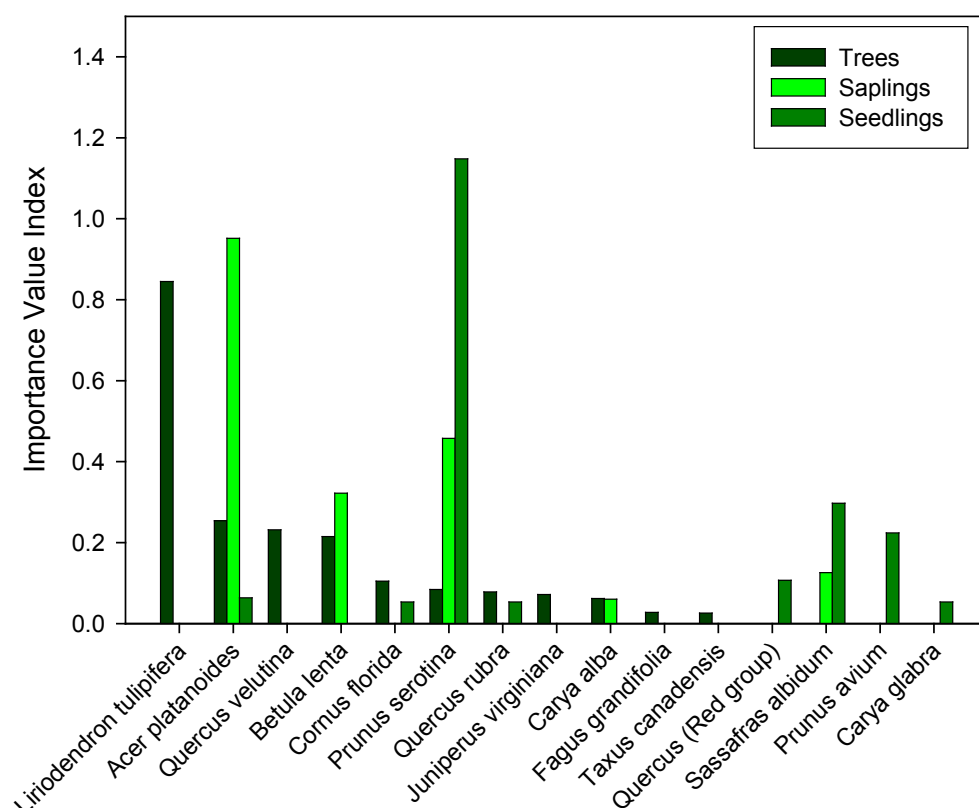


Figure 15. Composition of seedlings, saplings, and trees in forest vegetation plots at Sagamore Hill NHS.

Only four plots were established at Sagamore Hill NHS due to the small size of the park and total forested area. The dominant species in the canopy was tulip poplar (*Liriodendron tulipifera*), with a much lower but similar density of Norway maple (*Acer platanoides*), black oak (*Quercus velutina*), and sweet birch (*Betula lenta*) (Figure 15). Norway maple is an exotic species which was the dominant member of the sapling layer (Edinger et al. 2008). Most of the seedlings, however, were black cherry (*Prunus serotina*), a tree that does not reach the canopy. Black oak and red oak were virtually absent from the seedling layer. The mean seedling score at Sagamore Hill NHS was 3.5 per plot (“Significant Concern”), with 0% of the plots having adequate regeneration under low deer densities and 0% under high deer density (Figure 3 and Table 21).

Thomas Stone NHS

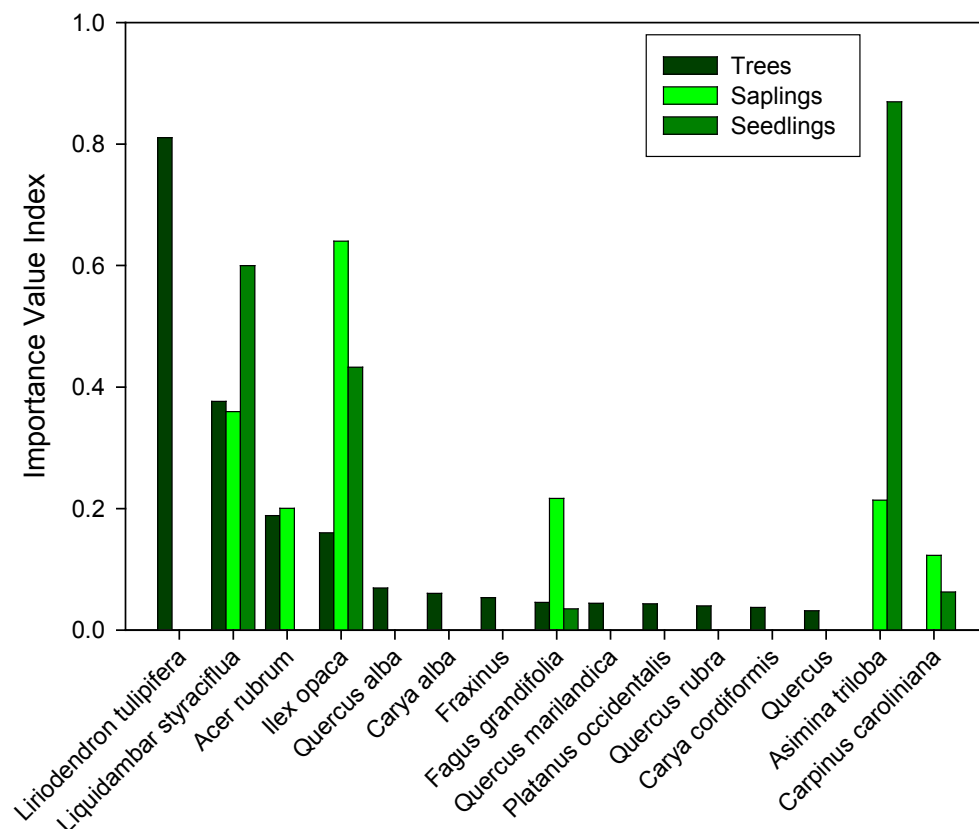


Figure 16. Composition of seedlings, saplings, and trees in forest vegetation plots at Thomas Stone NHS.

Much of the canopy at Thomas Stone NHS was dominated by the successional species tulip poplar (*Liriodendron tulipifera*) and sweetgum (*Liquidambar styraciflua*), the latter also an important component of the seedling and sapling layer along with American holly (*Ilex opaca*) (Figure 16). Unlike other parks in the Mid-Atlantic, pawpaw (*Asimina triloba*) formed an important component of the seedling and sapling layer; this species has also been observed in high densities at several parks in the National Capital Region Network (Schmit et al. 2010). The mean seedling score at Thomas Stone NHS was 15.8 per plot (“Significant Concern”), with 50% of the plots having adequate regeneration under low deer densities and 0% under high deer density (Figure 3 and Table 21).

Valley Forge NHP

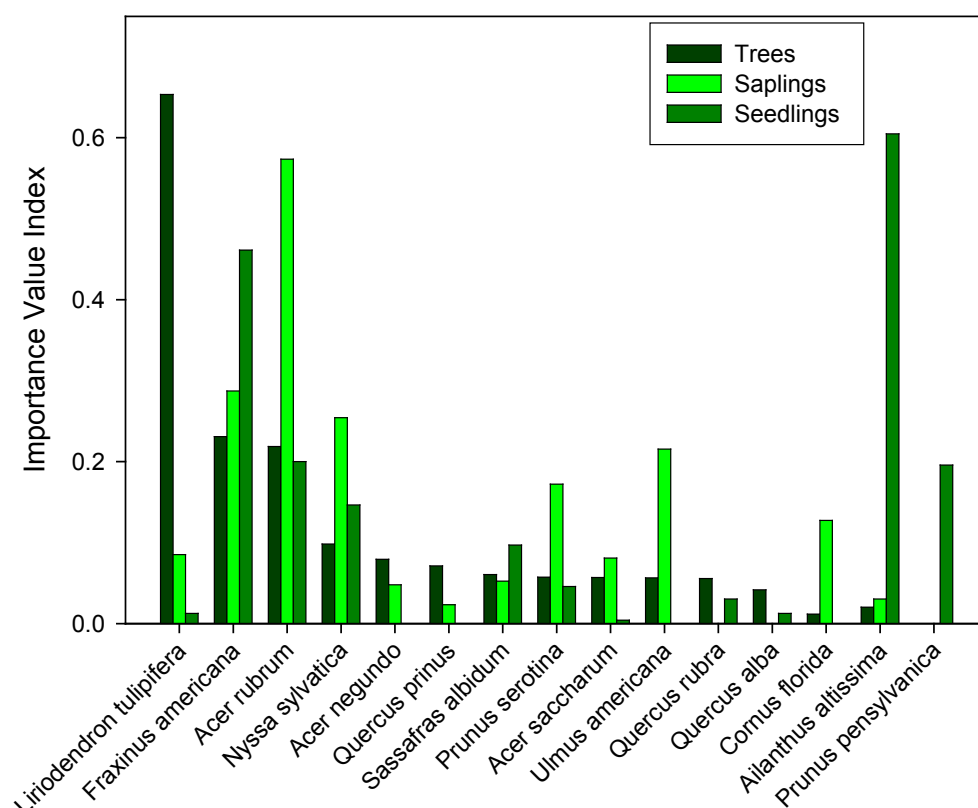


Figure 17. Composition of seedlings, saplings, and trees in forest vegetation plots at Valley Forge NHP.

The forests of Valley Forge NHP were largely composed of maturing successional species, tulip poplar (*Liriodendron tulipifera*), with very little regeneration and a sparse sapling layer (Figure 17). Among the saplings, the dominant species were red maple (*Acer rubrum*), white ash (*Fraxinus americana*), and blackgum (*Nyssa sylvatica*). The majority of the seedlings regenerating at Valley Forge NHP were tree of heaven (*Ailanthus altissima*), primarily due to their heavy resistance to deer grazing (Meloche and Murphy 2006), closely followed by white ash. The mean seedling score at Valley Forge NHP was 1.1 per plot (“Significant Concern”), with 0% of the plots having adequate regeneration under low deer densities and 0% under high deer density (Figure 3 and Table 21).

With the implementation of the deer management plan (NPS 2009), we expect to see regeneration at Valley Forge NHP increasing gradually over the coming years to levels comparable to those observed in Gettysburg NMP. However, like in Gettysburg NMP, we will likely also see a drastic expansion in the invasive exotic plant populations that are already well established in the park.

Soil Chemistry

Ecological integrity metrics are reported for soil chemistry as they are indicative of the effects of acid deposition on soil nutrients including calcium (Ca), magnesium (Mg), and potassium (K). Leaching can increase the availability of aluminum (Al) which is toxic to forest plants (Driscoll et al. 2001). For ratios as low as 1, there is an estimated 50% risk of adverse impact on growth across a wide range of tree species (Cronan and Grigal 1995).

Good: Ca:Al ratio > 4.0 in O and A horizons or in upper depth.

Caution: Ca:Al ratio from 1-4 in O or A horizon or in upper depth.

Significant Concern: Ca:Al ratio < 1.0 in O or A horizon or in upper depth.

In addition, increased nitrogen (N) loading can cause nitrification and reduce plant vigor. Ratios of C:N below 20-25 result in nitrification.

