



Forest Vegetation Monitoring

Mid-Atlantic Network 2012 Summary Report

Natural Resource Data Series NPS/MIDN/NRDS—2013/555



ON THE COVER

Hickory (*Carya* spp.) leaves in early spring.

Photograph by: James A. Comiskey, National Park Service

Forest Vegetation Monitoring

Mid-Atlantic Network 2012 Summary Report

Natural Resource Data Series NPS/MIDN/NRDS—2013/555

James A. Comiskey

National Park Service
120 Chatham Lane
Fredericksburg, VA, 22405

September 2013

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

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

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

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

This report is available from the Mid-Atlantic Network (<http://science.nature.nps.gov/im/units/midn/>) and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

Please cite this publication as:

Comiskey, J. A. 2013. Forest vegetation monitoring: Mid-Atlantic Network 2012 summary report. Natural Resource Data Series NPS/MIDN/NRDS—2013/555. National Park Service, Fort Collins, Colorado.

Contents

	Page
Contents	iii
Figures.....	v
Tables.....	viii
Executive Summary	xi
Acknowledgments.....	xii
Acronyms.....	xiii
Introduction.....	1
Methods.....	4
Field Methods	4
Shrubs	6
Indicator Taxa.....	7
Analyses.....	11
Results and Discussion	14
Trees	14
Structural Stage.....	23
Canopy Tree Condition.....	25
Snags.....	27
Tree Saplings	28
Tree Seedlings	34
Vine Indicator Species.....	38
Invasive Exotic Indicator Species.....	40
Deer-Browse Indicator Species	44
Coarse Woody Debris.....	48
Soil Chemistry	49
Park Summaries	51
Appomattox Court House National Historical Park	51
Booker T. Washington National Monument	52

Contents (continued)

	Page
Colonial National Historical Park.....	53
Fredericksburg and Spotsylvania National Military Park	55
Gettysburg National Military Park	56
George Washington Birthplace National Monument and Thomas Stone National Historic Site	57
Hopewell Furnace National Historic Site	59
Petersburg National Battlefield.....	60
Richmond National Battlefield Park.....	61
Valley Forge National Historical Park	63
Literature Cited	65
Appendix A. Maps of forest vegetation monitoring plots established between 2007 and 2010 and sampled in 2011 and 2012 in the Mid-Atlantic and Northeast Coastal and Barrier networks.....	71
Appendix B. List of shrub species sampled in forest vegetation monitoring plots between 2007 and 2012 in Mid-Atlantic and Northeast Coastal and Barrier networks.	83

Figures

	Page
Figure 1. Location of parks included in the Mid-Atlantic Network's Forest Vegetation Monitoring protocol	2
Figure 2. Layout of forest vegetation monitoring plot used in Mid-Atlantic and Northeast Coastal and Barrier network parks.	6
Figure 3. Mortality and recruitment of trees ≥ 10 cm DBH in Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012..	15
Figure 4. Growth rates of trees ≥ 10 cm DBH in Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012.....	16
Figure 5. Mortality and recruitment of trees ≥ 10 cm DBH in different vegetation community types in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012.....	17
Figure 6. Growth rates of trees ≥ 10 cm DBH in different community types in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012.....	18
Figure 7. Mortality and recruitment of tree species ≥ 10 cm DBH in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012..	19
Figure 8. Growth rates of tree species ≥ 10 cm DBH in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012..	20
Figure 9. Crown class category mortality rates of trees ≥ 10 cm DBH in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012.....	21
Figure 10. Crown category growth rates of trees ≥ 10 cm DBH in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012..	21
Figure 11. Diameter class mortality rates of trees ≥ 10 cm DBH in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012..	22
Figure 12. Diameter class growth rates of trees ≥ 10 cm DBH in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012. Standard errors are shown for each bar and number of trees in parentheses.....	23

Figures (continued)

	Page
Figure 13. Structural stage ratings of mature trees in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008 (Census 1), and remeasured in 2011 and 2012 (Census 2)	24
Figure 14. Tree sapling mortality and recruitment rates in different community types in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012.....	29
Figure 15. Tree sapling growth rates in different community types in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012.	30
Figure 16. Species mortality and recruitment rates of tree saplings in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012.	31
Figure 17. Species growth rates of tree saplings in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012	32
Figure 18. Diameter class mortality rates of tree saplings in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012.	33
Figure 19. Diameter class growth rates of tree saplings in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012.	34
Figure 20. Canopy tree species regeneration (average weighted seedling score per 1 m ² per plot) across Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008 (Census 1), and remeasured in 2011 and 2012 (Census 2).	36
Figure 21. Canopy tree species regeneration (average weighted seedling score per 1 m ² per plot) across different community types in the Mid-Atlantic and the Northeast Coastal and Barrier network parks for plots established in 2007 and 2008 (Census 1), and remeasured in 2011 and 2012 (Census 2)	37
Figure 22. Mean percent cover of invasive exotic indicator species and taxa in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008 (Census 1), and remeasured in 2011 and 2012 (Census 2)	42
Figure 23. Mean percent cover of invasive exotic indicator species and taxa in different community types in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008 (Census 1), and remeasured in 2011 and 2012 (Census 2).....	43

Figures (continued)

	Page
Figure 24. Mean percent cover of deer-browse indicator species and taxa in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008 (Census 1), and remeasured in 2011 and 2012 (Census 2)	46
Figure 25. Mean percent cover of deer-browse indicator species and taxa in different community types in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008 (Census 1), and remeasured in 2011 and 2012 (Census 2)	47
Figure 26. Growth rates of mature trees in different diameter size classes at Appomattox Court House NHP.	51
Figure 27. Growth rates of mature trees in different diameter size classes at Booker T. Washington NM.	53
Figure 28. Distribution of mature trees in different diameter size classes at Colonial NHP	54
Figure 29. Growth rates of mature trees in different diameter size classes at Fredericksburg unit of Fredericksburg and Spotsylvania NMP.	55
Figure 30. Growth rates of mature trees in different diameter size classes at Gettysburg NMP.	57
Figure 31. Growth rates of mature trees in different diameter size classes at George Washington Birthplace NM.	58
Figure 32. Growth rates of mature trees in different diameter size classes at Hopewell Furnace NHS.....	59
Figure 33. Growth rates of mature trees in different diameter size classes at Petersburg NB.....	61
Figure 34. Growth rates of mature trees in different diameter size classes at Richmond NBP.....	62
Figure 35. Growth rates of mature trees in different diameter size classes at Valley Forge NHP.	63

Tables

	Page
Table 1. Allocation of plots in Mid-Atlantic and Northeast Coastal and Barrier network parks in relation to forested area.	3
Table 2. Invasive exotic indicator species chosen for monitoring in the Mid-Atlantic and Northeast Coastal and Barrier networks.	9
Table 3. Native deer-browse indicator taxa chosen for monitoring the Mid-Atlantic and Northeast Coastal and Barrier networks.	10
Table 4. Vine indicator species chosen for monitoring the Mid-Atlantic and Northeast Coastal and Barrier networks.	11
Table 5. Vegetation community groupings used for parks in the Mid-Atlantic Network and Northeast Coastal and Barrier networks.	12
Table 6. Summary of trees ≥ 10 cm DBH in forest vegetation monitoring plots sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.	14
Table 7. Canopy tree condition in forest vegetation monitoring plots sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.	26
Table 8. Snags in forest vegetation monitoring plots sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.	27
Table 9. Tree saplings in forest vegetation monitoring plots sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.	28
Table 10. Height class categories for enumeration of seedlings and the associated weighted score to estimate stocking index (modified from McWilliams et al. 2005).	35
Table 11. Vine indicator species frequency (number of plots) in forest vegetation monitoring plot quadrats sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.	38
Table 12. Summary of indicator vines in forest vegetation monitoring plot sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.	39
Table 13. Summary of invasive exotic indicator species and taxa in forest vegetation monitoring plots sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.	40
Table 14. Invasive exotic indicator species and taxa in forest vegetation monitoring plots sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.	41
Table 15. Deer-browse indicator species and taxa in forest vegetation monitoring plots sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.	44

Tables (continued)

	Page
Table 16. Native deer-browse indicator species and taxa in forest vegetation monitoring plots sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.	45
Table 17. Native deer-browse indicator herbaceous and shrub species and taxa in forest vegetation monitoring plots sampled in 2011 and 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.	48
Table 18. Coarse woody debris in forest vegetation monitoring plots sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.	49
Table 19. Soil chemistry ratings for forest vegetation monitoring plots sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.	50

Executive Summary

In 2012, 75 forest vegetation monitoring plots that were established in 2008 in eight parks of the Mid-Atlantic Network and eight plots in two parks of the Northeast Coastal and Barrier Network were revisited. Twelve new plots were established in Colonial National Historical Park.

Summary statistics are provided for forest metrics. For plots that were revisited, preliminary forest dynamics metrics were calculated including mortality, recruitment, and growth and presented by park, community type, species, size class, and canopy category. Temporal analyses are preliminary as only half the plots have been resampled once.

Acknowledgments

We would like to thank members of the National Park Service's Forest Vegetation Working Group who have spent the last seven years collaboratively developing the monitoring protocols for networks in the Northeast, National Capital, Midwest, and Southeast Regions. In particular we are indebted to the staff of the National Capital Region Network and Northeast Temperate Network whose protocols form a significant basis for the Mid-Atlantic Network protocol. Our thanks are also extended to Wendy Cass, Shenandoah National Park, for providing a wealth of valuable experience and insights into the development and maintenance of a long term vegetation monitoring program. Sarah Wakamiya, Adam Kozlowski, and Kristina Callahan have provided invaluable data management and field support, and we are very grateful to our field crews over the last five years including: James Burka, Carolyn Davis, Sophia DeMaio, Thomas Faust, Johanna Fickenscher, Erika Gorczyca, Evan Heck, Nichole Lightle, John Martin, Camilla Seirup, Lindsey Sloat, Dana Spontak, Andrew Vincello, Katherine Wilkin, Jesse Wheeler, Caitlin White, and Elizabeth Wright. Brian Mitchell developed the ecological integrity database used to calculate some of the metrics. Early database development was provided by Zach Arcaro and Kunsheng Fang. Botanical support was provided by John Kunsman, Kate Miller, and Timothy Draude. We would also like to thank John Karish, Regional I&M Program Manager, and Mary Foley, NER Chief Scientist, as well as the park resource managers, including Kristen Allen, Steve Ambrose, Tim Blumenschine, Zachary Bolitho, Brian Eick, Dorothy Geyer, Scott Gurney, Kristina Heister, Sara Koenig, Gregg Kneipp, Rijk Morawe, Dave Shockley, and Timbo Sims for their continued support for the implementation of all Mid-Atlantic Network inventory and monitoring activities. Additional review comments were provided by Mark J. Johnson. Support for the Northeast Coastal and Barrier Network parks was provided by Sara Stevens. Fagan Johnson provided guidance and templates for the document layout.

Acronyms

APCO	Appomattox Court House National Historical Park
BA	Basal area
BOWA	Booker T. Washington National Monument
COLO	Colonial National Historical Park
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 additional monitoring plots between 2008 and 2010. Four Northeast Coastal and Barrier Network (NCBN) parks were incorporated, three in 2008 and one in 2011 (Table 1). The full forest vegetation monitoring protocol was finalized and published in 2009 (Comiskey et al. 2009). In 2011, the first set of plots established in 2007 were revisited, while in 2012, plots established in 2008 were remeasured for the first time. The second year of plot establishment was conducted in 2012 at Colonial National Historical Park, with an additional 12 plots per year to be established in 2013 and 2014.

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. 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 et al. 2011), and forest cover is low at Eisenhower NHS), and four NCBN parks (Figure 1).