Good: C:N ratio > 25 in O and A horizon or in upper depth.

Caution: C:N ratio from 20-25 in O and A horizon or in upper depth.

Significant Concern: C:N ratio < 20 in O and A horizon or in upper depth.

Soil samples were collected from the O and A horizons at three locations in each plot in 2010. If the horizons were not apparent, a composite sample was collected from the top 10 cm (upper depth). The soils were analyzed for a suite of metrics, but currently we only report on the ratio of Ca to Al as an indicator of acid stress, and the ratio of total C to total N as an indicator of nitrogen status.

Results show that all parks across the network had at least one metric that was either of “Significant Concern” or “Caution” (Table 22). Acidification is of “Concern” in Fredericksburg and Spotsylvania NMP, Hopewell Furnace NHS, Petersburg NB, Richmond NBP, Thomas Stone NHS, and Valley Forge NHP. Nitrification is of “Concern” in all parks except in the Five Forks unit of Petersburg NB.

This data needs to be interpreted with caution as soil sampling was only conducted in 2010, so the sample size is based on one quarter of the plots established. In addition, there is disagreement among soil scientists as to whether these metrics are sufficient for interpreting acid deposition stress on forest soils. Furthermore, different labs use different extraction methods that may overestimate the values beyond those that would normally be available and affect plants. Over the coming years we hope to gain a better understanding and approach to sampling and reporting soil chemistry.

Table 22. Soil chemistry ratings for forest vegetation monitoring plots sampled in 2010 in the Mid-Atlantic and Northeast Coastal and Barrier networks.

Unit	Median Ca:Al	Ca:Al Rating	Median C:N	C:N Rating
APCO	15.00	Good	14.73	Significant Concern
BOWA	44.96	Good	18.89	Significant Concern
FRSP_CHWILD	0.07	Significant Concern	24.99	Caution
FRSP_FRED	0.41	Significant Concern	19.52	Significant Concern
FRSP_SPOT	0.66	Significant Concern	19.19	Significant Concern
GETT	37.13	Good	14.29	Significant Concern
GEWA	19.04	Good	14.52	Significant Concern
HOFU	0.73	Significant Concern	15.89	Significant Concern
PETE_EAST	0.27	Significant Concern	20.61	Caution
PETE_FIVE	0.20	Significant Concern	27.79	Good
RICH	1.05	Caution	22.06	Caution
THST	0.46	Significant Concern	14.25	Significant Concern
VAFO	1.28	Caution	21.42	Caution

Park Summaries

Appomattox Court House NHP

Twenty-eight plots were established at Appomattox Court House NHP containing 617 trees ≥ 10 cm DBH belonging to 37 species with an average of 6.1 species per plot. The most common tree species were tulip poplar (*Liriodendron tulipifera*) and Virginia pine (*Pinus virginiana*). About 50% of the plots were composed of mature to late-successional forests. Most of the plots displayed few negative tree conditions. One plot was categorized as “Significant Concern” for tree condition due to the proportion of tree leaves with necrosis and holes. Over 9% of standing trees were snags, with 5% being snags with a diameter ≥ 30 cm. For saplings, 693 were measured belonging to 42 species with an average of 7 species per plot. The most common saplings were flowering dogwood (*Cornus florida*) and red maple (*Acer rubrum*). For shrubs, 146 were measured belonging to 10 species. The most common shrub species was blueberries (*Vaccinium* spp.). Tree seedlings were measured in 12 quadrats per plot, resulting in 495 individuals belonging to 33 species with an average of 4.3 species per plot. An additional eight species of tree seedlings were noted in the quadrats but were below the minimum height of the smallest height class category. The most common tree seedlings were flowering dogwood (*Cornus florida*) and red maple (*Acer rubrum*). In terms of forest regeneration, 39% of plots had adequate regeneration under high deer densities. Native and exotic vines were common in the park, with nine species occurring in quadrats and two species reaching the canopy. The most common vine species reaching the canopy at Appomattox Court House NHP were grape (*Vitis* spp.) and eastern poison ivy (*Toxicodendron radicans*). Among the target list of 29 invasive exotic indicator species, eight occurred in quadrats and one additional species was found in a plot outside the quadrats. Twenty-six plots and 54% of quadrats had exotic indicators. Japanese honeysuckle (*Lonicera japonica*) occurred in quadrats in the greatest number of plots and Japanese stiltgrass (*Microstegium vimineum*) had the greatest average cover per quadrat. Of the target list of 33 native indicator species and taxa, 23 were encountered; Virginia creeper (*Parthenocissus quinquefolia*) occurred in the greatest number of plots and Christmas fern (*Polystichum acrostichoides*) and blueberries (*Vaccinium* spp.) had the greatest average cover per quadrat. The most common deer-preferred herbaceous species encountered were greenbrier (*Smilax* spp.), feathery false lily of the valley (*Maianthemum racemosum*), and perfoliate bellwort (*Uvularia perfoliata*). The mean ratio of CWD to live standing trees was about 20%, a rating considered to be “Good”. Soils were sampled only in 2010. The ratio of calcium to aluminum was ranked as “Good” and that of carbon to nitrogen as “Significant Concern”.

Booker T. Washington NM

Eight plots were established at Booker T. Washington NM containing 175 trees ≥ 10 cm DBH belonging to 23 species with an average of 6.5 species per plot. The most common tree species were Virginia pine (*Pinus virginiana*) and red maple (*Acer rubrum*). About 75% of the plots were composed of mature to late-successional forests. Most of the plots displayed few negative tree conditions. One plot was categorized as “Significant Concern” for tree condition due to the proportion of tree leaves with necrosis and holes. Over 15% of standing trees were snags, with 7% being snags with a diameter ≥ 30 cm. For saplings, 128 were measured belonging to 18 species with an average of 5.1 species per plot. The most common saplings were flowering dogwood (*Cornus florida*) and blackgum (*Nyssa sylvatica*). For shrubs, 13 were measured belonging to one species. The most common shrub species was spicebush (*Lindera benzoin*).

Tree seedlings were measured in 12 quadrats per plot, resulting in 306 individuals belonging to 21 species with an average of 5.9 species per plot. An additional two species of tree seedlings were noted in the quadrats but were below the minimum height of the smallest height class category. The most common tree seedlings were white oak (*Quercus alba*) and musclewood (*Carpinus caroliniana*). In terms of forest regeneration, 50% of plots had adequate regeneration under high deer densities. Native and exotic vines were common in the park, with seven species occurring in quadrats and one species reaching the canopy. The most common vine species reaching the canopy at Booker T. Washington NM was common trumpet creeper (*Campsis radicans*). Among the target list of 29 invasive exotic indicator species, four occurred in quadrats and with no additional species found in a plot outside the quadrats. Seven plots and 65% of quadrats had exotic indicators. India mockstrawberry (*Duchesnea indica*) occurred in quadrats in the greatest number of plots and Japanese honeysuckle (*Lonicera japonica*) had the greatest average cover per quadrat. Of the target list of 33 native indicator species and taxa, 17 were encountered; Virginia creeper (*Parthenocissus quinquefolia*) occurred in the greatest number of plots and grasses (*Poaceae* spp.) had the greatest average cover per quadrat. The most common deer-preferred herbaceous species encountered were common greenbrier (*Smilax* spp.), cat greenbrier (*Smilax glauca*), and smooth Solomons seal (*Polygonatum biflorum*). The mean ratio of CWD to live standing trees was about 14%, a rating considered to be “Caution”. Soils were sampled only in 2010. The ratio of calcium to aluminum was ranked as “Good” and that of carbon to nitrogen as “Significant Concern”.

Chancellorsville and Wilderness unit of Fredericksburg and Spotsylvania NMP

Forty-eight plots were established at Chancellorsville and Wilderness unit of Fredericksburg and Spotsylvania NMP containing 902 trees ≥ 10 cm DBH belonging to 30 species with an average of 5.8 species per plot. The most common tree species were white oak (*Quercus alba*) and Virginia pine (*Pinus virginiana*). About 87% of the plots were composed of mature to late-successional forests. Most of the plots displayed few negative tree conditions. Three plots were categorized as “Significant Concern” for tree condition due to the proportion of tree leaves with necrosis and holes. Over 9% of standing trees were snags, with 4% being snags with a diameter ≥ 30 cm. For saplings, 557 were measured belonging to 27 species with an average of 3.8 species per plot. The most common saplings were blackgum (*Nyssa sylvatica*) and red maple (*Acer rubrum*). For shrubs, 258 were measured belonging to five species. The most common shrub species was blueberries (*Vaccinium* spp.). Tree seedlings were measured in 12 quadrats per plot, resulting in 796 individuals belonging to 27 species with an average of 3.7 species per plot. An additional four species of tree seedlings were noted in the quadrats but were below the minimum height of the smallest height class category. The most common tree seedlings were white oak (*Quercus alba*) and sweetgum (*Liquidambar styraciflua*). In terms of forest regeneration, 42% of plots had adequate regeneration under high deer densities. Native and exotic vines were common in the park, with nine species occurring in quadrats and three species reaching the canopy. The most common vine species reaching the canopy at Chancellorsville and Wilderness unit of Fredericksburg and Spotsylvania NMP were eastern poison ivy (*Toxicodendron radicans*) and grape (*Vitis* spp.). Among the target list of 29 invasive exotic indicator species, five occurred in quadrats and two additional species were found in a plot outside the quadrats. Eight plots and 10% of quadrats had exotic indicators. Japanese honeysuckle (*Lonicera japonica*) occurred in quadrats in the greatest number of plots and also had the greatest average cover per quadrat. Of the target list of 33 native indicator species and taxa, 22 were encountered; blueberries (*Vaccinium* spp.) occurred in the greatest number of plots and also had the greatest average cover

per quadrat. The most common deer-preferred herbaceous species encountered were roundleaf greenbrier (*Smilax rotundifolia*) and perfoliate bellwort (*Uvularia perfoliata*). The mean ratio of CWD to live standing trees was about 20%, a rating considered to be “Good”. Soils were sampled only in 2010. The ratio of calcium to aluminum was ranked as “Significant Concern” and that of carbon to nitrogen as “Caution”.