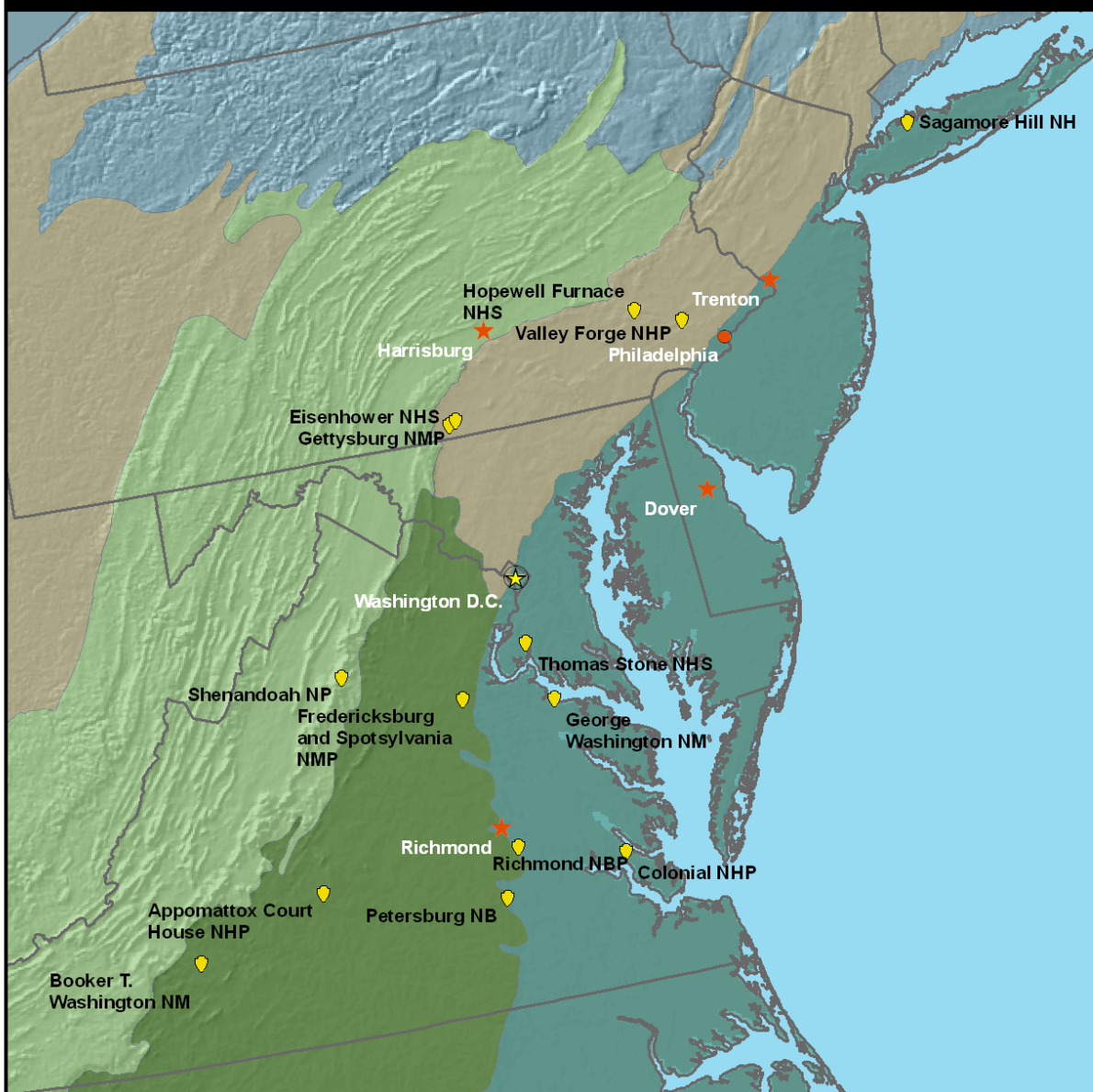
Specific monitoring objectives include:

- 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.

This report focuses on a subset of the data collected between 2011 and 2012 (census 2) and is compared to the same plots established between 2007 and 2008 (census 1). Inferences are made on a park basis, but comparisons for Fredericksburg and Spotsylvania NMP, Petersburg NB, and Colonial NHP analyses and summary statistics are reported for individual units within the parks. Table 1 shows the allocation of plots in relation to forest area in the MIDN and NCBN parks.

USFS Bailey's Ecoregion Provinces Mid-Atlantic Network

National Park Service
U.S. Department of the Interior



- | | |
|---|---|
| <ul style="list-style-type: none"> National Parks National Capital State Capital County Seat States - Outline | USFS Bailey's Ecoregion Provinces <ul style="list-style-type: none"> Central Appalachian Broadleaf Forest-Coniferous Forest-Meadow Eastern Broadleaf Forest (Oceanic) Outer Coastal Plain Mixed Forest Southeastern Mixed Forest |
|---|---|



Mid-Atlantic Network
Inventory and
Monitoring Program

0 40 80 120
Km

October 2008

Figure 1. Location of parks included in the Mid-Atlantic Network's Forest Vegetation Monitoring protocol. Four 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 and Spotsylvania National Military Park (NMP)	Fredericksburg Battlefield	FRSP-FRED	28	459.6
	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 Network²				
Colonial National Historical Park (NHP)	Jamestown Island	COLO-JAMES	4 ¹	243.4
	Yorktown	COLO-YORK	20 ¹	1,290.2
George Washington Birthplace National Monument (NM)		GEWA	8	86.6
Sagamore Hill National Historic Site (NHS)		SAHI	4 ³	16.6
Thomas Stone National Historic Site (NHS)		THST	8	89.0
Total			332	7,289.0

¹ Colonial NHP plots were incorporated in 2011. An additional 12 plots per year will be established in 2013 and 2014. Sampling intensity is lower than in other parks due to funding constraints.

² George Washington Birthplace NM and Thomas Stone NHS plots were incorporated beginning in 2008.

³ At Sagamore Hill NHS, 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 approach (GRTS; Stevens and Olsen 2004) 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 forest vegetation protocol (Comiskey et al. 2009) and Standard Operating Procedure (SOPs) shared with the Northeast Temperate Network (Tierney et al. 2012).

In 2007, one-fourth of the allocated plots in each of the eight MIDN parks (Table 1) were established by a crew of two people between May and September. Beginning in 2008, 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. Another NCBN park, Colonial NHP, was added in 2011; 12 additional plots per year will be established in Colonial NHP between 2013 and 2014. 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 year, with the first set of remeasurements for plots established in 2007 being conducted in 2011. Appendix A provides maps showing locations of all plots and the year they were established in each of the parks.

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 plane (irrespective of the slope). Fiberglass posts were used to mark the plot corners and the microplots (rebar was used in 2007, and all plot markers are being changed to rebar except in COLO); a survey marker attached to rebar was placed at the plot center (except in COLO where fiberglass was used). Site data were recorded for all plots (except in 2007) including slope, aspect, physiographic class, stand structure and height, crown closure, ground

cover and disturbance, microtopography¹, and presence of water. Digital photographs were taken to provide a visual characterization of each plot.

Within the main plot, all trees and shrubs² 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 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. In each of the three microplots, trees³ and shrubs with a DBH ≥ 1 cm and < 10 cm were identified, measured, marked, and tagged. In each of the twelve quadrats, the number, height, and cover of tree seedlings⁴, as well as cover of a list of native and invasive exotic indicator plants and vines were measured. Coarse woody debris was measured along three transects. Soil sampling was incorporated in 2010.

¹ Microtopography is small-scale variation in the soil surface caused by tree tip-ups which create a pit and mound undulation. Microtopography indicates site history. Lack of microtopography indicates the site has been plowed prior to establishment of second-growth forest. Earthworks do not count as microtopography.

² 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.

³ Trees with a DBH ≥ 1 cm and < 10 cm are also referred to as saplings.

⁴ 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.

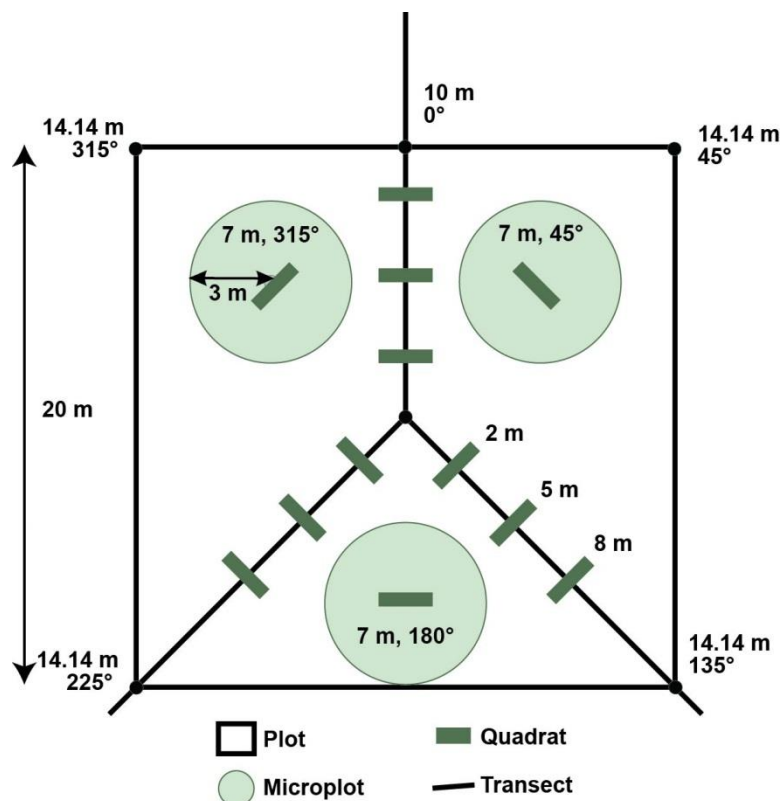


Figure 2. Layout of forest vegetation monitoring plot used in Mid-Atlantic and Northeast Coastal and Barrier network parks.

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 (entire plant) 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 species by measuring the Diameter at Root Crown (DRC). For yet other shrub species, not even DRC was a practical measure, and the only option available has been to estimate total cover. In 2011, DRC measurements were dropped in favor of cover.

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 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), and, for the appropriate subset of species, DRC was measured and tagged for all individuals with a DRC ≥ 1 cm in the microplots.
- 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. In 2009 to 2010, cover was measured in microplots for all shrubs that were not measured or counted.

- In 2011, the protocol for shrubs was standardized with NETN, where cover was measured for all shrubs except for a small subset (*Prunus* spp. and *Crataegus* spp.). For these species, DBH of the first five individuals of each species in each microplot was measured and the remainder counted.

Differences in the how shrubs have been measured over the past five years presents a challenge in analyzing temporal changes. For that reason, shrub dynamics will not be analyzed until all plots have been resampled.

Indicator Taxa

The Mid-Atlantic Network uses a series of 12 quadrats to focus on indicator taxa. The taxa that have been selected are 1) invasive exotic indicators, 2) native 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 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 in reference to the indicators in the list. In total (including vines), 34 native and 29 invasive exotic indicator taxa are monitored.

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). Of these, five are shrubs and nine are vines. A series of native taxa, either preferred or avoided by deer, are monitored as indicators of deer-browse effects (34 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.

The indicators of deer browse are organized into those preferred by deer (20 taxa) and those avoided by deer (14 taxa; Table 3). The presence / absence of these indicators is 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 points outline 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 taxa 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 when 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 three avoided taxa) separate from that of the herbaceous indicators (18 preferred and eight 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 taxa between 2007 and 2010. Plots established in the first few years were sampled for fewer taxa than the plots sampled 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 taxa at each plot will provide a clearer picture; for example, a decline in deer-preferred versus deer-avoided species in a plot 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> ^v	five-leaved akebia	
<i>Alliaria petiolata</i>	garlic mustard	
<i>Ampelopsis brevipedunculata</i> ^v	porcelain berry	
<i>Berberis thunbergii</i> ^s	Japanese barberry	
<i>Cardamine impatiens</i>	narrowleaf bittercress	
<i>Celastrus orbiculatus</i> ^v	Oriental bittersweet	
<i>Centaurea biebersteinii</i>	spotted knapweed	
<i>Cirsium arvense</i>	Canada thistle	
<i>Clematis ternifolia</i> ^v	yam-leaf clematis	
<i>Duchesnea indica</i>	mock strawberry	
<i>Euonymus fortunei</i> ^v	creeping euonymus	
<i>Glechoma hederacea</i>	ground ivy	
<i>Hedera helix</i> ^v	English ivy	
<i>Hemerocallis fulva</i>	common daylily	
<i>Lespedeza cuneata</i>	Chinese lespedeza	<i>Sericea lespedeza</i>
<i>Ligustrum spp.</i> ^{1,s}	Privet	
<i>Lonicera japonica</i> ^v	Japanese honeysuckle	
<i>Lonicera spp.</i> ^s	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> ^v	Kudzu	
<i>Ranunculus ficaria</i>	lesser celandine	
<i>Rosa multiflora</i> ^s	multi-flora rose	
<i>Rubus phoenicolasius</i> ^s	Wineberry	
<i>Vinca minor</i>	Periwinkle	
<i>Wisteria sinensis</i> ^{1,v}	wisteria vine	

¹ Species added in 2009. ^s Shrubs. ^v Vines.

Table 3. Native 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	Balgooyen and Waller (1995)
<i>Arisaema triphyllum</i> ¹	jack in the pulpit	Avoided	Ruhren and Handel (2000), Heckel et al (2010)
<i>Campsis radicans</i> ^v	trumpet creeper	Avoided	Castleberry et al. (1999)
<i>Cyperaceae</i> ⁵	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> ⁵	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. ⁵	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> ⁵	orchids	Preferred	Miller et al. (1992)
<i>Parthenocissus quinquefolia</i> ^v	Virginia creeper	Avoided	Castleberry et al. (1999)
<i>Poaceae</i> ⁵	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>Polygonatum pubescens</i>	hairy Solomon's seal	Preferred	
<i>Polystichum acrostichoides</i>	Christmas fern	Avoided	Diefenbach and Fritsky (2007)
<i>Rubus</i> spp. ^{6,s}	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. ^{7,v}	Common greenbrier	Preferred	
<i>Smilax glauca</i> ^{2,v}	cat greenbrier	Preferred	Maxey (1976), Blair and Brunett (1980), Diefenbach and Fritsky (2007)
<i>Smilax rotundifolia</i> ^{2,v}	roundleaf greenbrier	Preferred	
<i>Thelypteris noveboracensis</i>	New York fern	Avoided / Impede Regeneration	Williams et al. 2000, Horsley et al. (2003)
<i>Toxicodendron radicans</i> ^v	eastern poison ivy	Avoided	Castleberry et al. (1999)
<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> ^{8,s}	blueberries		
<i>Vaccinium corymbosum</i> ^s	highbush blueberry	Avoided / Impede Regeneration	Diefenbach and Fritsky (2007)
<i>Vaccinium stamineum</i> ^s	deer berry		
<i>Vitis</i> spp. ^v	grape	Preferred	Castleberry et al. (1999)

¹ Species added in 2008. ² Species added in 2009. ³ Species added in 2010. ⁴ Species added in 2011.