Fredericksburg unit of Fredericksburg and Spotsylvania NMP

Twenty-eight plots were established at Fredericksburg unit of Fredericksburg and Spotsylvania NMP containing 467 trees ≥ 10 cm DBH belonging to 25 species with an average of 5.3 species per plot. The most common tree species were white oak (*Quercus alba*) and willow oak (*Quercus phellos*). About 89% of the plots were composed of mature to late-successional forests. Most of the plots displayed few negative tree conditions. Over 8% of standing trees were snags, with 7% being snags with a diameter ≥ 30 cm. For saplings, 301 were measured belonging to 21 species with an average of 3.8 species per plot. The most common saplings were eastern redcedar (*Juniperus virginiana*) and blackgum (*Nyssa sylvatica*). For shrubs, 97 were measured belonging to four species. The most common shrub species was blueberries (*Vaccinium* spp.). Tree seedlings were measured in 12 quadrats per plot, resulting in 202 individuals belonging to 19 species with an average of 2.6 species per plot. An additional seven species of tree seedlings were noted in the quadrats but were below the minimum height of the smallest height class category. The most common tree seedlings were sweetgum (*Liquidambar styraciflua*) and sassafras (*Sassafras albidum*). In terms of forest regeneration, 29% of plots had adequate regeneration under high deer densities. Native and exotic vines were common in the park, with eight species occurring in quadrats and three species reaching the canopy. The most common vine species reaching the canopy at Fredericksburg unit of Fredericksburg and Spotsylvania NMP were eastern poison ivy (*Toxicodendron radicans*) and grape (*Vitis* spp.). Among the target list of 29 invasive exotic indicator species, five occurred in quadrats and four additional species were found in a plot outside the quadrats. Seven plots and 5% of quadrats had exotic indicators. Japanese honeysuckle (*Lonicera japonica*) occurred in quadrats in the greatest number of plots and Japanese stiltgrass (*Microstegium vimineum*) had the greatest average cover per quadrat. Of the target list of 33 native indicator species and taxa, 19 were encountered; greenbrier (*Smilax* spp.) occurred in the greatest number of plots and highbush blueberry (*Vaccinium corymbosum*) and ferns had the greatest average cover per quadrat. The most common deer-preferred herbaceous species encountered were common greenbrier (*Smilax* spp.), roundleaf greenbrier (*Smilax rotundifolia*), and cat greenbrier (*Smilax glauca*). The mean ratio of CWD to live standing trees was about 27%, a rating considered to be “Good”. Soils were sampled only in 2010. The ratio of calcium to aluminum was ranked as “Significant Concern” and that of carbon to nitrogen as “Significant Concern”.

Spotsylvania unit of Fredericksburg and Spotsylvania NMP

Twenty-eight plots were established at Spotsylvania unit of Fredericksburg and Spotsylvania NMP containing 575 trees ≥ 10 cm DBH belonging to 24 species with an average of 6.1 species per plot. The most common tree species were white oak (*Quercus alba*) and willow oak (*Quercus phellos*). About 89% of the plots were composed of mature to late-successional forests. Most of the plots displayed few negative tree conditions. Over 10% of standing trees were snags, with 5% being snags with a diameter ≥ 30 cm. For saplings, 314 were measured belonging to 18 species with an average of 3.8 species per plot. The most common saplings were eastern redcedar (*Juniperus virginiana*) and blackgum (*Nyssa sylvatica*). For shrubs, 7 were measured

belonging to four species. The most common shrub species was blueberries (*Vaccinium* spp.). Tree seedlings were measured in 12 quadrats per plot, resulting in 462 individuals belonging to 19 species with an average of 3.6 species per plot. An additional seven species of tree seedlings were noted in the quadrats but were below the minimum height of the smallest height class category. The most common tree seedlings were sweetgum (*Liquidambar styraciflua*) and sassafras (*Sassafras albidum*). In terms of forest regeneration, 68% of plots had adequate regeneration under high deer densities. Native and exotic vines were common in the park, with seven species occurring in quadrats and two species reaching the canopy. The most common vine species reaching the canopy at Spotsylvania unit of Fredericksburg and Spotsylvania NMP were grape (*Vitis* spp.) and greenbrier (*Smilax* spp.). Among the target list of 29 invasive exotic indicator species, four occurred in quadrats and one additional species was found in a plot outside the quadrats. Four plots and 3% of quadrats had exotic indicators. India mockstrawberry (*Duchesnea indica*) occurred in quadrats in the greatest number of plots and also had the greatest average cover per quadrat. Of the target list of 33 native indicator species and taxa, 20 were encountered; blueberries (*Vaccinium* spp.) occurred in the greatest number of plots and deerberry (*Vaccinium stamineum*) and New York fern (*Thelypteris noveboracensis*) had the greatest average cover per quadrat. The most common deer-preferred herbaceous species encountered were common greenbrier (*Smilax* spp.), roundleaf greenbrier (*Smilax rotundifolia*), and feathery false lily of the valley (*Maianthemum racemosum*). The mean ratio of CWD to live standing trees was about 10%, a rating considered to be “Caution”. Soils were sampled only in 2010. The ratio of calcium to aluminum was ranked as “Significant Concern” and that of carbon to nitrogen as “Significant Concern”.

Gettysburg NMP

Thirty-two plots were established at Gettysburg NMP containing 410 trees ≥ 10 cm DBH belonging to 33 species with an average of 5.5 species per plot. The most common tree species were red oak (*Quercus rubra*) and white oak (*Quercus alba*). About 85% of the plots were composed of mature to late-successional forests. Most of the plots displayed few negative tree conditions. Over 14% of standing trees were snags, with 10% being snags with a diameter ≥ 30 cm. For saplings, 284 were measured belonging to 23 species with an average of 2.6 species per plot. The most common saplings were white ash (*Fraxinus americana*) and eastern redbud (*Cercis canadensis*). For shrubs, 394 were measured belonging to nine species. The most common shrub species was spicebush (*Lindera benzoin*). Tree seedlings were measured in 12 quadrats per plot, resulting in 747 individuals belonging to 32 species with an average of 4.1 species per plot. An additional nine species of tree seedlings were noted in the quadrats but were below the minimum height of the smallest height class category. The most common tree seedlings were white ash (*Fraxinus americana*) and sassafras (*Sassafras albidum*). In terms of forest regeneration, 59% of plots had adequate regeneration under high deer densities. Native and exotic vines were common in the park, with eight species occurring in quadrats and three species reaching the canopy. The most common vine species reaching the canopy at Gettysburg NMP were grape (*Vitis* spp.) and Virginia creeper (*Parthenocissus quinquefolia*). Among the target list of 29 invasive exotic indicator species, 12 occurred in quadrats and with no additional species found in a plot outside the quadrats. Thirty-two plots and 86% of quadrats had exotic indicators. Japanese honeysuckle (*Lonicera japonica*) occurred in quadrats in the greatest number of plots and Japanese stiltgrass (*Microstegium vimineum*) and Japanese barberry (*Berberis thunbergii*) had the greatest average cover per quadrat. Of the target list of 33 native indicator species and taxa, 20 were encountered; Virginia creeper (*Parthenocissus quinquefolia*)

occurred in the greatest number of plots and grasses (*Poaceae* spp.) and Virginia creeper (*Parthenocissus quinquefolia*) had the greatest average cover per quadrat. The most common deer-preferred herbaceous species encountered were common greenbrier (*Smilax* spp.), Lilies (*Lilium*), and jewelweed (*Impatiens capensis*). The mean ratio of CWD to live standing trees was about 21%, a rating considered to be “Good”. Soils were sampled only in 2010. The ratio of calcium to aluminum was ranked as “Good” and that of carbon to nitrogen as “Significant Concern”.

George Washington Birthplace NM

Six plots were established at George Washington Birthplace NM containing 142 trees ≥ 10 cm DBH belonging to 17 species with an average of 5.3 species per plot. The most common tree species were loblolly pine (*Pinus taeda*) and sweetgum (*Liquidambar styraciflua*). About 100% of the plots were composed of mature to late-successional forests. Most of the plots displayed few negative tree conditions. Over 10% of standing trees were snags, with 11% being snags with a diameter ≥ 30 cm. For saplings, 45 were measured belonging to 5 species with an average of 1.5 species per plot. The most common saplings were American holly (*Ilex opaca*) and pawpaw (*Asimina triloba*). For shrubs, 9 were measured belonging to one species. The most common shrub species was spicebush (*Lindera benzoin*). Tree seedlings were measured in 12 quadrats per plot, resulting in 20 individuals belonging to four species with an average of 1.7 species per plot. An additional three species of tree seedlings were noted in the quadrats but were below the minimum height of the smallest height class category. The most common tree seedlings were American holly (*Ilex opaca*) and pawpaw (*Asimina triloba*). In terms of forest regeneration, 0% of plots had adequate regeneration under high deer densities. Native and exotic vines were common in the park, with eight species occurring in quadrats and four species reaching the canopy. The most common vine species reaching the canopy at George Washington Birthplace NM were grape (*Vitis* spp.) and eastern poison ivy (*Toxicodendron radicans*). Among the target list of 29 invasive exotic indicator species, three occurred in quadrats and one additional species was found in a plot outside the quadrats. Three plots and 32% of quadrats had exotic indicators. Japanese honeysuckle (*Lonicera japonica*) occurred in quadrats in the greatest number of plots and Japanese stiltgrass (*Microstegium vimineum*) had the greatest average cover per quadrat. Of the target list of 33 native indicator species and taxa, 13 were encountered; roundleaf greenbrier (*Smilax rotundifolia*) occurred in the greatest number of plots and grape (*Vitis* spp.) had the greatest average cover per quadrat. The most common deer-preferred herbaceous species encountered were jewelweed (*Impatiens capensis*), roundleaf greenbrier (*Smilax rotundifolia*), and common greenbrier (*Smilax* spp.). The mean ratio of CWD to live standing trees was about 7%, a rating considered to be “Caution”. Soils were sampled only in 2010. The ratio of calcium to aluminum was ranked as “Good” and that of carbon to nitrogen as “Significant Concern”.

Hopewell Furnace NHS

Sixteen plots were established at Hopewell Furnace NHS containing 228 trees ≥ 10 cm DBH belonging to 22 species with an average of 5.4 species per plot. The most common tree species were red maple (*Acer rubrum*) and black oak (*Quercus velutina*). About 93% of the plots were composed of mature to late-successional forests. Most of the plots displayed few negative tree conditions. One plot was categorized as “Significant Concern” for tree condition due to the proportion of tree leaves with necrosis and holes. Over 7% of standing trees were snags, with 3% being snags with a diameter ≥ 30 cm. For saplings, 37 were measured belonging to 9 species with an average of 0.9 species per plot. The most common saplings were blackgum (*Nyssa*

sylvatica) and tulip poplar (*Liriodendron tulipifera*). For shrubs, 166 were measured belonging to four species. The most common shrub species was Japanese barberry (*Berberis thunbergii*). Tree seedlings were measured in 12 quadrats per plot, resulting in 150 individuals belonging to 14 species with an average of 2.4 species per plot. An additional two species of tree seedlings were noted in the quadrats but were below the minimum height of the smallest height class category. The most common tree seedlings were sweet birch (*Betula lenta*) and sassafras (*Sassafras albidum*). In terms of forest regeneration, 13% of plots had adequate regeneration under high deer densities. Native and exotic vines were common in the park, with nine species occurring in quadrats and four species reaching the canopy. The most common vine species reaching the canopy at Hopewell Furnace NHS were grape (*Vitis* spp.) and Virginia creeper (*Parthenocissus quinquefolia*). Among the target list of 29 invasive exotic indicator species, 10 occurred in quadrats and with no additional species found in a plot outside the quadrats. Thirteen plots and 61% of quadrats had exotic indicators. Japanese stiltgrass (*Microstegium vimineum*) occurred in quadrats in the greatest number of plots and also had the greatest average cover per quadrat. Of the target list of 33 native indicator species and taxa, 22 were encountered; Virginia creeper (*Parthenocissus quinquefolia*) occurred in the greatest number of plots and New York fern (*Thelypteris noveboracensis*) had the greatest average cover per quadrat. The most common deer-preferred herbaceous species encountered were jewelweed (*Impatiens capensis*), common greenbrier (*Smilax* spp.), and roundleaf greenbrier (*Smilax rotundifolia*). The mean ratio of CWD to live standing trees was about 8%, a rating considered to be “Caution”. Soils were sampled only in 2010. The ratio of calcium to aluminum was ranked as “Significant Concern” and that of carbon to nitrogen as “Significant Concern”.