⁵ All species grouped. ⁶ *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). ⁷ Excluding *S. glauca* and *S. rotundifolia* that are identified to species. ⁸ Includes *Gaylussacia* spp but excludes *V. corymbosum* and *V. stamineum*. ^s Shrubs. ^v Vines.

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

Species	Common Name
<i>Akebia quinata</i> ¹	five-leaved akebia
<i>Ampelopsis brevipedunculata</i> ⁱ	porcelain berry
<i>Campsis radicans</i>	common trumpet creeper
<i>Celastrus orbiculatus</i> ⁱ	oriental bittersweet
<i>Clematis ternifolia</i> ⁱ	yam-leaf clematis
<i>Euonymus fortunei</i> ⁱ	climbing euonymus, winter creeper
<i>Hedera helix</i> ^{1,i}	English ivy
<i>Lonicera japonica</i> ⁱ	Japanese honeysuckle
<i>Parthenocissus quinquefolia</i>	Virginia creeper
<i>Pueraria montana</i> ⁱ	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,i}	wisteria vine

¹ Species added in 2008. ² Species added in 2009. ⁱ 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 presented for the park and compared to the network level results where applicable.

Vegetation Communities

All vegetation monitoring plots (excluding those established in Colonial NHP in 2011 and 2012) were grouped into vegetation community types based on cluster analysis of the mature tree data. Indicator species analysis was used to determine the optimum number of clusters or groups (community types), and to identify the species that best represented each group (Dufrêne and Legendre 1997, McCune and Grace 2002). The community types identified were characterized by two types dominated by pines, loblolly and Virginia pine; two by oaks, white oak and a second represented by oaks and hickories; two successional communities ranging from drier to more mesic forests, tulip poplar and sweetgum; and one modified successional community dominated by white ash (Table 5). An additional group was a mixed community, providing a grouping for a variety of sites with diverse species assemblages and characteristics. A more extensive description of the methods used in classifying the vegetation communities as well as community descriptions and a cross-walk to the United States National Vegetation Classification (USNVC), the vegetation maps prepared for each park, is currently in preparation.

Table 5. Vegetation community groupings used for parks in the Mid-Atlantic Network and Northeast Coastal and Barrier networks.

Vegetation Community	Dominant Species	General Characteristics
White Oak	white oak (<i>Quercus alba</i>)	Slower growing, heavy seeded, shade tolerant species.
Oak Hickory	red oak (<i>Quercus rubra</i>) white oak (<i>Quercus alba</i>) mockernut hickory (<i>Carya alba</i>) pignut hickory (<i>Carya glabra</i>)	
Tulip Poplar	tulip poplar (<i>Liriodendron tulipifera</i>) red maple (<i>Acer rubrum</i>) American beech (<i>Fagus grandifolia</i>)	Shade intolerant, fast growing species to more shade tolerant species. Mostly pioneers but can persist in the canopy for extended time.
Sweetgum	sweetgum (<i>Liquidambar styraciflua</i>) American holly (<i>Ilex opaca</i>) red maple (<i>Acer rubrum</i>)	
White Ash	white ash (<i>Fraxinus americana</i>) box elder (<i>Acer negundo</i>) American elm (<i>Ulmus americana</i>)	Fast growing shade tolerant species that can persist in the understory.
Virginia Pine	Virginia pine (<i>Pinus virginiana</i>)	Pioneer species forming first wave of the canopy. These species do not persist in canopy, giving way to hardwoods in many locations.
Loblolly Pine	loblolly pine (<i>Pinus taeda</i>)	
Mixed	black walnut (<i>Juglans nigra</i>) eastern redcedar (<i>Juniperus virginiana</i>) black cherry (<i>Prunus serotina</i>)	Variety of habitats composed of species ranging from pioneer to long-lived shade intolerant species.

Forest Dynamics

Once plots are revisited, we are able to determine how the structure and composition is changing over time. The most commonly used metrics to determine forest dynamics are mortality, recruitment, and growth. Mortality refers to the death of individuals, recruitment to the addition of individuals that attain the minimum diameter size class, and growth to the yearly mean diameter increment.

Annual mortality rate (m ; % stems/year) is calculated from successive observations as the percent of stems that died during an interval converted to an annual basis. Mortality is calculated as:

$$m = \frac{N_d \times 100}{N_o \times t}$$

where N_o is the number of trees in the previous census, and N_d is the number of trees that died after t years.

In a similar fashion, recruitment is calculated using annual recruitment (r):

$$r = \frac{N_r \times 100}{N_o \times t}$$

where N_o is the number of trees in the previous census, and N_r is the number of recruited trees after t years.

The Mean Annual Diameter Increment (MADI) has been used extensively to measure growth rates. MADI is the sum of the annual diameter increment (in cm) for all stems in the plot:

$$MADI = \frac{\sum(DBH_2 - DBH_1)/t}{n}$$

where, for each stem, DBH_1 is the diameter of the tree in the first census, DBH_2 is the diameter in the next census after t years. Only stems that were present and alive in both censuses were used to calculate MADI; trees that died prior to the second census were not included.

The forest dynamics data (mortality, recruitment, and growth) are presented as a series of graphs in this report. Data from the first census (2007 and 2008) were compared to the second census (2011 and 2012). This represents just one-half of the total number of plots. All MIDN plots will have been revisited at least once by 2014, while the NCBN parks (GEWA and THST) will be completed by 2015, except COLO which will not have a completed second census until 2018. Therefore, our sample sizes, in many cases, are small. All the graphics display bars with standard errors, estimates of the precision of our sample means (i.e. how good our means are). In addition, the graphics show the number of plots or trees that were used to estimate the mean. The larger the standard error, the less confidence we have in the precision of our estimate. Likewise, the smaller the sample size, the likelier it is that we will have larger standard errors and lower confidence in our estimated means. Over the coming years, as we increase our sample sizes, we expect to decrease our standard errors and thus increase the precision of our estimated means. In the meantime, estimates based on small sample sizes or those that have large standard errors should be treated with caution.

Results and Discussion

It is important to note that the temporal trends presented here are for one-half of the total number of plots established in the network (except at GEWA and THST where only one-quarter of the plots have been resampled), and hence we have a relatively low level of confidence in the results. This is particularly the case when we present summaries for data subsets, for example, by species, where some of the groupings may be represented by only a few plots or individuals. In the coming years as we remeasure more plots, our sample sizes will increase and with them our confidence in the detected trends. Once we have revisited all plots, we will present summaries for each park in comparison to the network means. At this stage, presenting such data is premature and may provide a misleading interpretation of the trends.

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 and sub-canopy. In 2012, trees were measured in plots established in 2008 and in new plots established at Colonial NHP (Table 6). Tree mortality, recruitment, and growth are presented by park, vegetation community types, and species across the Mid-Atlantic Network (Figures 3 to 8). Recruitment is excluded from the crown class and diameter size class results since most recruits generally fall within the smallest size class and lowest crown class (Figures 9 to 12).

Table 6. Summary of trees ≥ 10 cm DBH in forest vegetation monitoring plots sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.

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	7	46.0	1,150	2.10	52.51	21	4.9
BOWA	2	49.0	1,225	1.54	38.59	13	10.5
COLO_JAMES	2	12.5	313	1.10	27.40	8	5.0
COLO_YORK	10	18.9	473	1.29	32.15	23	6.0
FRSP_CHWILD	13	38.3	958	2.54	63.57	18	5.4
FRSP_FRED	7	42.1	1,054	2.24	55.97	21	6.1
FRSP_SPOT	8	58.0	1,450	3.17	79.27	21	6.6
GETT	9	26.4	661	1.36	34.03	24	6.4
GEWA	2	41.5	1,038	3.29	82.29	9	5.0
HOFU	4	30.5	763	2.89	72.16	11	6.2
PETE_EAST	7	44.7	1,118	2.27	56.76	18	5.3
PETE_FIVE	6	85.0	2,125	2.85	71.17	12	5.3
RICH	8	46.0	1,150	2.10	52.46	25	7.2
THST	2	27.0	675	2.17	54.29	6	4.0
VAFO	7	33.3	832	2.56	63.89	18	4.9

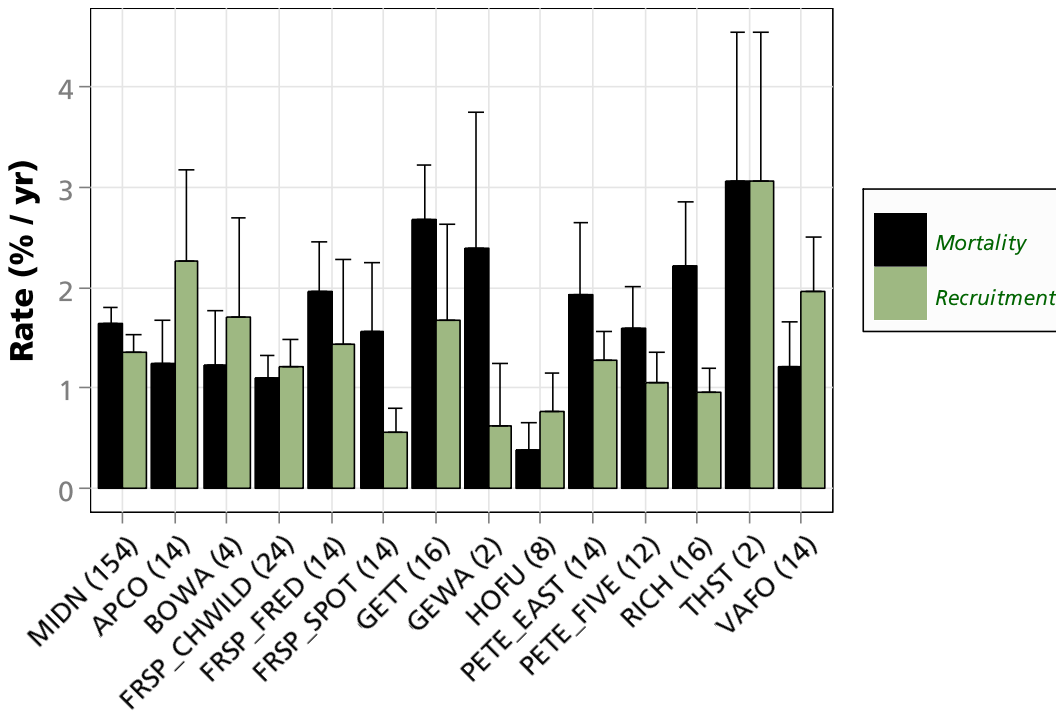


Figure 3. Mortality and recruitment of trees ≥ 10 cm DBH in Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012. Standard errors are shown for each bar and number of plots is shown in parentheses.

Mortality and recruitment rates varied substantially across the MIDN and NCBN parks (Figure 3). However, mortality rates were higher than recruitment rates. In some parks this trend was reversed, most notably in APCO and VAFO. In parks with a low number of plots (fewer than 10 plots), we have less confidence in our estimated mean as indicated by the large standard error bars (e.g. GEWA, THST, and BOWA). Over time, increased sample sizes will help decrease standard errors and increase our confidence in the estimates.

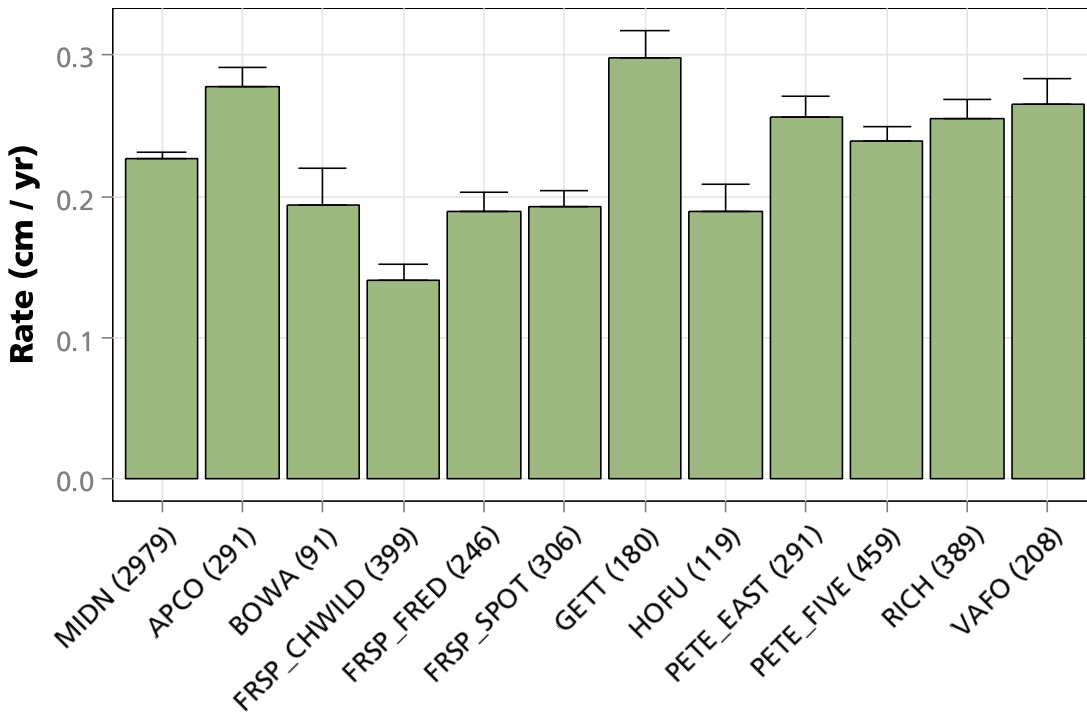


Figure 4. Growth rates of trees ≥ 10 cm DBH in Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012. Standard errors are shown for each bar and number of trees is shown in parentheses.