Eastern unit of Petersburg NB

Twenty-eight plots were established at Eastern unit of Petersburg NB containing 588 trees ≥ 10 cm DBH belonging to 29 species with an average of 5.3 species per plot. The most common tree species were sweetgum (*Liquidambar styraciflua*) and loblolly pine (*Pinus taeda*). About 83% of the plots were composed of mature to late-successional forests. Most of the plots displayed few negative tree conditions. Over 10% of standing trees were snags, with 15% being snags with a diameter ≥ 30 cm. For saplings, 205 were measured belonging to 25 species with an average of 3.1 species per plot. The most common saplings were sweetgum (*Liquidambar styraciflua*) and American holly (*Ilex opaca*). For shrubs, 52 were measured belonging to three species. The most common shrub species was blackberry (*Rubus* spp.). Tree seedlings were measured in 12 quadrats per plot, resulting in 322 individuals belonging to 20 species with an average of 2.2 species per plot. An additional six species of tree seedlings were noted in the quadrats but were below the minimum height of the smallest height class category. The most common tree seedlings were sweetgum (*Liquidambar styraciflua*) and white oak (*Quercus alba*). In terms of forest regeneration, 36% of plots had adequate regeneration under high deer densities. Native and exotic vines were common in the park, with nine species occurring in quadrats and six species reaching the canopy. The most common vine species reaching the canopy at Eastern unit of Petersburg NB were grape (*Vitis* spp.) and eastern poison ivy (*Toxicodendron radicans*). Among the target list of 29 invasive exotic indicator species, three occurred in quadrats and with no additional species found in a plot outside the quadrats. Nineteen plots and 32% of quadrats had exotic indicators. Japanese stiltgrass (*Microstegium vimineum*) occurred in quadrats in the greatest number of plots and also had the greatest average cover per quadrat. Of the target list of 33 native indicator species and taxa, 17 were encountered; grape (*Vitis* spp.) occurred in the greatest number of plots and blueberries (*Vaccinium* spp.) had the greatest average cover per

quadrat. The most common deer-preferred herbaceous species encountered were common greenbrier (*Smilax* spp.), orchids, and cat greenbrier (*Smilax glauca*). The mean ratio of CWD to live standing trees was about 37%, a rating considered to be “Good”. Soils were sampled only in 2010. The ratio of calcium to aluminum was ranked as “Significant Concern” and that of carbon to nitrogen as “Caution”.

Five Forks unit of Petersburg NB

Twenty-eight plots were established at Five Forks unit of Petersburg NB containing 972 trees $\geq$ 10 cm DBH belonging to 21 species with an average of 5.8 species per plot. The most common tree species were loblolly pine (*Pinus taeda*) and white oak (*Quercus alba*). About 33% of the plots were composed of mature to late-successional forests. Most of the plots displayed few negative tree conditions. Over 5% of standing trees were snags, with 0% being snags with a diameter $\geq$ 30 cm. For saplings, 558 were measured belonging to 21 species with an average of 6.3 species per plot. The most common saplings were white oak (*Quercus alba*) and sweetgum (*Liquidambar styraciflua*). For shrubs, 105 were measured belonging to seven species. The most common shrub species was highbush blueberry (*Vaccinium corymbosum*). Tree seedlings were measured in 12 quadrats per plot, resulting in 189 individuals belonging to 19 species with an average of 2.6 species per plot. An additional seven species of tree seedlings were noted in the quadrats but were below the minimum height of the smallest height class category. The most common tree seedlings were sweetgum (*Liquidambar styraciflua*) and white oak (*Quercus alba*). In terms of forest regeneration, 38% of plots had adequate regeneration under high deer densities. Native and exotic vines were common in the park, with nine species occurring in quadrats and one species reaching the canopy. The most common vine species reaching the canopy at Five Forks unit of Petersburg NB was grape (*Vitis* spp.). Among the target list of 29 invasive exotic indicator species, three occurred in quadrats and with no additional species found in a plot outside the quadrats. Three plots and 2% of quadrats had exotic indicators. Japanese honeysuckle (*Lonicera japonica*) occurred in quadrats in the greatest number of plots and also had the greatest average cover per quadrat. Of the target list of 33 native indicator species and taxa, 21 were encountered; blueberries (*Vaccinium* spp.) occurred in the greatest number of plots and also had the greatest average cover per quadrat. The most common deer-preferred herbaceous species encountered were roundleaf greenbrier (*Smilax rotundifolia*), common greenbrier (*Smilax* spp.), and cat greenbrier (*Smilax glauca*). The mean ratio of CWD to live standing trees was about 3%, a rating considered to be “Significant Concern”. Soils were sampled only in 2010. The ratio of calcium to aluminum was ranked as “Significant Concern” and that of carbon to nitrogen as “Good”.

Richmond NBP

Thirty-two plots were established at Richmond NBP containing 798 trees $\geq$ 10 cm DBH belonging to 35 species with an average of 6.3 species per plot. The most common tree species were sweetgum (*Liquidambar styraciflua*) and tulip poplar (*Liriodendron tulipifera*). About 77% of the plots were composed of mature to late-successional forests. Most of the plots displayed few negative tree conditions. One plot was categorized as “Significant Concern” for tree condition due to the proportion of tree leaves with necrosis and holes. Over 5% of standing trees were snags, with 5% being snags with a diameter $\geq$ 30 cm. For saplings, 448 were measured belonging to 31 species with an average of 4.1 species per plot. The most common saplings were American holly (*Ilex opaca*) and tulip poplar (*Liriodendron tulipifera*). For shrubs, 65 were measured belonging to eight species. The most common shrub species was highbush blueberry

(*Vaccinium corymbosum*). Tree seedlings were measured in 12 quadrats per plot, resulting in 167 individuals belonging to 25 species with an average of 2.3 species per plot. An additional four species of tree seedlings were noted in the quadrats but were below the minimum height of the smallest height class category. The most common tree seedlings were American holly (*Ilex opaca*) and musclewood (*Carpinus caroliniana*). In terms of forest regeneration, 31% of plots had adequate regeneration under high deer densities. Native and exotic vines were common in the park, with 10 species occurring in quadrats and eight species reaching the canopy. The most common vine species reaching the canopy at Richmond NBP were grape (*Vitis* spp.) and honeysuckle (*Lonicera* spp.). Among the target list of 29 invasive exotic indicator species, eight occurred in quadrats and one additional species was found in a plot outside the quadrats. Seventeen plots and 36% of quadrats had exotic indicators. Japanese honeysuckle (*Lonicera japonica*) occurred in quadrats in the greatest number of plots and Japanese stiltgrass (*Microstegium vimineum*) had the greatest average cover per quadrat. Of the target list of 33 native indicator species and taxa, 19 were encountered; grape (*Vitis* spp.) occurred in the greatest number of plots and ferns (all families) had the greatest average cover per quadrat. The most common deer-preferred herbaceous species encountered were roundleaf greenbrier (*Smilax rotundifolia*), jewelweed (*Impatiens capensis*), and cat greenbrier (*Smilax glauca*). The mean ratio of CWD to live standing trees was about 10%, a rating considered to be “Caution”. Soils were sampled only in 2010. The ratio of calcium to aluminum was ranked as “Caution” and that of carbon to nitrogen as “Caution”.

Sagamore Hill NHS

Four plots were established at Sagamore Hill NHS containing 41 trees ≥ 10 cm DBH belonging to 10 species with an average of 4.0 species per plot. The most common tree species were tulip poplar (*Liriodendron tulipifera*) and Norway maple (*Acer platanoides*). About 100% of the plots were composed of mature to late-successional forests. Most of the plots displayed few negative tree conditions. Over 5% of standing trees were snags, with 4% being snags with a diameter ≥ 30 cm. For saplings, 20 were measured belonging to 6 species with an average of 2.5 species per plot. The most common saplings were Norway maple (*Acer platanoides*) and black cherry (*Prunus serotina*). For shrubs, 88 were measured belonging to four species. The most common shrub species was spicebush (*Lindera benzoin*). Tree seedlings were measured in 12 quadrats per plot, resulting in 23 individuals belonging to seven species with an average of 2.2 species per plot. An additional four species of tree seedlings were noted in the quadrats but were below the minimum height of the smallest height class category. The most common tree seedlings were black cherry (*Prunus serotina*) and sassafras (*Sassafras albidum*). In terms of forest regeneration, 0% of plots had adequate regeneration under high deer densities. Native and exotic vines were common in the park, with six species occurring in quadrats and three species reaching the canopy. The most common vine species reaching the canopy at Sagamore Hill NHS were eastern poison ivy (*Toxicodendron radicans*) and grape (*Vitis* spp.). Among the target list of 29 invasive exotic indicator species, four occurred in quadrats and three additional species were found in a plot outside the quadrats. Four plots and 58% of quadrats had exotic indicators. Japanese honeysuckle (*Lonicera japonica*) occurred in quadrats in the greatest number of plots and oriental bittersweet (*Celastrus orbiculatus*) had the greatest average cover per quadrat. Of the target list of 33 native indicator species and taxa, eight were encountered; Virginia creeper (*Parthenocissus quinquefolia*) and eastern poison ivy (*Toxicodendron radicans*) occurred in the greatest number of plots and white wood aster (*Eurybia divaricata*) and eastern poison ivy (*Toxicodendron radicans*) had the greatest average cover per quadrat. The most common deer-

preferred herbaceous species encountered were jewelweed (*Impatiens capensis*), roundleaf greenbrier (*Smilax rotundifolia*), and smooth Solomons seal (*Polygonatum biflorum*). The mean ratio of CWD to live standing trees was about 2%, a rating considered to be “Significant Concern”. Soils have not been sampled in the park and therefore we cannot provide any data on the ratio of calcium to aluminum nor that of carbon to nitrogen.

Thomas Stone NHS

Six plots were established at Thomas Stone NHS containing 90 trees ≥ 10 cm DBH belonging to 13 species with an average of 5.2 species per plot. The most common tree species were tulip poplar (*Liriodendron tulipifera*) and sweetgum (*Liquidambar styraciflua*). About 83% of the plots were composed of mature to late-successional forests. Most of the plots displayed few negative tree conditions. Over 8% of standing trees were snags, with 0% being snags with a diameter ≥ 30 cm. For saplings, 33 were measured belonging to 9 species with an average of 2.2 species per plot. The most common saplings were American holly (*Ilex opaca*) and sweetgum (*Liquidambar styraciflua*). For shrubs, 107 were measured belonging to one species. The most common shrub species was spicebush (*Lindera benzoin*). Tree seedlings were measured in 12 quadrats per plot, resulting in 36 individuals belonging to five species with an average of 2.0 species per plot. An additional 11 species of tree seedlings were noted in the quadrats but were below the minimum height of the smallest height class category. The most common tree seedlings were pawpaw (*Asimina triloba*) and sweetgum (*Liquidambar styraciflua*). In terms of forest regeneration, 50% of plots had adequate regeneration under high deer densities. Native and exotic vines were common in the park, with seven species occurring in quadrats and three species reaching the canopy. The most common vine species reaching the canopy at Thomas Stone NHS were Virginia creeper (*Parthenocissus quinquefolia*) and eastern poison ivy (*Toxicodendron radicans*). Among the target list of 29 invasive exotic indicator species, four occurred in quadrats and with no additional species found in a plot outside the quadrats. Four plots and 50% of quadrats had exotic indicators. Japanese honeysuckle (*Lonicera japonica*) occurred in quadrats in the greatest number of plots and Japanese stiltgrass (*Microstegium vimineum*) had the greatest average cover per quadrat. Of the target list of 33 native indicator species and taxa, 20 were encountered; Virginia creeper (*Parthenocissus quinquefolia*) occurred in the greatest number of plots and ferns (all families) had the greatest average cover per quadrat. The most common deer-preferred herbaceous species encountered were Canadian woodnettle (*Laportea canadensis*), roundleaf greenbrier (*Smilax rotundifolia*), and cat greenbrier (*Smilax glauca*). The mean ratio of CWD to live standing trees was about 12%, a rating considered to be “Caution”. Soils were sampled only in 2010. The ratio of calcium to aluminum was ranked as “Significant Concern” and that of carbon to nitrogen as “Significant Concern”.

Valley Forge NHP

Twenty-eight plots were established at Valley Forge NHP containing 452 trees ≥ 10 cm DBH belonging to 31 species with an average of 4.6 species per plot. The most common tree species were tulip poplar (*Fraxinus americana*). About 92% of the plots were composed of mature to late-successional forests. Most of the plots displayed few negative tree conditions. Over 9% of standing trees were snags, with 6% being snags with a diameter ≥ 30 cm. For saplings, 84 were measured belonging to 13 species with an average of 1.6 species per plot. The most common saplings were red maple (*Acer rubrum*) and white ash (*Fraxinus americana*). For shrubs, 85 were measured belonging to seven species. The most common shrub species was American witchhazel (*Hamamelis virginiana*). Tree seedlings were measured in 12 quadrats per plot,

resulting in 243 individuals belonging to 15 species with an average of 1.4 species per plot. An additional two species of tree seedlings were noted in the quadrats but were below the minimum height of the smallest height class category. The most common tree seedlings were tree of heaven (*Ailanthus altissima*) and white ash (*Fraxinus americana*). In terms of forest regeneration, 0% of plots had adequate regeneration under high deer densities. Native and exotic vines were common in the park, with eight species occurring in quadrats and five species reaching the canopy. The most common vine species reaching the canopy at Valley Forge NHP were grape (*Vitis* spp.) and oriental bittersweet (*Celastrus orbiculatus*). Among the target list of 29 invasive exotic indicator species, 13 occurred in quadrats and with no additional species found in a plot outside the quadrats. Twenty-two plots and 62% of quadrats had exotic indicators. Japanese stiltgrass (*Microstegium vimineum*) occurred in quadrats in the greatest number of plots and also had the greatest average cover per quadrat. Of the target list of 33 native indicator species and taxa, 18 were encountered; Virginia creeper (*Parthenocissus quinquefolia*) occurred in the greatest number of plots and blackberry (*Rubus* spp.) had the greatest average cover per quadrat. The most common deer-preferred herbaceous species encountered were common greenbrier (*Smilax* spp.) and cat greenbrier (*Smilax glauca*). The mean ratio of CWD to live standing trees was about 19%, a rating considered to be “Good”. Soils were sampled only in 2010. The ratio of calcium to aluminum was ranked as “Caution” and that of carbon to nitrogen as “Caution”.

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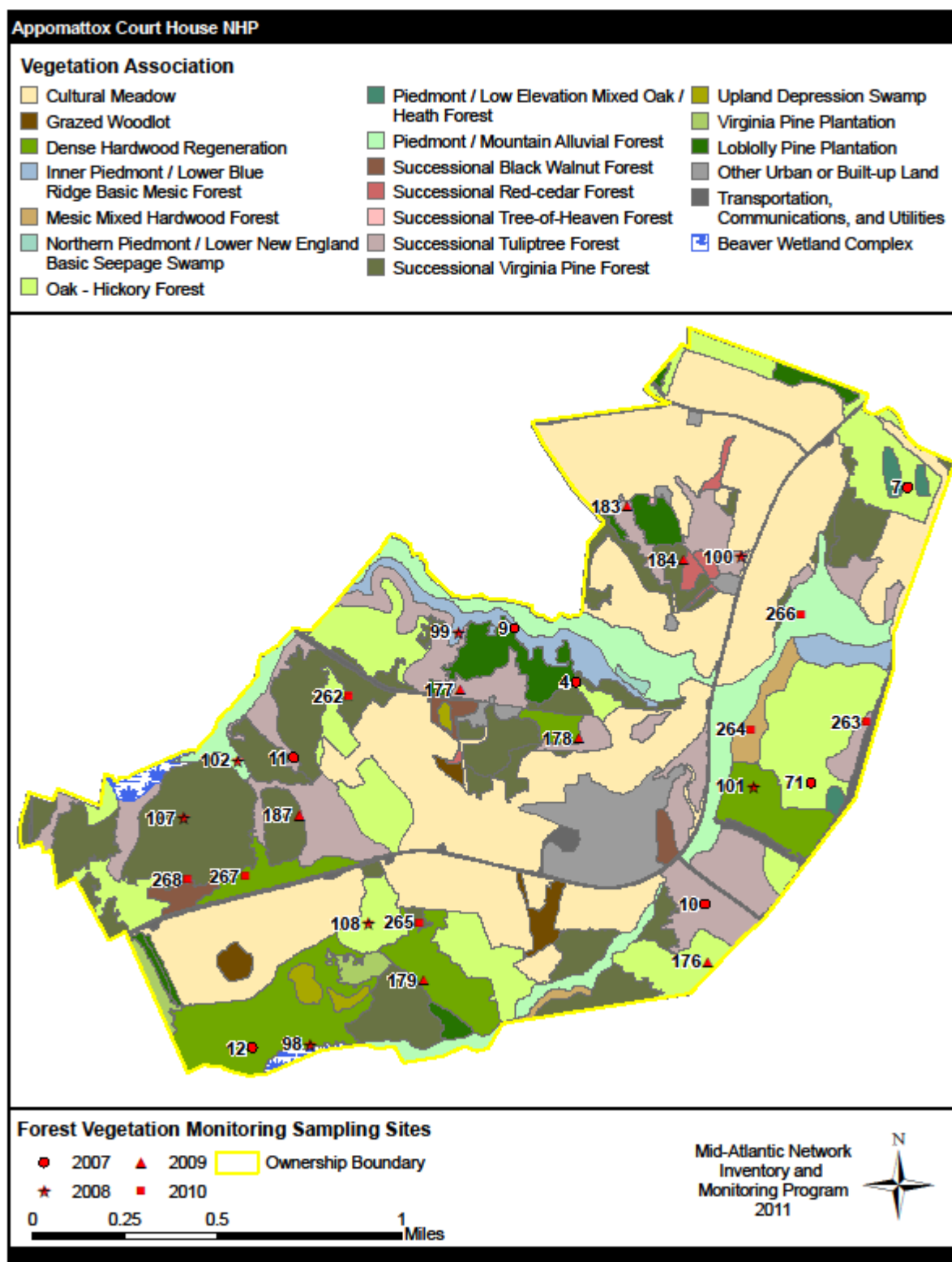
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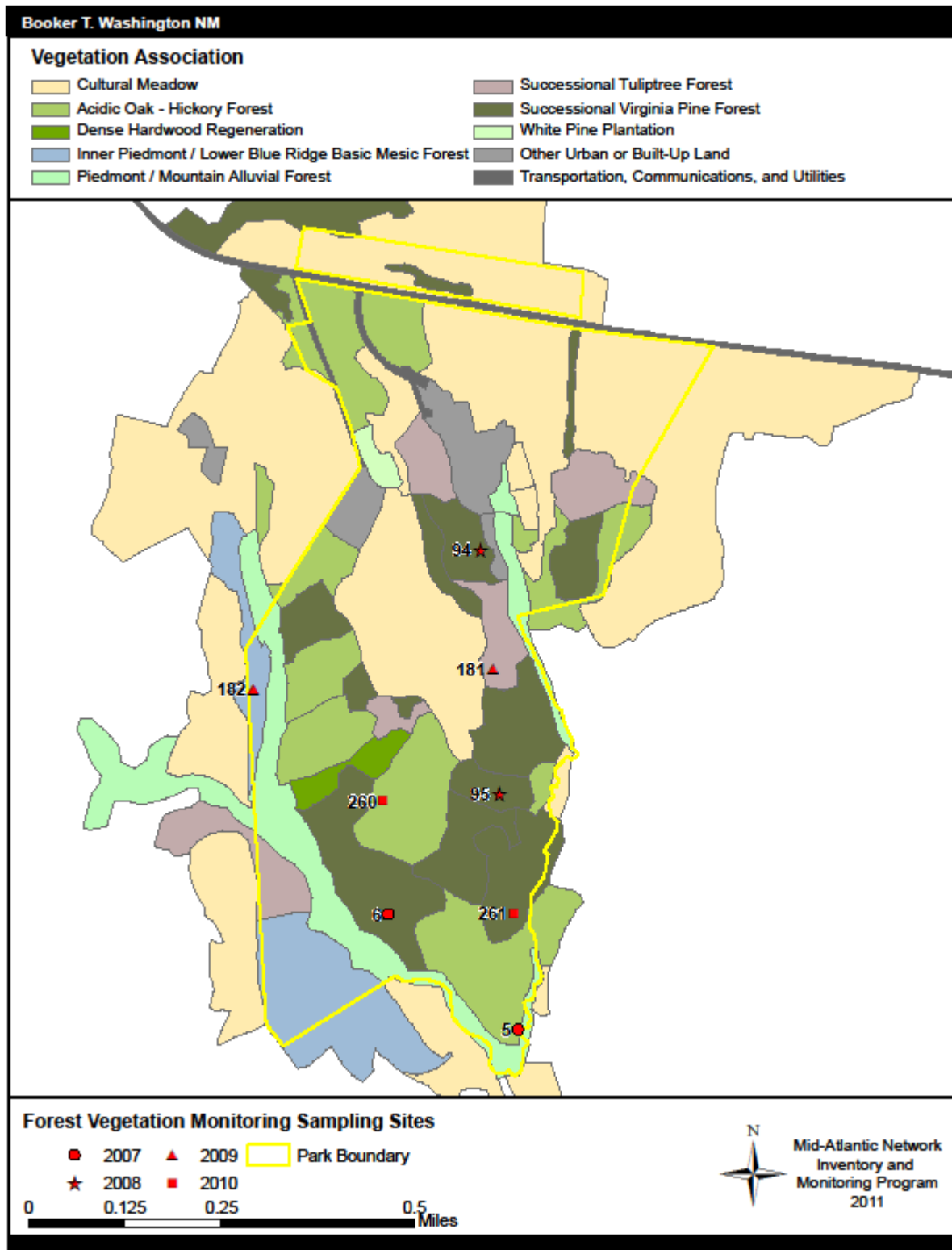
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Appendix A. Maps of forest vegetation monitoring plots established between 2007 and 2010 in the Mid-Atlantic and Northeast Coastal and Barrier networks.