An average growth rate of 0.23 cm / yr was registered for trees across the Mid-Atlantic and Northeast Coastal and Barrier networks. The lowest growth rates were at the Chancellorsville and Wilderness unit of Fredericksburg and Spotsylvania NMP while the highest rates were in Gettysburg NMP. The large sample sizes and small standard errors suggest that we have good estimates of growth rates across the parks.

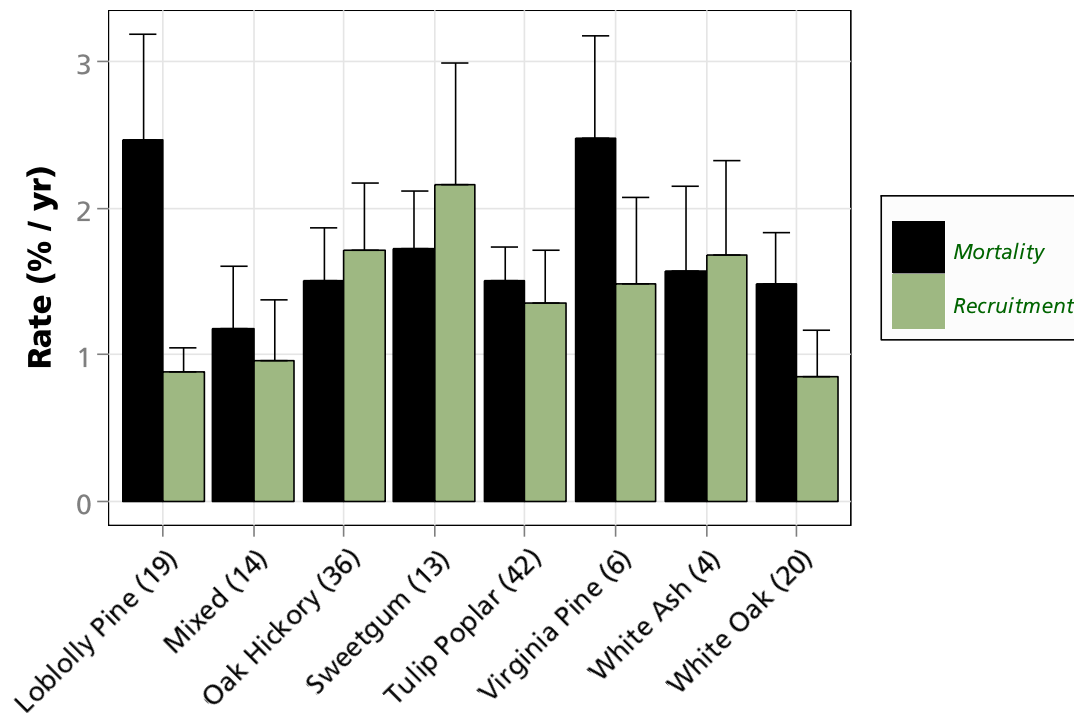


Figure 5. Mortality and recruitment of trees ≥ 10 cm DBH in different vegetation community types in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012. Standard errors are shown for each bar and number of plots is shown in parentheses.

Virginia pine and Loblolly pine communities both had higher levels of mortality than recruitment (Figure 5). As these early successional communities mature, the pines die out and are replaced by hardwood species present in the understory and sub-canopy. The low number of plots in the White Ash community results in decreased confidence in our estimates.

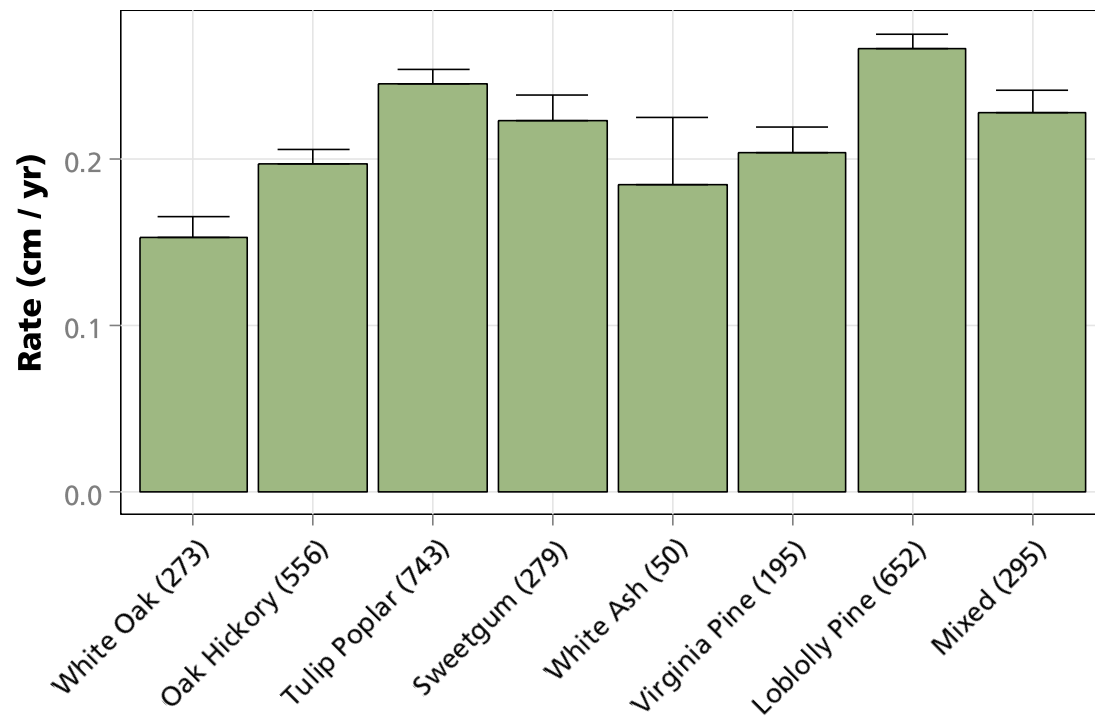


Figure 6. Growth rates of trees ≥ 10 cm DBH in different community types in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012. Standard errors are shown for each bar and number of trees is shown in parentheses.

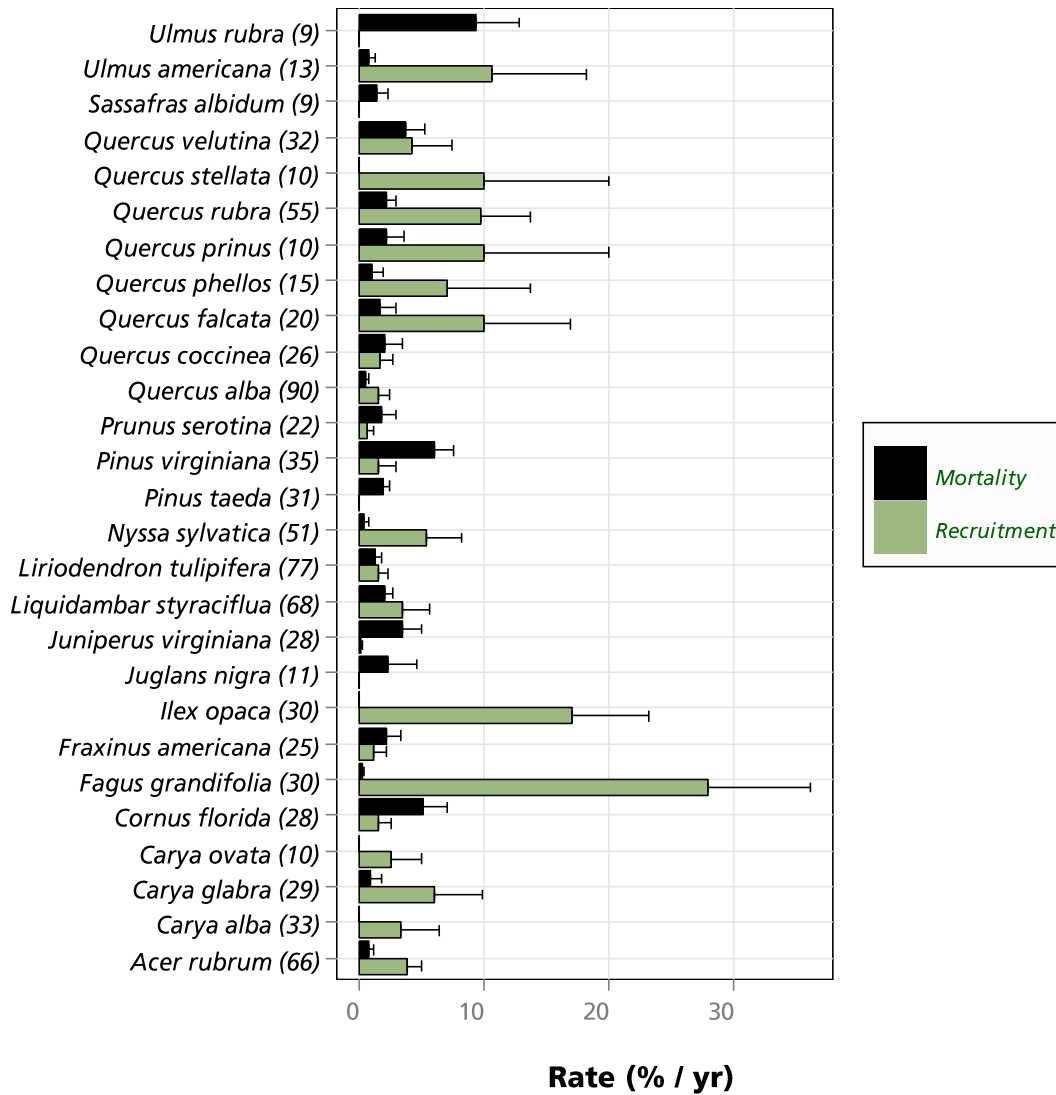


Figure 7. Mortality and recruitment of tree species ≥ 10 cm DBH in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012. Standard errors are shown for each bar and number of plots is shown in parentheses.

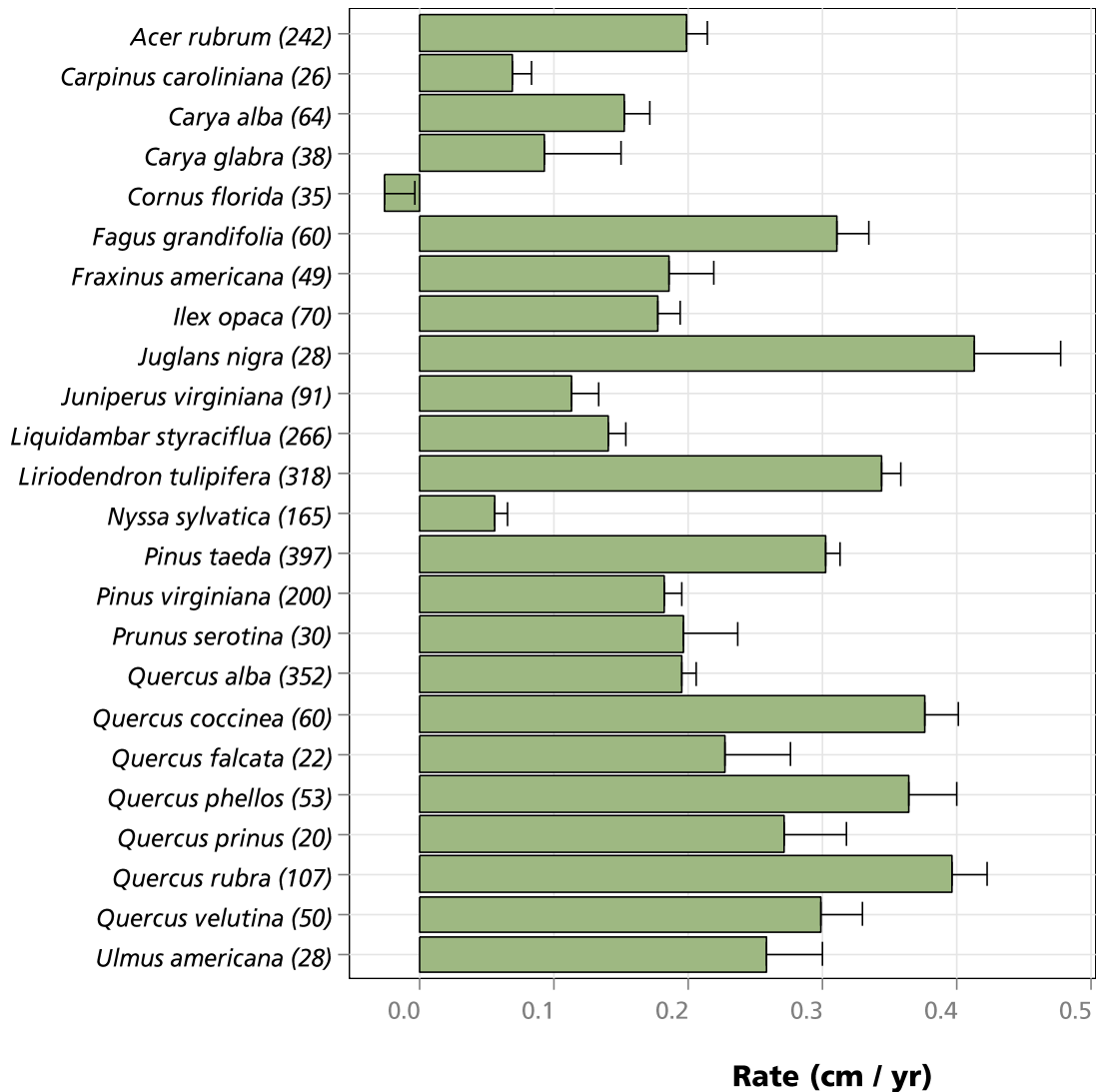


Figure 8. Growth rates of tree species ≥ 10 cm DBH in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012. Standard errors are shown for each bar and number of trees is shown in parentheses.