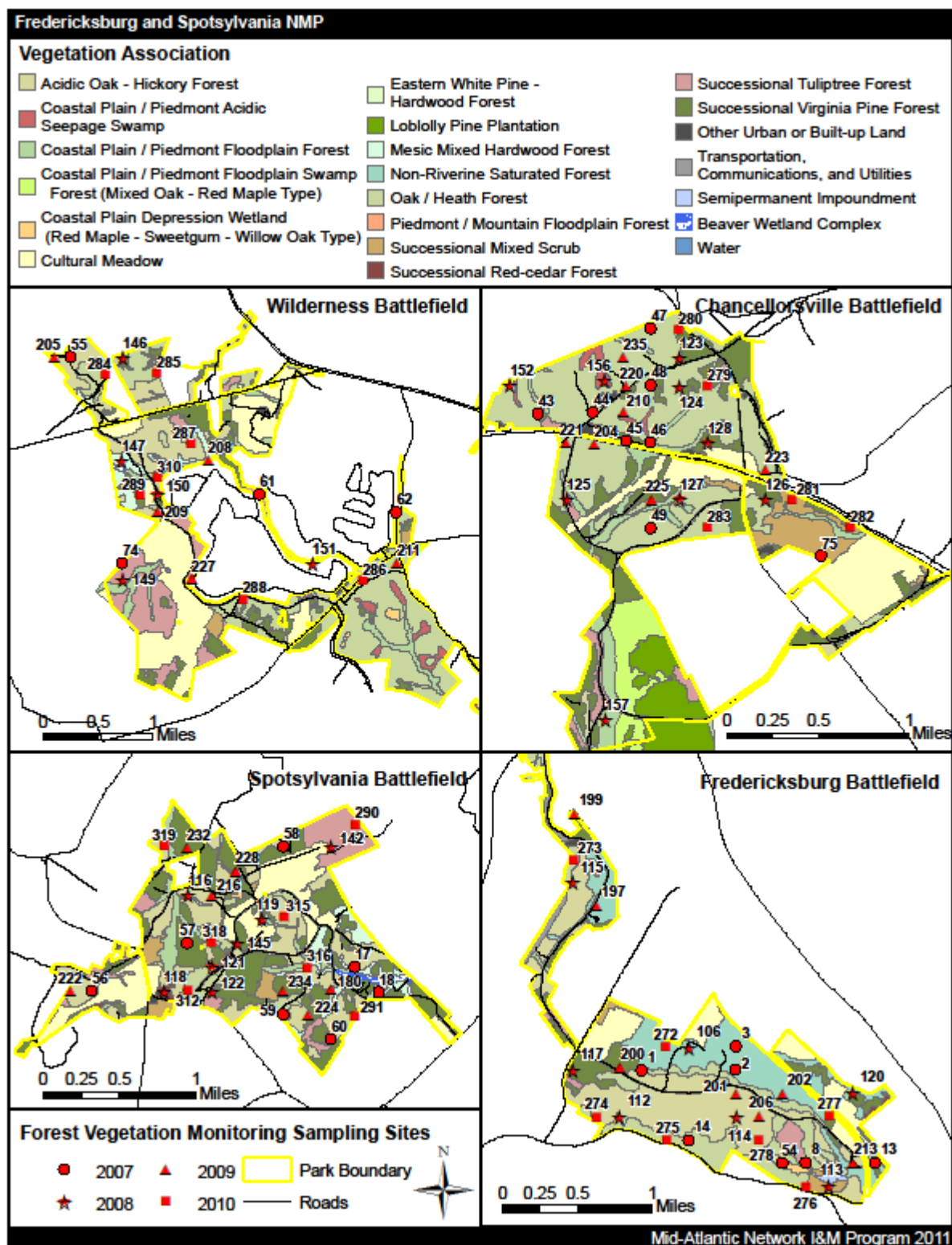
Appendix A1. Forest vegetation monitoring plots established between 2007 and 2010 at Appomattox Court House NHP.



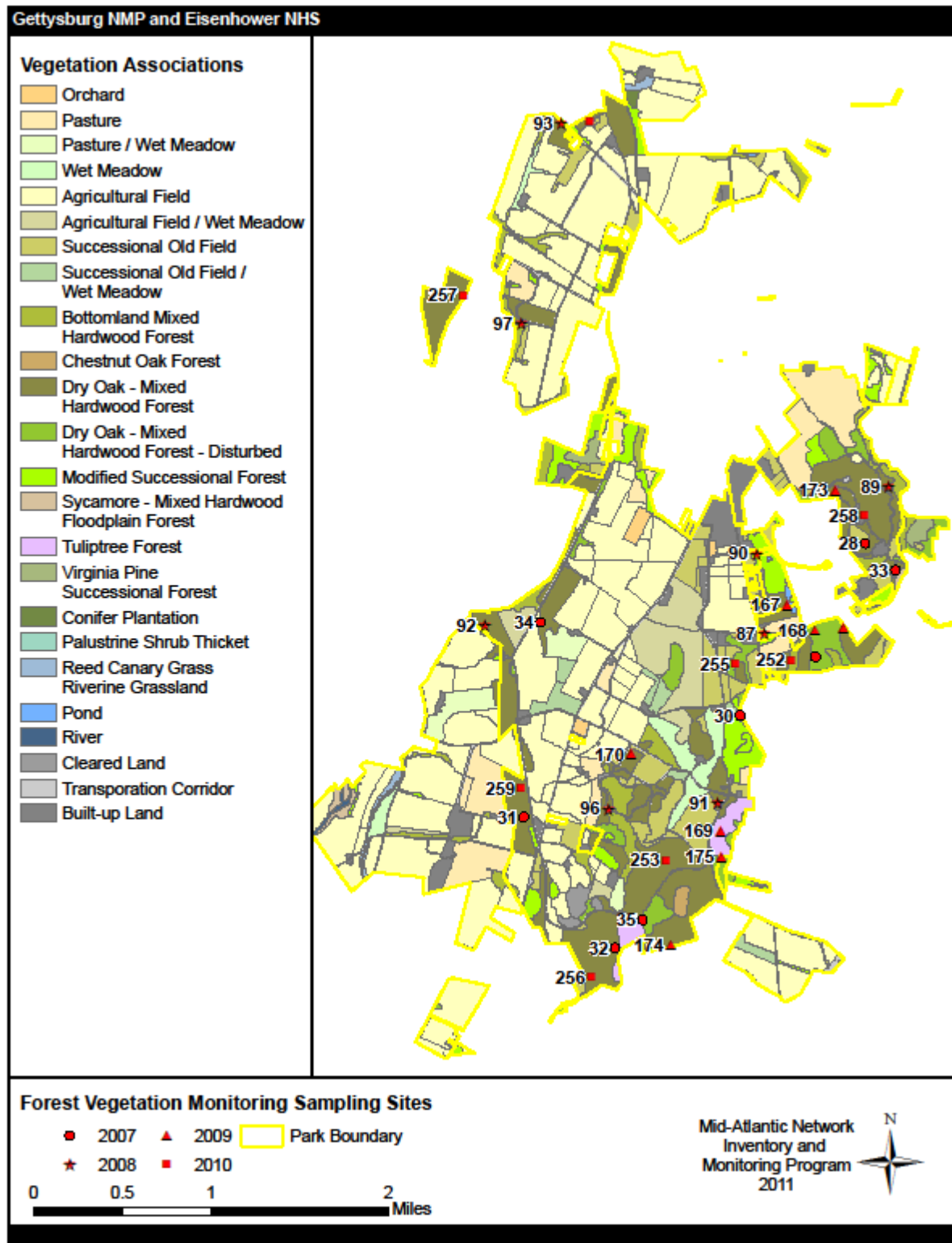
Appendix A2. Forest vegetation monitoring plots established between 2007 and 2010 at Booker T. Washington NM.



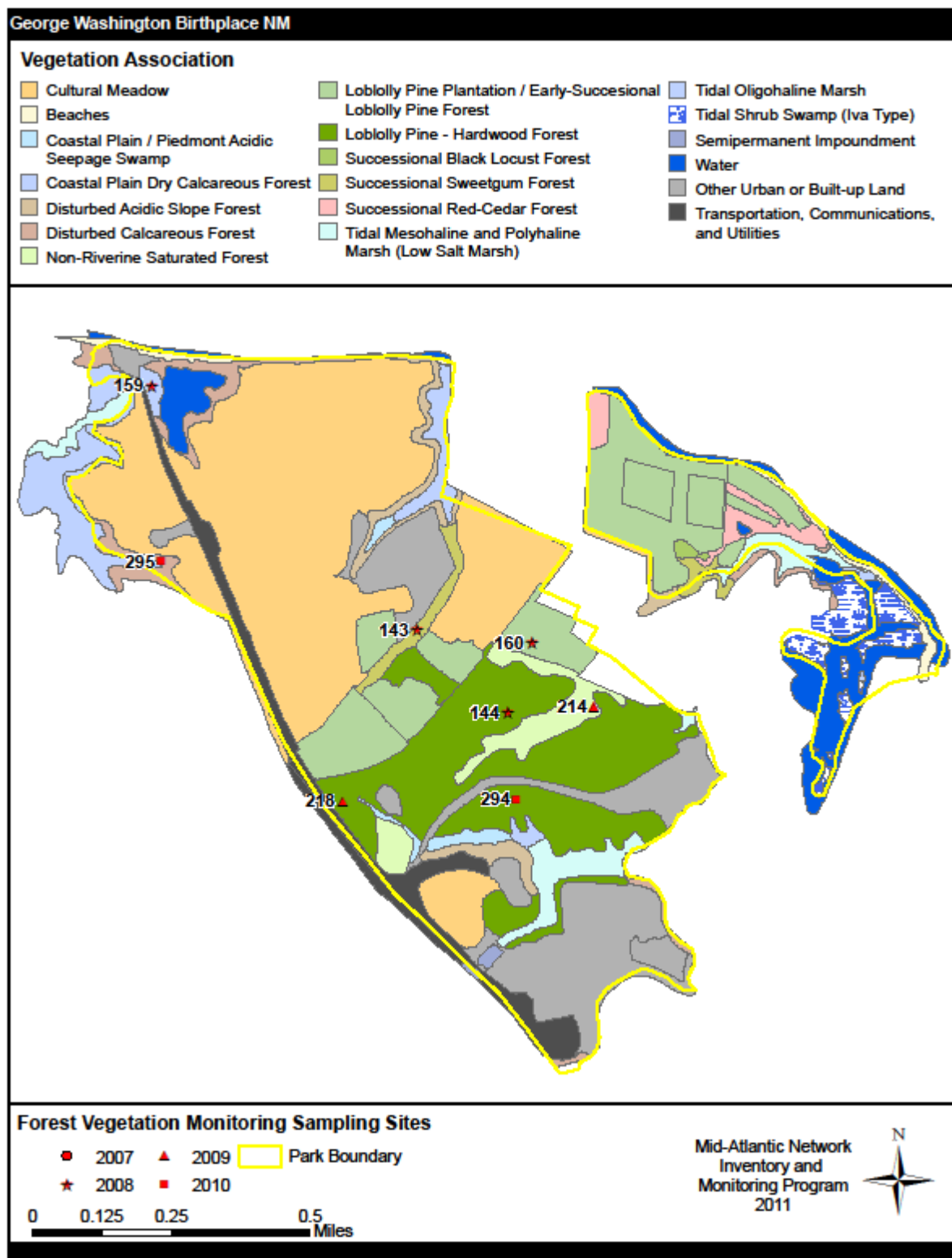
Appendix A3. Forest vegetation monitoring plots established between 2007 and 2010 at Fredericksburg and Spotsylvania NMP.



Appendix A4. Forest vegetation monitoring plots established between 2007 and 2010 at Gettysburg NMP.

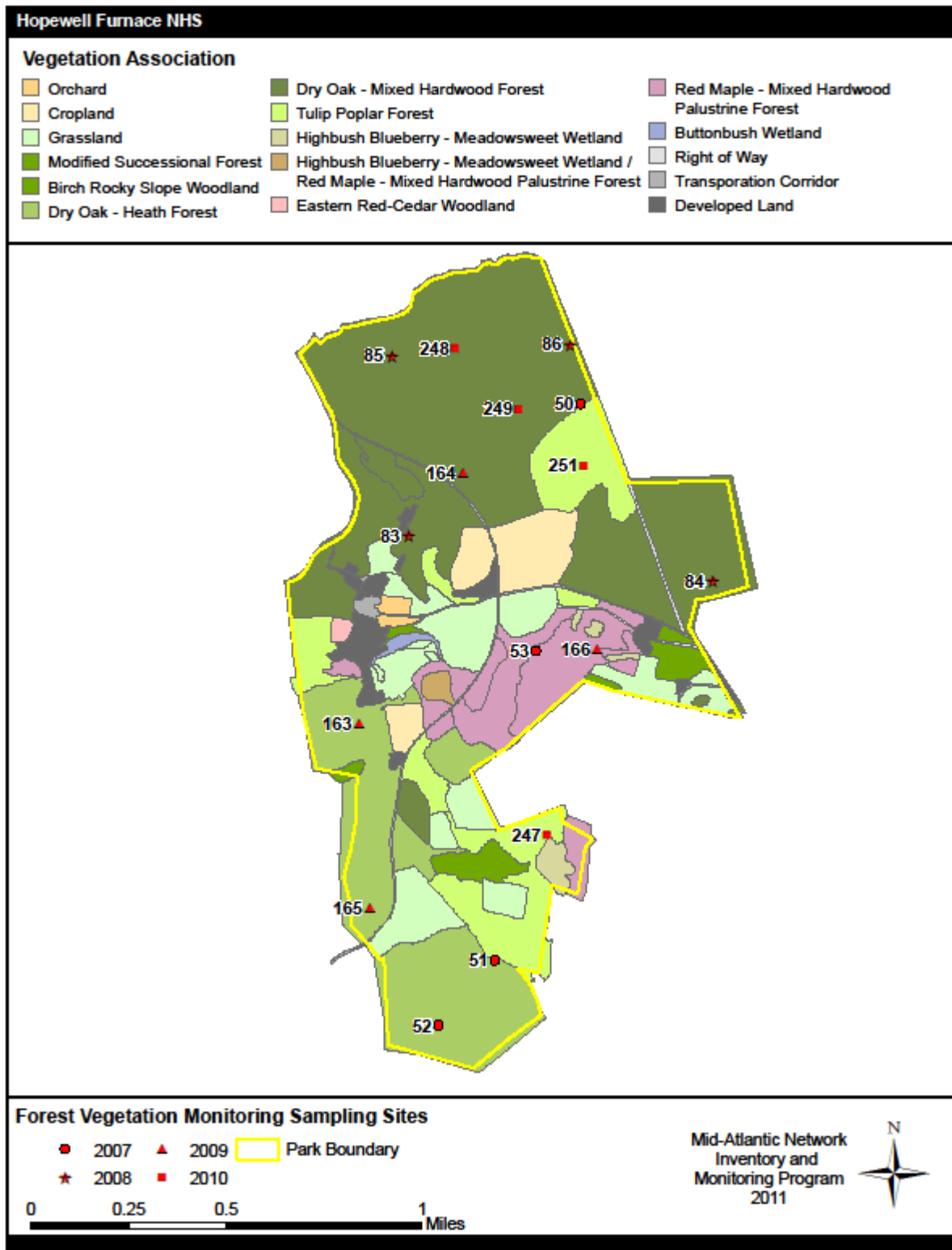


Appendix A5. Forest vegetation monitoring plots established between 2008 and 2010 at George Washington Birthplace NM.

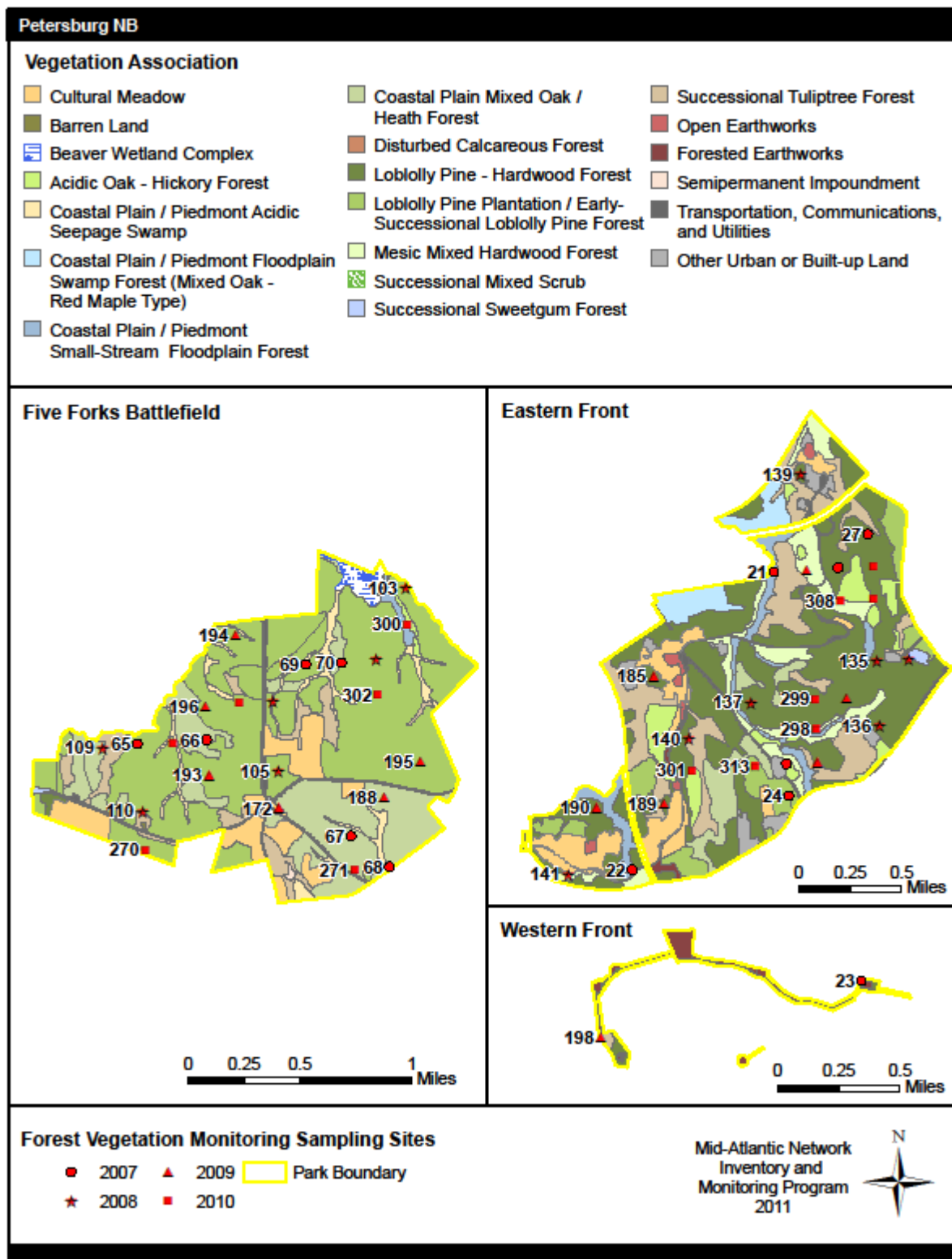


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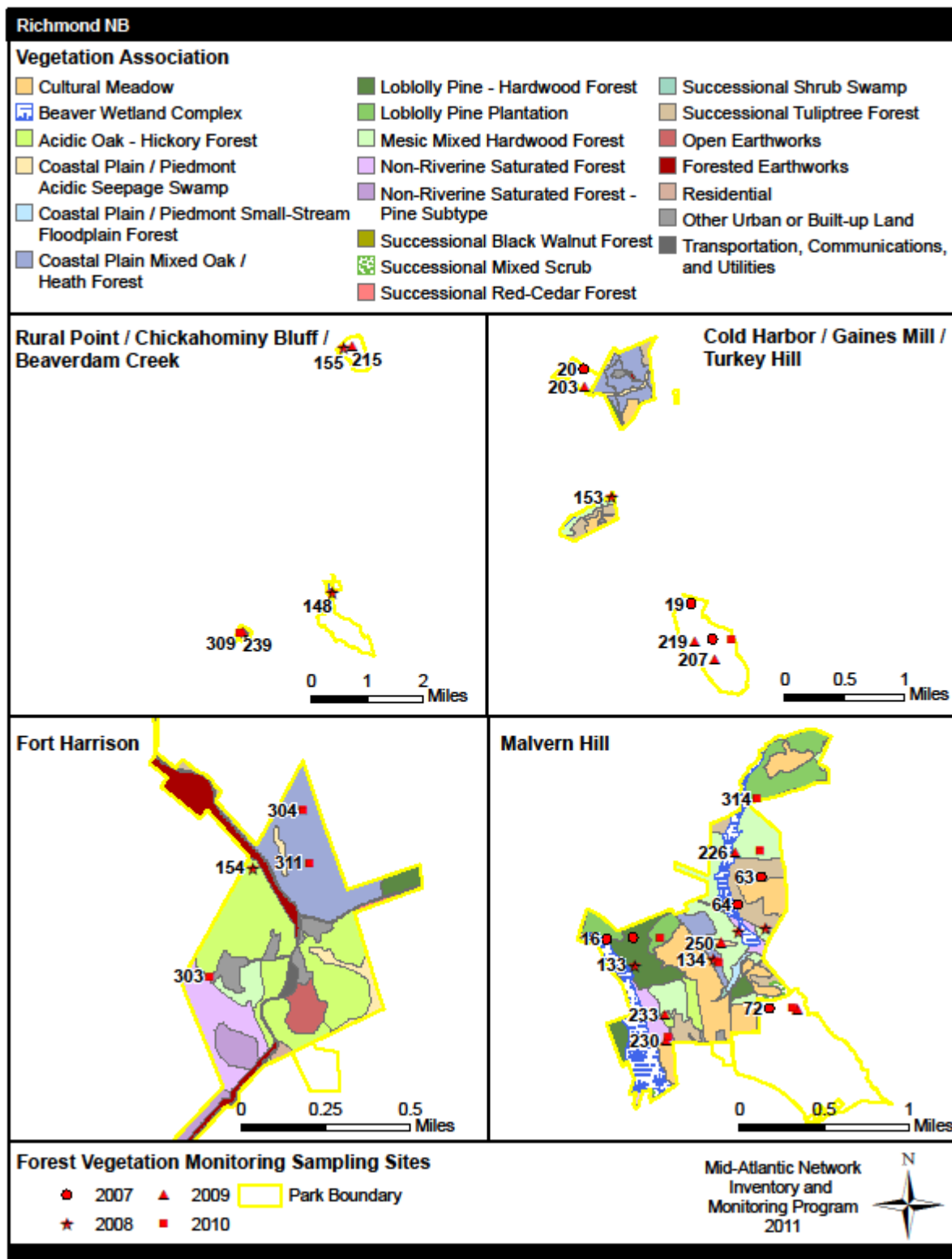
Appendix A6. Forest vegetation monitoring plots established between 2007 and 2010 at Hopewell Furnace NHS.