Flowering dogwood (*Cornus florida*) showed a mean negative growth rate (Figure 8). This value is based on 35 trees in nine park units, of which 18 trees had negative growth rates. Most of the park units had dogwoods showing negative growth. It is not clear what is causing this negative growth rate, though we suspect it to be dogwood anthracnose. We will monitor individuals of the species closely as well as conduct additional quality control checks on our data collection methods.

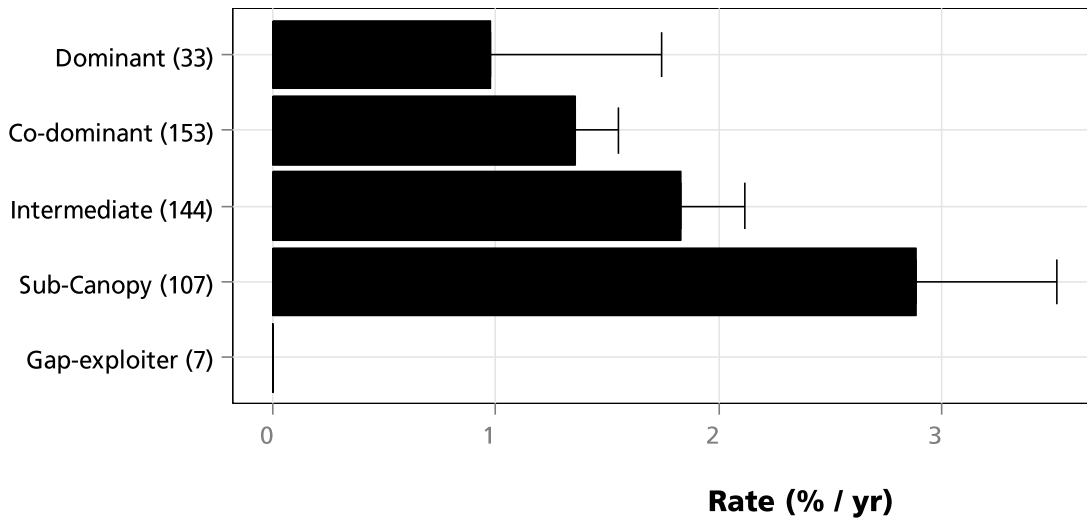


Figure 9. Crown class category mortality rates of trees ≥ 10 cm DBH in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012. Standard errors are shown for each bar and number of plots is shown in parentheses.

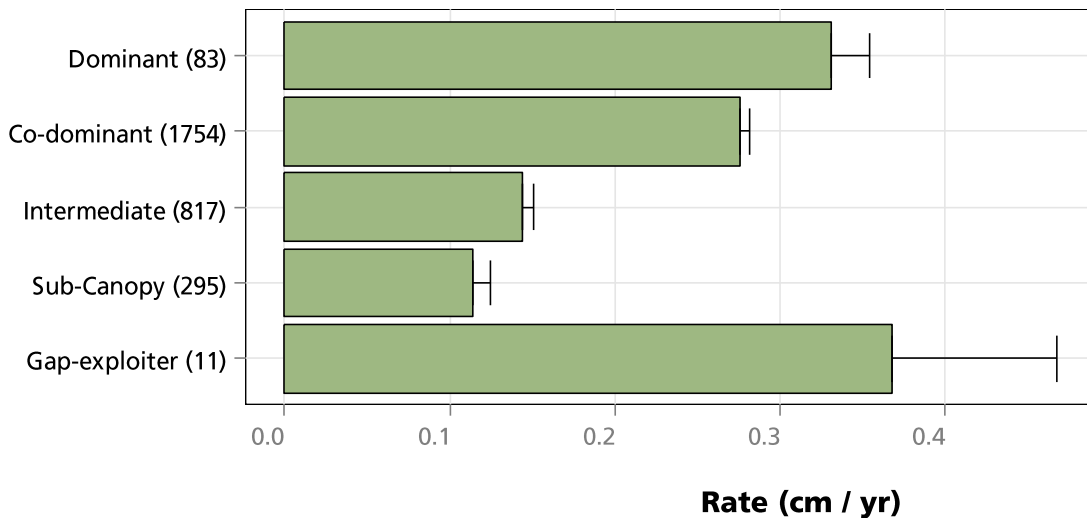


Figure 10. Crown category growth rates of trees ≥ 10 cm DBH in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012. Standard errors are shown for each bar and number of trees is shown in parentheses.

Trees are grouped based on their position in the forest canopy relative to other individuals in the plot. Co-dominant trees mark the main canopy with dominant trees extending above, and intermediate below. Sub-canopy trees are entirely below the canopy, while a gap-exploiter is a tree of intermediate or sub-canopy height, but is exploiting a gap within otherwise closed canopy forest and receives direct light from above (Tierney et al. 2013). Gap-exploiters had the highest growth rate across all parks sampled, though the number of trees in this category is very low.

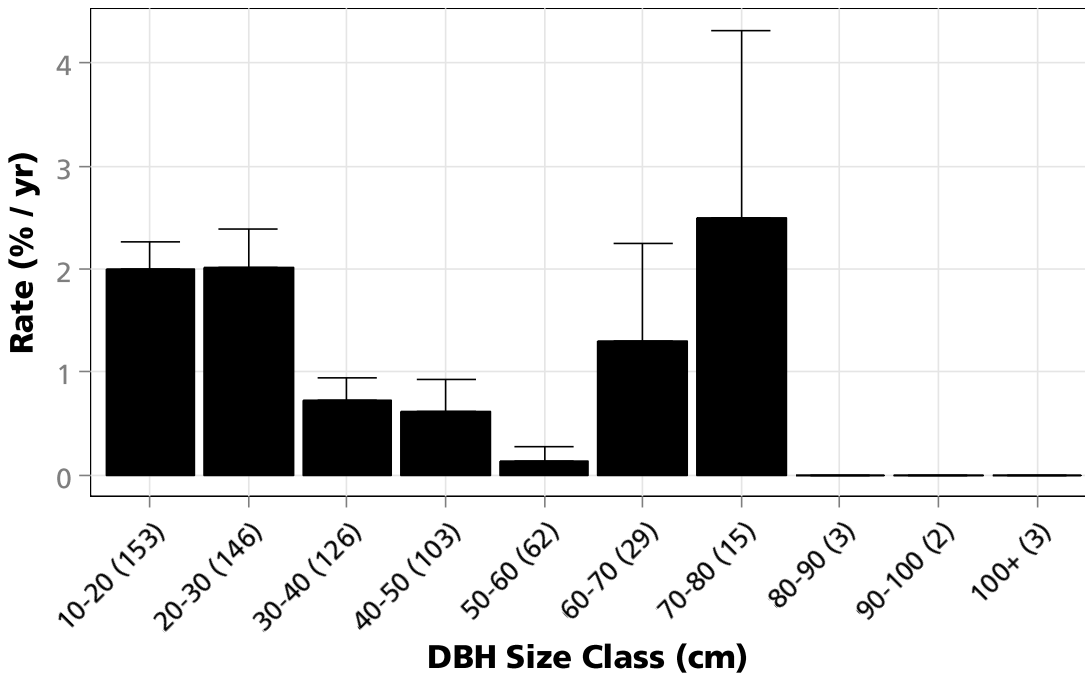


Figure 11. Diameter class mortality rates of trees ≥ 10 cm DBH in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012. Standard errors are shown for each bar and number of plots is shown in parentheses.

Trees are grouped into size class categories based on their diameter in the last remeasurement. The diameter groupings are 10 cm increments up to 1 m in diameter. In general, smaller trees are more likely to die, however, as there are fewer larger trees, the death of several individuals will be represented by a higher rate in that size class (Figure 11). We therefore have lower confidence in the mortality estimates among larger trees as indicated by the larger standard errors. Likewise, growth rates are generally higher among larger individuals, but rates are also more variable as seen by the error bars (Figure 12). It is not clear why the largest size class has the lowest growth rate, but we can also see that there is a high level of variability in this category as the estimate is based on only two trees.

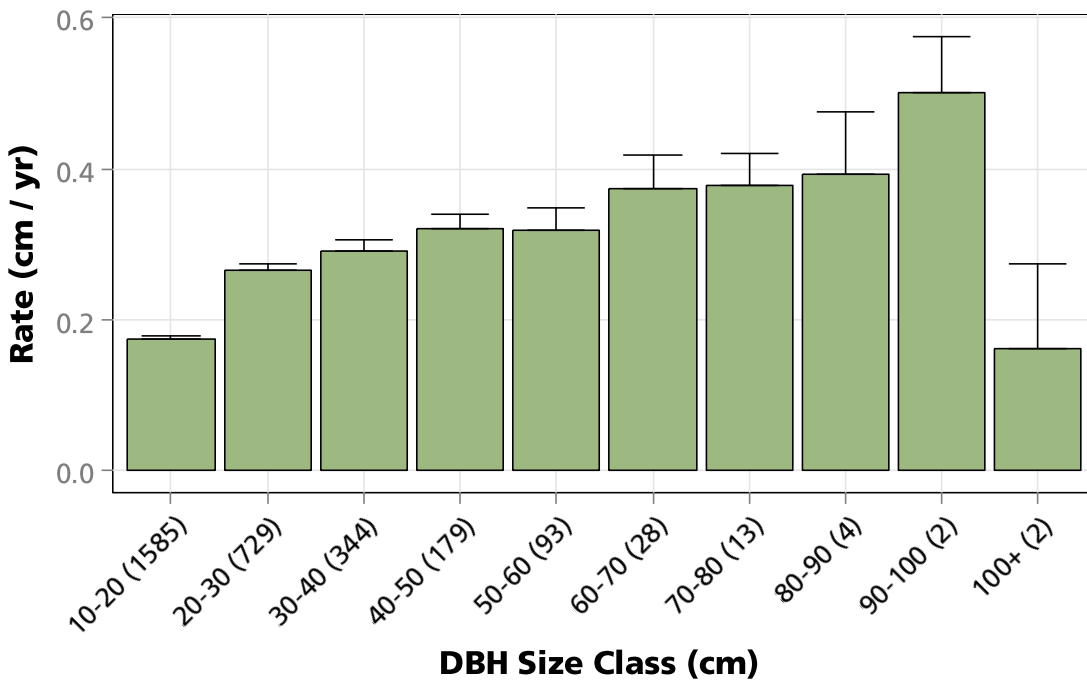


Figure 12. Diameter class growth rates of trees ≥ 10 cm DBH in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012. Standard errors are shown for each bar and number of trees is shown in parentheses. We have a lower confidence in the estimate for size classes with fewer than 20 trees.

Structural Stage

A range of forest structural stages enhances species diversity by providing multiple habitats within park units (McShea and Rappole 2000). 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. 2009).

Structural stage distribution is assessed for each park based on calculations from canopy trees 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). Canopy trees are defined as 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. 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 stage, mature stage, 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.

Structural stage 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.

For the plots sampled in 2011 and 2012, the distribution of structural stages in Mid-Atlantic and Northeast Coastal and Barrier network forests is generally classified as “Good”, with only Booker T. Washington NM, the Chancellorsville and Wilderness unit and Fredericksburg unit of Fredericksburg and Spotsylvania NMP, and the Five Forks unit of Petersburg NB rated as “Caution”. Plots at Appomattox Court House NHP showed an improvement from “Caution” in Census 1 to “Good” in Census 2 (Figure 13).

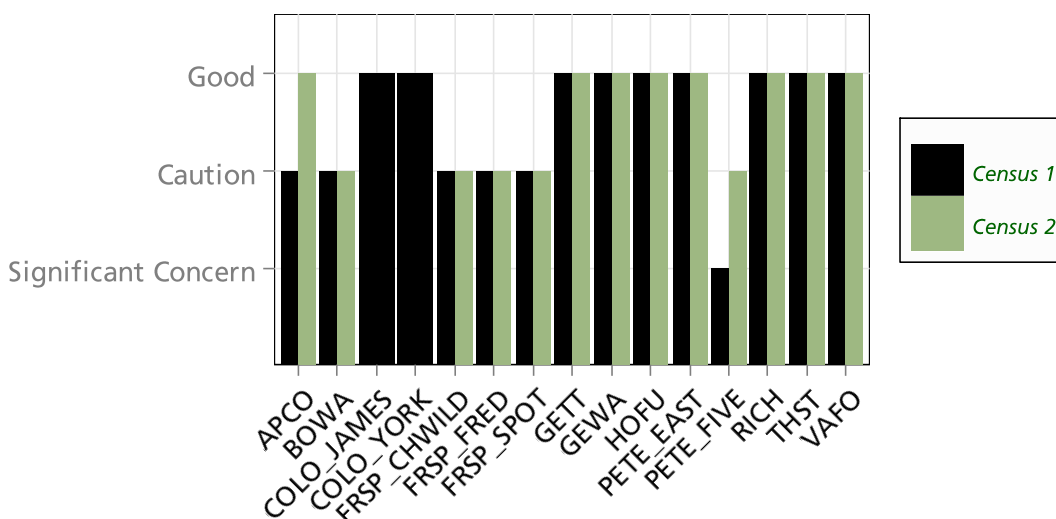


Figure 13. Structural stage ratings of mature trees in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008 (Census 1), and remeasured in 2011 and 2012 (Census 2). COLO plots have only been measured once.

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 and NCBN plots as they are sampled between late July and the end of September. More extensive damage, however, can indicate a wide variety of stressors ranging from forest pests and pathogens, to air quality and climate 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 pest and pathogen 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. For this metric, any plot that had a high priority pest was ranked as “Significant Concern”, and plots with BC, EHS, or HWA, or a high severity of BBD were ranked as “Caution”. Foliar damage (insect damage, chlorosis, etc.) is visually estimated within broad classes (0-1, 1-10, 10-50, 50-90 and 90-100%). The average foliage problem for the plot is calculated. Rankings are assigned to each plot as follows:

Good: Average foliage problem with $< 10\%$ for canopy stems in plot, and no HWA, BC, EHS, ALB, EAB or SOD, and an average BBD severity ≤ 2 among all canopy beech stems in plot.

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

About one third of the plots were classified as having canopy trees in "Good" condition, while 5% were classified as "Significant Concern" (Table 7). In 2012, RICH had the highest number of plots classified as significant concern due to the proportion of trees with holes in leaves and wilting.

Table 7. Canopy tree condition in forest vegetation monitoring plots sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.

Park	# of Plots in a Good Condition	# of Plots in a Caution Condition	# of Plots in a Significant Concern Condition
APCO	2	5	0
BOWA	1	1	0
COLO_JAMES	2	0	0
COLO_YORK	8	2	0
FRSP_CHWILD	1	10	1
FRSP_FRED	2	4	1
FRSP_SPOT	0	7	0
GETT	4	5	0
GEWA	1	1	0
HOFU	0	4	0
PETE_EAST	6	1	0
PETE_FIVE	3	3	0
RICH	1	4	3
THST	0	2	0
VAFO	2	5	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, Petranks 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 sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.

Plot	# of plots	Mean # of snags/plot	Snags / ha	BA (m ²) / ha	Snags / ha ≥ 30 cm	% snags	% snags ≥ 30 cm	Rating ¹	
								2008	2012
APCO	7	6.1	153.6	0.28	7.1	6	1.6	C	C
BOWA	2	24.5	612.5	0.65	16.2	2	2.0	SC	SC
COLO_JAMES	2	1.5	37.5	0.07	1.7	3	1.5	-	C
COLO_YORK	10	1.0	25.0	0.14	3.4	3	1.5	-	C
FRSP_CHWILD	13	8.8	219.2	0.23	5.8	8	1.6	SC	SC
FRSP_FRED	7	5.7	142.9	0.21	5.3	10	2.0	C	C
FRSP_SPOT	8	6.4	159.4	0.30	7.6	7	1.8	SC	C
GETT	9	5.2	130.6	0.17	4.3	7	1.5	SC	SC
GEWA	2	12.0	300.0	1.02	25.4	4	2.0	G	C
HOFU	4	6.0	150.0	0.30	7.5	5	1.3	C	C
PETE_EAST	7	6.7	167.9	0.65	16.2	6	2.2	G	C
PETE_FIVE	6	3.5	87.5	0.06	1.5	4	1.6	SC	SC
RICH	8	6.4	159.4	0.30	7.5	11	1.9	C	C
THST	2	3.5	87.5	0.07	1.6	3	1.5	SC	SC
VAFO	7	5.6	139.3	1.20	30.1	3	1.0	C	SC

¹ Rating for 2008 and 2012 as G: Good; C: Caution; SC: Significant Concern.

The rating for snags generally remained constant across the network between 2008 and 2012 (Table 8). Ratings improved in the Spotsylvania unit of Fredericksburg and Spotsylvania NMP,

while in George Washington Birthplace NM, Eastern Front unit of Petersburg NB, and Valley Forge NHP the rating declined. Among the plots sampled in 2012, none of the parks were ranked as having a “Good” proportion of snags. This is possibly due to the young age of forests across the parks and the low number of samples. At GEWA and PETE, the ranking declined from “Good” in 2008 as snags fell and insufficient trees died to make up for the deficit.

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. In 2012, saplings were measured in plots established in 2008 and in new plots established in Colonial NHP (Table 9). Tree sapling mortality, recruitment, and growth are presented for vegetation community types and species across the Mid-Atlantic Network (Figures 14 to 17). Figure 18 presents diameter class mortality rates of tree saplings; recruitment is excluded as most recruits generally fall within the smallest size class category. Figure 19 shows tree sapling growth rates by diameter size class.

Table 9. Tree saplings in forest vegetation monitoring plots sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.

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	7	13.4	1,583	0.02	2.65	22	5.7
BOWA	2	18.0	2,122	0.03	3.36	11	7.5
COLO_JAMES	2	9.5	1,120	0.01	1.74	2	1.5
COLO_YORK	10	8.4	990	0.01	1.76	8	1.6
FRSP_CHWILD	13	14.2	1,670	0.02	2.52	18	4.7
FRSP_FRED	7	12.1	1,432	0.02	2.89	15	4.1
FRSP_SPOT	8	10.4	1,230	0.02	2.26	12	4.3
GETT	9	21.4	2,528	0.01	1.70	22	5.0
GEWA	2	8.5	1,002	0.02	2.00	1	1.0
HOFU	4	2.0	236	0.00	0.46	3	1.0
PETE_EAST	7	8.0	943	0.02	2.01	12	2.9
PETE_FIVE	6	21.2	2,495	0.04	4.29	19	7.5
RICH	8	14.5	1,709	0.02	2.88	16	3.6
THST	2	3.0	354	0.01	1.20	3	1.5
VAFO	7	2.1	253	0.01	0.76	6	1.1

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

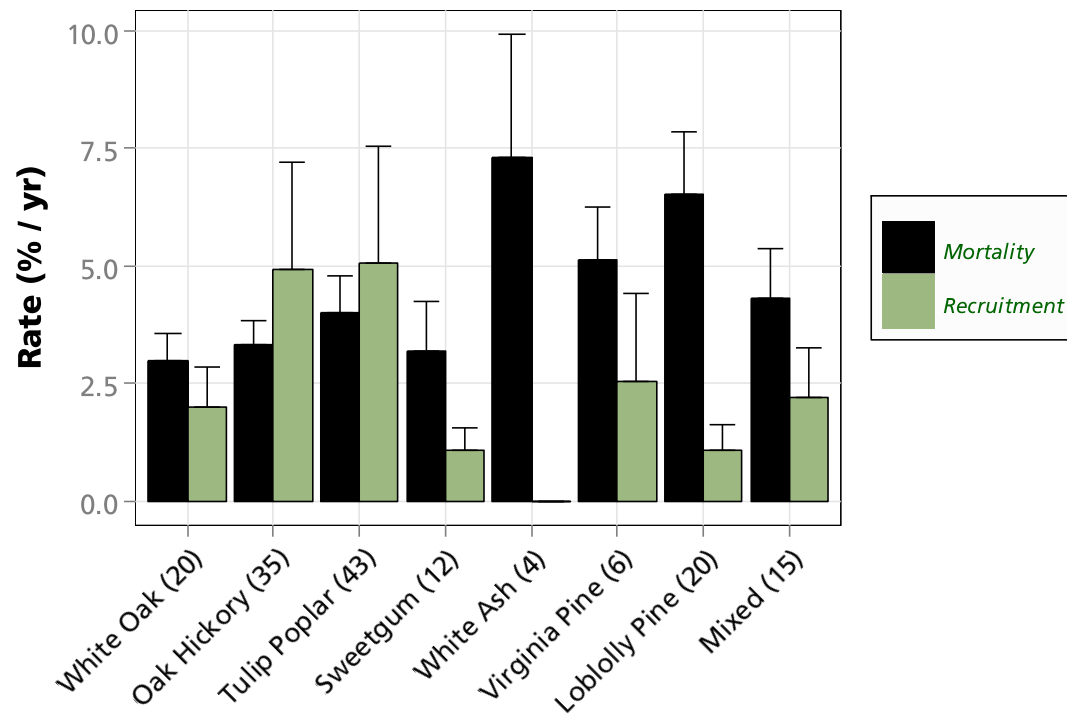


Figure 14. Tree sapling mortality and recruitment rates in different community types in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012. Standard errors are shown for each bar and number of plots is shown in parentheses.

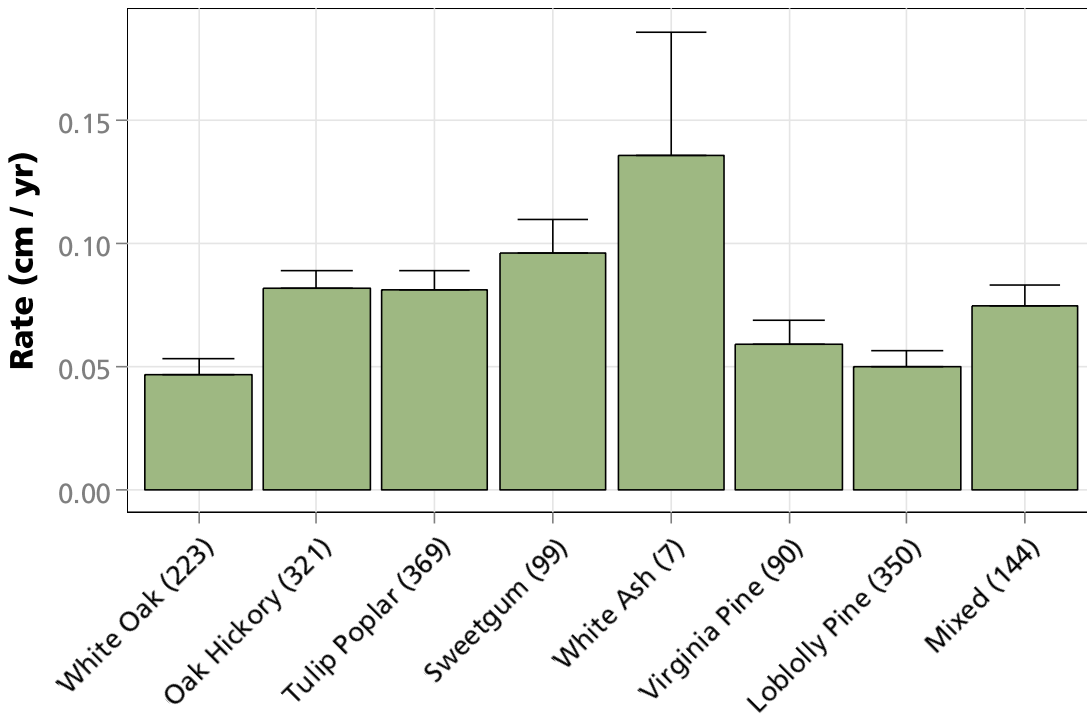


Figure 15. Tree sapling growth rates in different community types in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012. Standard errors are shown for each bar and number of tree saplings is shown in parentheses.

It is interesting to note that mortality rates were high in the white ash community (Figure 14), and, correspondingly, the growth rates for saplings in that community were higher than other vegetation communities (Figure 15). It is likely that higher mortality is also creating better growing conditions for those surviving individuals. However, sample sizes were small so our confidence in the estimates is also low. Additional years of sampling will help improve our estimated growth and mortality rates in this community type.