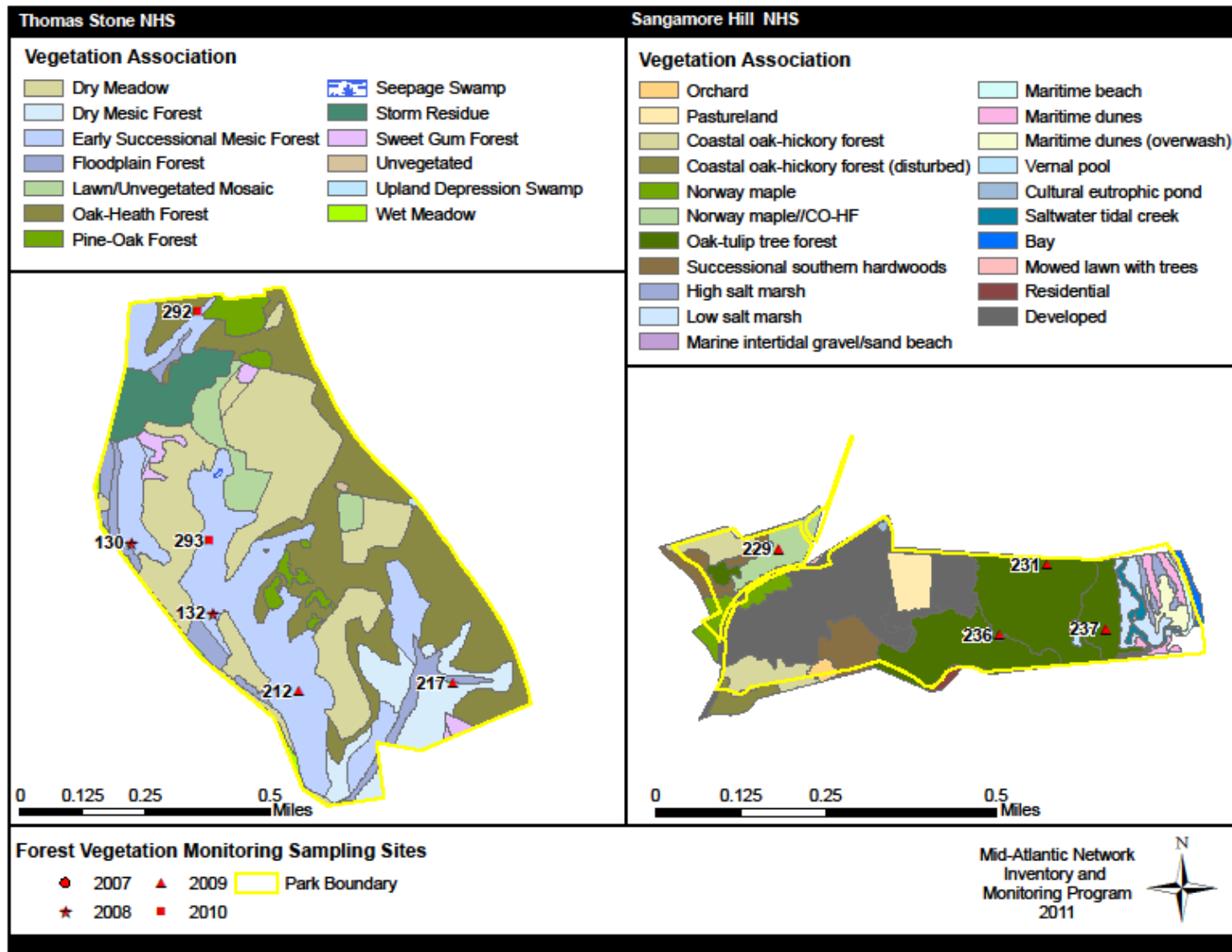
Appendix A7. Forest vegetation monitoring plots established between 2007 and 2010 at Petersburg NB.



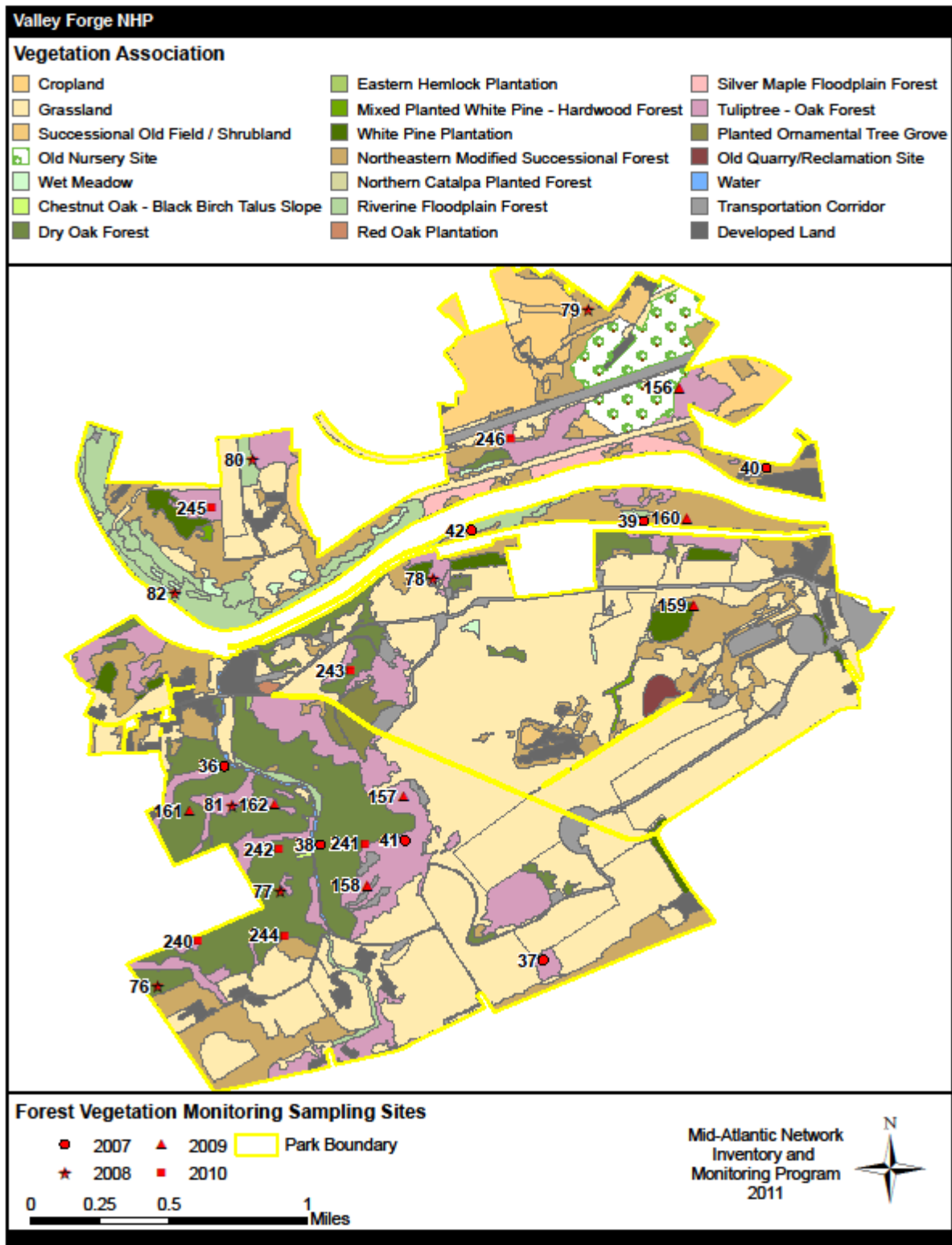
Appendix A8. Forest vegetation monitoring plots established between 2007 and 2010 at Richmond NBP.



Appendix A9. Forest vegetation monitoring plots established between 2008 and 2010 at Thomas Stone NHS and Sangamore Hill NHS.



Appendix A10. Forest vegetation monitoring plots established between 2007 and 2010 at Valley Forge NHP.



Appendix B. List of shrub species sampled in forest vegetation monitoring plots between 2007 and 2010 in Mid-Atlantic and Northeast Coastal and Barrier networks.

Latin Name	Common Name	Measurement Type ²
<i>Alnus serrulata</i>	hazel alder	DRC
<i>Berberis thunbergii</i> ¹	Japanese barberry	Cover
<i>Clethra acuminata</i>	cinnamon clethra, mountain sweetpepperbush	DRC
<i>Clethra alnifolia</i>	summersweet clethra	DRC
<i>Cornus</i> spp.	dogwood	DRC
<i>Cornus rugosa</i>	roundleaf dogwood	DRC
<i>Corylus americana</i>	American hazelnut	DRC
<i>Crataegus</i> spp.	hawthorns	DBH
<i>Elaeagnus umbellata</i> ¹	autumn olive	DRC
<i>Euonymus alata</i> ¹	burning bush	DRC
<i>Hamamelis virginiana</i>	American witchhazel	DRC
<i>Hypericum prolificum</i>	shrubby St. Johnswort	DRC
<i>Kalmia latifolia</i>	mountain laurel	DRC
<i>Ligustrum</i> spp.	ligustrum, privet	DRC
<i>Ligustrum vulgare</i> ¹	European privet	DRC
<i>Lindera benzoin</i>	northern spicebush	DRC
<i>Lonicera</i> spp.	honeysuckle	Cover
<i>Lonicera</i> — Exotic ¹	honeysuckle - exotic	Cover
<i>Lonicera</i> — Native	native - exotic	Cover
<i>Lonicera maackii</i> ¹	Amur honeysuckle, Amur honeysuckle bush	DRC
<i>Prunus</i> spp.	chokecherry	DBH
<i>Prunus virginiana</i>	chokecherry (common)	DBH
<i>Rhododendron</i>	rhododendron	DRC
<i>Ribes</i> spp.	currant	DRC
<i>Rosa multiflora</i> ¹	multiflora rose	Cover
<i>Rubus</i> spp.	blackberry	Cover
<i>Rubus occidentalis</i>	black raspberry	Cover
<i>Rubus phoenicolasius</i> ¹	Japanese wineberry	Cover
<i>Symphoricarpos orbiculatus</i>	Indiandurrant coralberry, coralberry, coralberry	DRC
<i>Vaccinium</i> spp.	blueberries	Cover
<i>Vaccinium corymbosum</i>	highbush blueberry	DRC
<i>Vaccinium stamineum</i>	deerberry	DRC
<i>Viburnum acerifolium</i>	mapleleaf viburnum	DRC
<i>Viburnum dentatum</i>	arrowwood	DRC
<i>Viburnum rufidulum</i>	rusty blackhaw	DRC

¹ Invasive exotic species.

² Measurement types are: diameter at breast height (DBH), diameter at root crown (DRC), and percent cover (Cover).

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