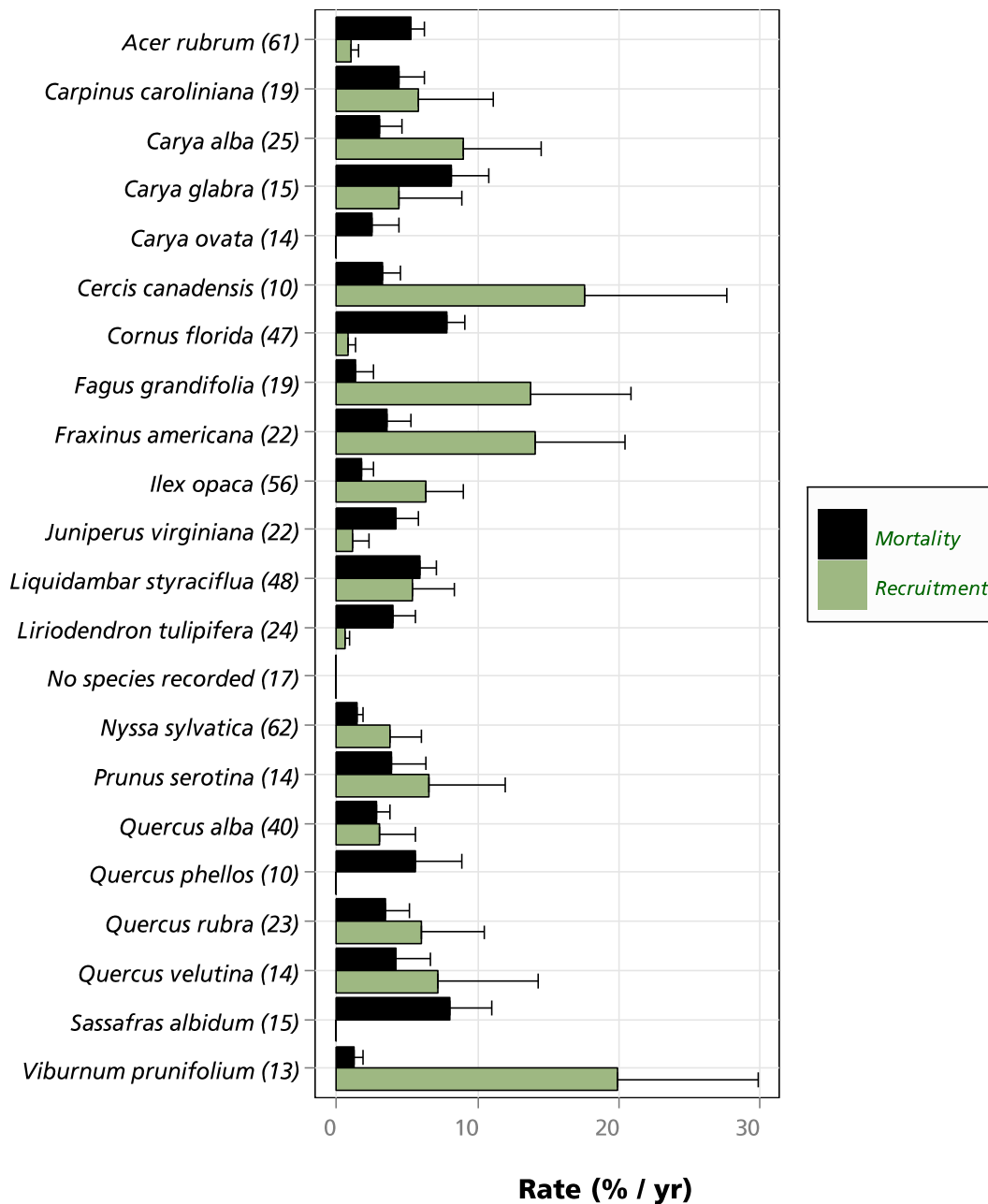


Figure 16. Species mortality and recruitment rates of tree saplings in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012. Standard errors are shown for each bar and number of plots in parentheses.

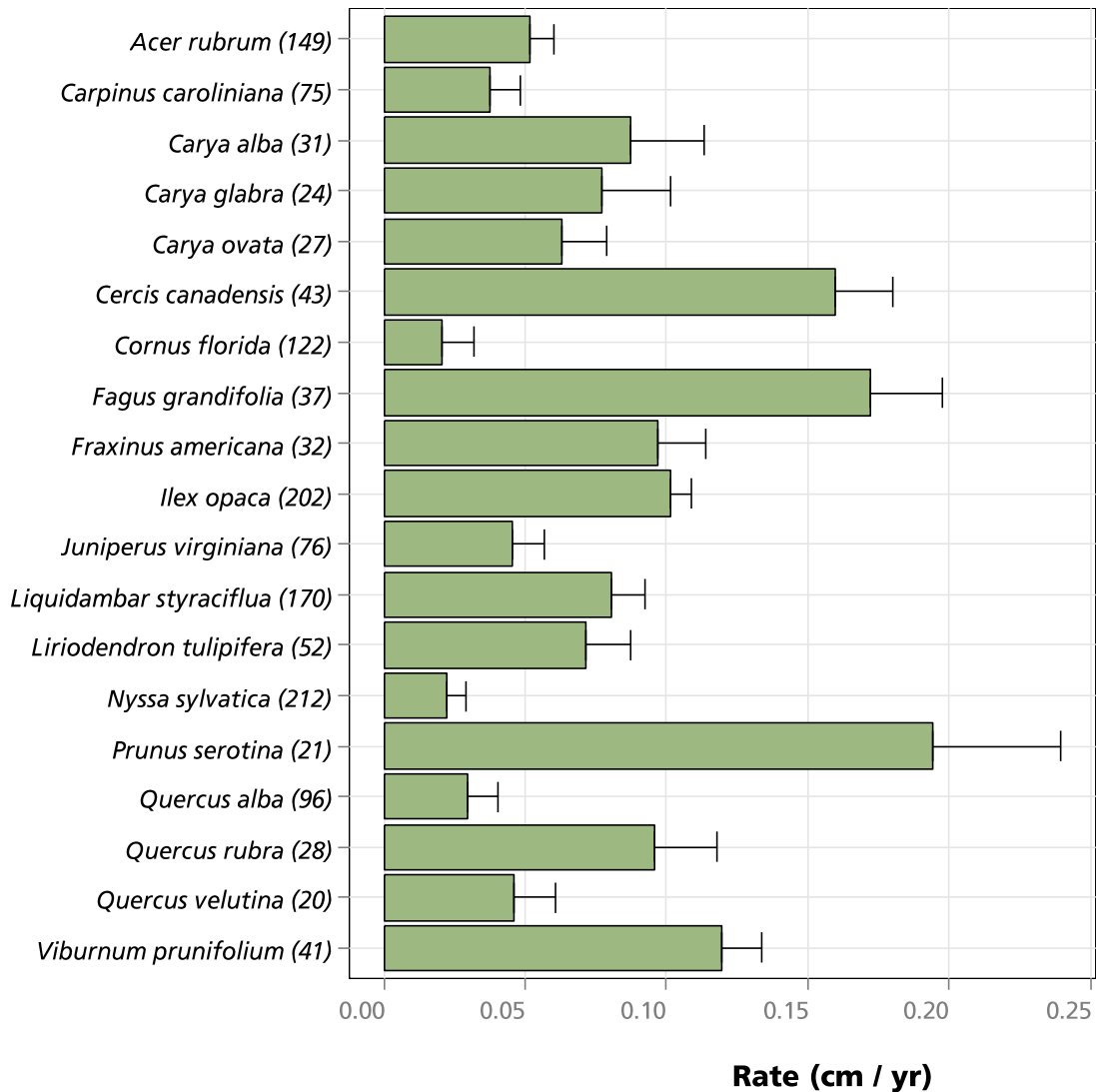


Figure 17. Species growth rates of tree saplings in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012. Standard errors are shown for each bar and number of trees shown in parentheses.

Unlike the trees (≥ 10 cm DBH), the growth rate of flowering dogwood saplings (*Cornus florida*) was positive rather than negative (Figure 17). This seems unusual as dogwood anthracnose appears to affect trees of all ages especially in the shade, conditions most likely for saplings. However, mortality rates far exceeded recruitment for this species (Figure 16). Continued monitoring will help us determine the long-term health of flowering dogwoods.

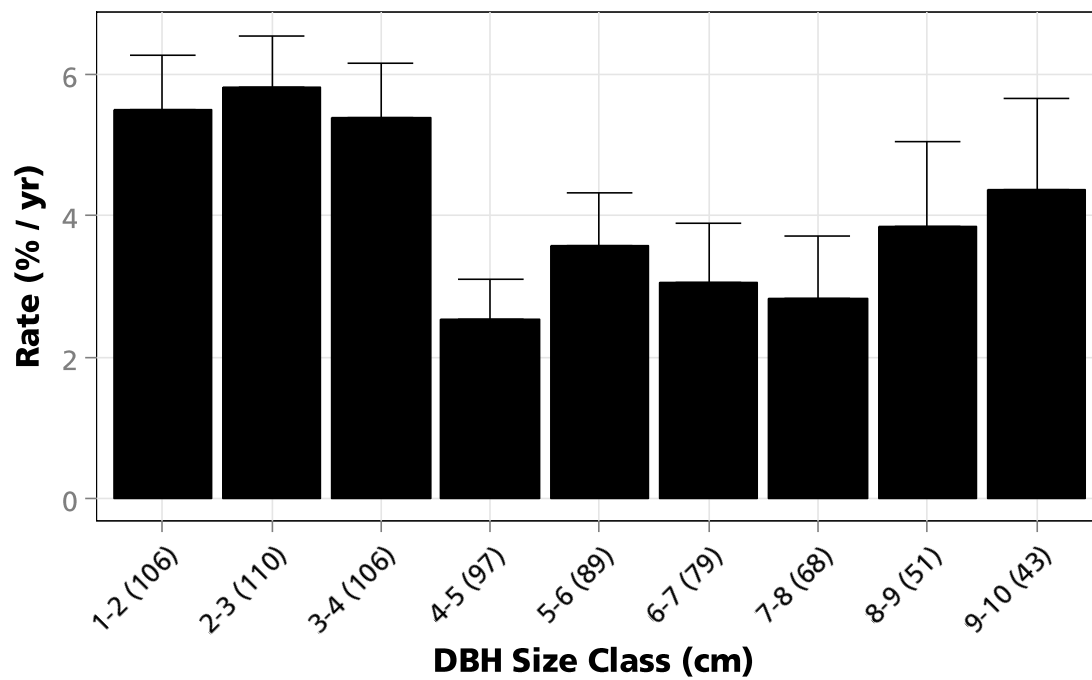


Figure 18. Diameter class mortality rates of tree saplings in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012. Standard errors are shown for each bar and number of plots is shown in parentheses.

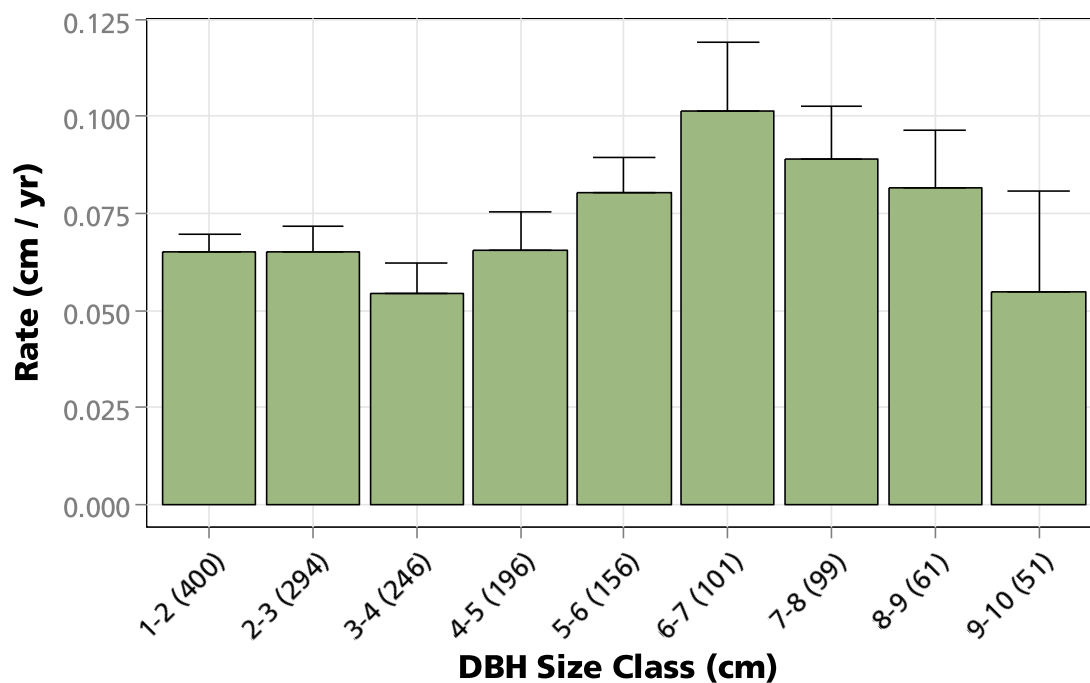


Figure 19. Diameter class growth rates of tree saplings in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008, and remeasured in 2011 and 2012. Standard errors are shown for each bar and number of trees is shown in parentheses.

Tree Seedlings

Forest regeneration in the Mid-Atlantic and Northeast Coastal and Barrier networks is primarily affected by deer browse 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 km^2 or about 22 per mi^2 (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 and Northeast Coastal and Barrier network parks included in this protocol. 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-m^2 quadrats. A score is 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 10). In Valley Forge NHP, an additional height class category (0.05 – 0.15 m) is included due to the low density of seedlings as a result of high deer browse pressure. 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 is considered adequately stocked (i.e. having sustainable regeneration) if there is an average weighted score or stocking index of 24 or more seedlings per twelve 1-m^2 quadrats, or about 2 or more seedlings per 1-m^2 . In high deer density areas, an average stocking index of 8 or more seedlings per 1-m^2 is required. Since deer densities are generally considered to be high throughout the Mid-Atlantic region, we consider regeneration to be “Good” if the stocking index is above 8 seedlings per m^2 averaged

across all plots, “Caution” if less than or equal to 8 but greater than 2 per m², and “Significant Concern” if stocking index is below or equal to 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 m² in areas with low deer densities and > 8 per m² in areas with high deer densities); if 70% of plots meet the appropriate criterion, then regeneration is deemed to be adequate. Again, the criterion we use is > 8 per m².

Table 10. 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
0.05 – 0.15 m ¹	1
0.15 – 0.3 m	1
0.3 – 1 m	2
1 – 1.5 m	20
>1.5	50

¹ Only in Valley Forge NHP due to the high density of deer in the park.

Figure 20 shows the average weighted seedling score per m² per plot in each of the parks as compared to the mean for the Mid-Atlantic and Northeast Coastal and Barrier networks. The two dashed lines show the lower limits for adequate stocking established for high and low deer densities. Each bar shows the 95% confidence limits of the scores; any value within that limit is not significantly different from the mean (i.e. the difference may be due to chance). The figure shows that Appomattox Court House NHP, Gettysburg NMP, and Hopewell Furnace NHS have the highest seedling regeneration, with means that have increased substantially over the past four years. However, only Gettysburg NMP is classified in the “Good” level. All units in Fredericksburg and Spotsylvania NMP, Eastern Front of Petersburg NB, and Richmond NBP showed declines in seedling scores over the past four years and are ranked as significant concern, except Spotsylvania Battlefield in Fredericksburg and Spotsylvania NMP which is ranked as caution. Valley Forge NHP is showing a gradual increase in regeneration. Regeneration also varied across community types (Figure 21).

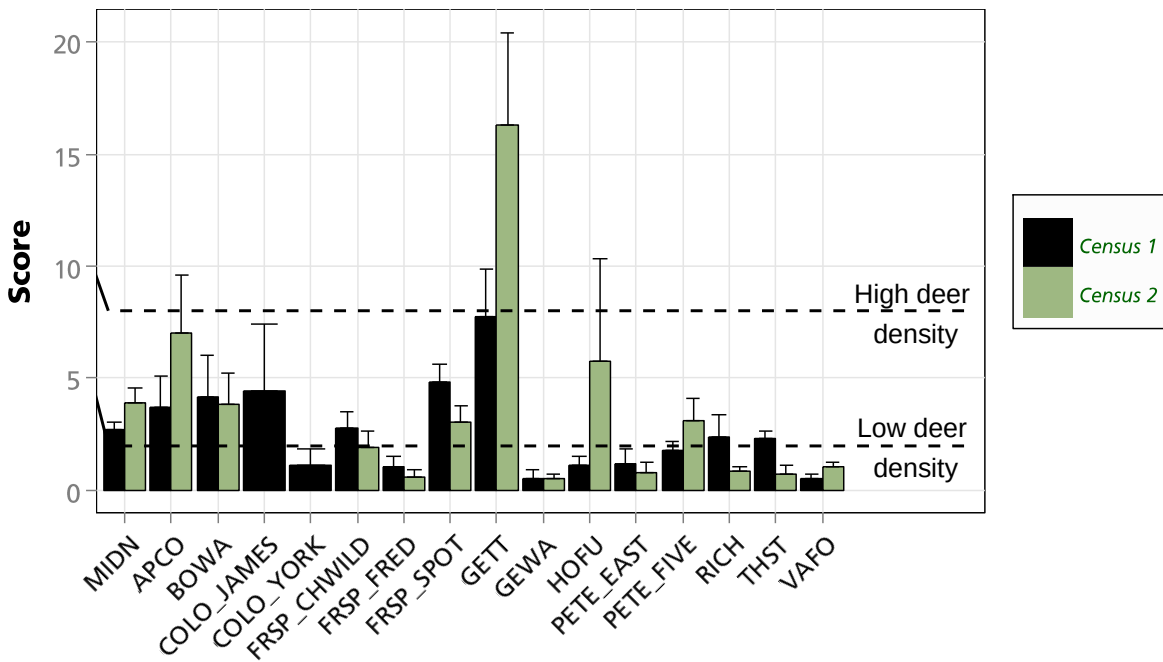


Figure 20. Canopy tree species regeneration (average weighted seedling score per 1 m² per plot) across Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008 (Census 1), and remeasured in 2011 and 2012 (Census 2). Exotic tree species and species that do not reach the canopy are excluded from the seedling index score. Bars show the 95% confidence interval. Colonial NHP was only sampled on one occasion.

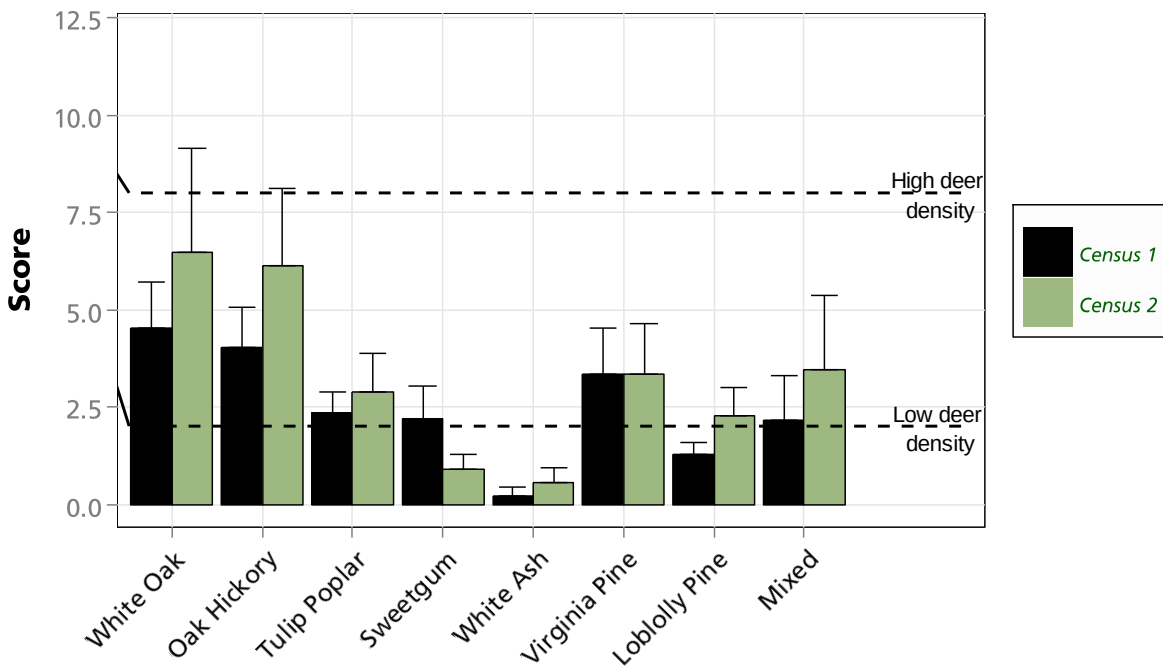


Figure 21. Canopy tree species regeneration (average weighted seedling score per 1 m² per plot) across different community types in the Mid-Atlantic and the Northeast Coastal and Barrier network parks for plots established in 2007 and 2008 (Census 1), and remeasured in 2011 and 2012 (Census 2). Bars show the 95% confidence interval.

Vine Indicator Species

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).

Table 11 shows the vine species documented in the two networks, while Table 12 summarizes vine occurrence across the networks in 2012. The most common species across the networks was Virginia creeper (*Parthenocissus quinquefolia*) which occurred in all parks.

Table 11. Vine indicator species frequency (number of plots) in forest vegetation monitoring plot quadrats sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.

Species	APCO	BOWA	COLO_JAMES	COLO_YORK	FRSP_CHWILD	FRSP_FRED	FRSP_SPOT	GETT	GEWA	HOFU	PETE_EAST	PETE_FIVE	RICH	THST	VAFO
<i>Campsis radicans</i>	-	-	-	-	-	-	1	-	1	-	3	2	2	1	1
<i>Celastrus orbiculatus</i> ¹	1	-	-	-	-	-	-	-	-	1	-	-	-	-	2
<i>Euonymus fortunei</i> ¹	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1
<i>Hedera helix</i> ¹	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-
<i>Lonicera japonica</i> ¹	6	1	-	2	2	2	1	8	1	-	5	1	5	2	2
<i>Parthenocissus quinquefolia</i>	7	2	2	4	2	3	2	9	1	3	5	1	3	2	3
<i>Smilax</i> spp.	-	-	2	3	-	-	1	-	-	-	2	-	-	-	-
<i>Smilax glauca</i>	4	-	-	3	8	4	4	-	-	1	6	5	6	1	1
<i>Smilax rotundifolia</i>	6	2	2	1	9	4	7	-	2	2	6	-	8	2	1
<i>Toxicodendron radicans</i>	4	2	-	3	1	2	-	7	-	1	3	1	3	1	2
<i>Vinca minor</i> ¹	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
<i>Vitis</i>	7	1	-	6	-	2	2	6	1	-	3	4	8	2	3
Total species/taxa	7	5	3	7	5	6	8	5	6	5	9	6	7	7	9

¹ Invasive exotic species.

Table 12. Summary of indicator vines in forest vegetation monitoring plot sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.

Park	# of plots	# species in trees in plot ¹	# species in quadrats ¹	# trees with vines in plot	Mean # of trees per plot with vines	# tree species in plot with vines
APCO	7	2	7	20	2.86	10
BOWA	0	0	0	0	0.00	0
COLO_JAMES	2	1	3	2	1.00	2
COLO_YORK	10	3	7	9	0.90	4
FRSP_CHWILD	13	1	5	1	0.08	1
FRSP_FRED	7	3	6	20	2.86	6
FRSP_SPOT	8	4	8	14	2.00	6
GETT	9	3	5	20	2.22	11
GEWA	2	4	6	6	3.00	2
HOFU	0	0	0	0	0.00	0
PETE_EAST	7	6	9	21	3.00	8
PETE_FIVE	0	0	0	0	0.00	0
RICH	8	4	7	12	1.5.0	6
THST	2	2	7	6	3.00	3
VAFO	7	3	9	24	3.43	9

¹ Species richness only includes vine indicator taxa.

Invasive Exotic Indicator Species

A list of 29 invasive exotic indicator species and taxa is targeted for monitoring by the Mid-Atlantic and Northeast Coastal and Barrier networks. The cover of these exotic indicators is recorded in each of the 12 quadrats per plot, and additional species of indicator exotics present in the plot but outside the quadrats are noted. Table 13 summarizes exotic indicator species sampled in 2012 by park, while Table 14 summarizes species data. The change in mean percent cover of invasive exotic indicator species (Figure 22) and their occurrence in different community types (Figure 23) between 2007 and 2008 (Census 1) and 2011 and 2012 (Census 2) in Mid-Atlantic and Northeast Coastal and Barrier network parks is illustrated.

Japanese stiltgrass (*Microstegium vimineum*) was the species that occurred in the most number of plots (Table 14) and had the highest average percent cover per quadrat (Figure 22). More extensive analysis of invasive exotic indicator data will be conducted once more plots have been remeasured.

Table 13. Summary of invasive exotic indicator species and taxa in forest vegetation monitoring plots sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.

Park	# of plots	# plots with exotics ¹	% quadrats with exotics	Mean # quadrats / plot with exotics	Total # exotic species ²	Mean # exotic species ²
APCO	7	7 (0)	81.0%	9.7	8 (0)	3.00 (0.29)
BOWA	2	2 (0)	91.7%	11.0	2 (0)	1.00 (0.00)
COLO_JAMES	2	2 (0)	62.5%	7.5	1 (2)	1.00 (1.00)
COLO_YORK	10	6 (1)	30.8%	3.7	4 (1)	1.20 (0.30)
FRSP_CHWILD	13	2 (0)	5.8%	0.8	1 (0)	0.15 (0.00)
FRSP_FRED	7	2 (2)	3.6%	0.4	1 (0)	0.29 (0.29)
FRSP_SPOT	8	1 (0)	10.4%	1.4	3 (0)	0.38 (0.00)
GETT	9	8 (1)	85.2%	10.2	11 (1)	4.78 (1.11)
GEWA	2	1 (0)	41.7%	5.0	4 (0)	2.00 (0.00)
HOFU	4	3 (1)	43.8%	5.3	7 (1)	2.25 (1.50)
PETE_EAST	7	7 (0)	47.6%	5.7	4 (0)	2.00 (0.14)
PETE_FIVE	6	1 (0)	2.8%	0.3	2 (0)	0.33 (0.00)
RICH	8	5 (2)	41.7%	5.0	5 (2)	1.38 (0.62)
THST	2	2 (0)	95.8%	11.5	4 (1)	3.50 (1.00)
VAFO	7	5 (0)	59.5%	7.1	12 (0)	3.86 (0.43)

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

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

Table 14. Invasive exotic indicator species and taxa in forest vegetation monitoring plots sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.

Latin Name	Common Name	# of plots ¹	Mean cover class / plot ²
<i>Alliaria petiolata</i>	garlic mustard	10 (0)	0-1%
<i>Berberis thunbergii</i>	Japanese barberry	5 (3)	0-1%
<i>Celastrus orbiculatus</i>	oriental bittersweet	4 (2)	0-1%
<i>Duchesnea indica</i>	Indian strawberry	8 (0)	0-1%
<i>Euonymus fortunei</i>	climbing euonymus, winter creeper	2 (0)	0-1%
<i>Hedera helix</i>	English ivy	2 (3)	0-1%
<i>Lespedeza cuneata</i>	Chinese lespedeza, sericea lespedeza	1 (0)	0-1%
<i>Ligustrum</i>	ligustrum, privet	18 (1)	0-1%
<i>Lonicera - Exotic</i>	honeysuckle - exotic	7 (1)	0-1%
<i>Lonicera japonica</i>	Japanese honeysuckle	38 (4)	0-1%
<i>Microstegium vimineum</i>	Japanese stiltgrass	40 (5)	5-10%
<i>Polygonum caespitosum</i>	Oriental lady's thumb	9 (2)	0-1%
<i>Rosa multiflora</i>	multiflora rose	9 (8)	0-1%
<i>Rubus phoenicolasius</i>	wine raspberry	7 (6)	0-1%
<i>Vinca minor</i>	Myrtle	1 (0)	0-1%
Total Species:	15		

¹ Number of plots with invasive exotic indicator species in quadrats. Values in parentheses are additional number of plots with exotic indicator species 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.

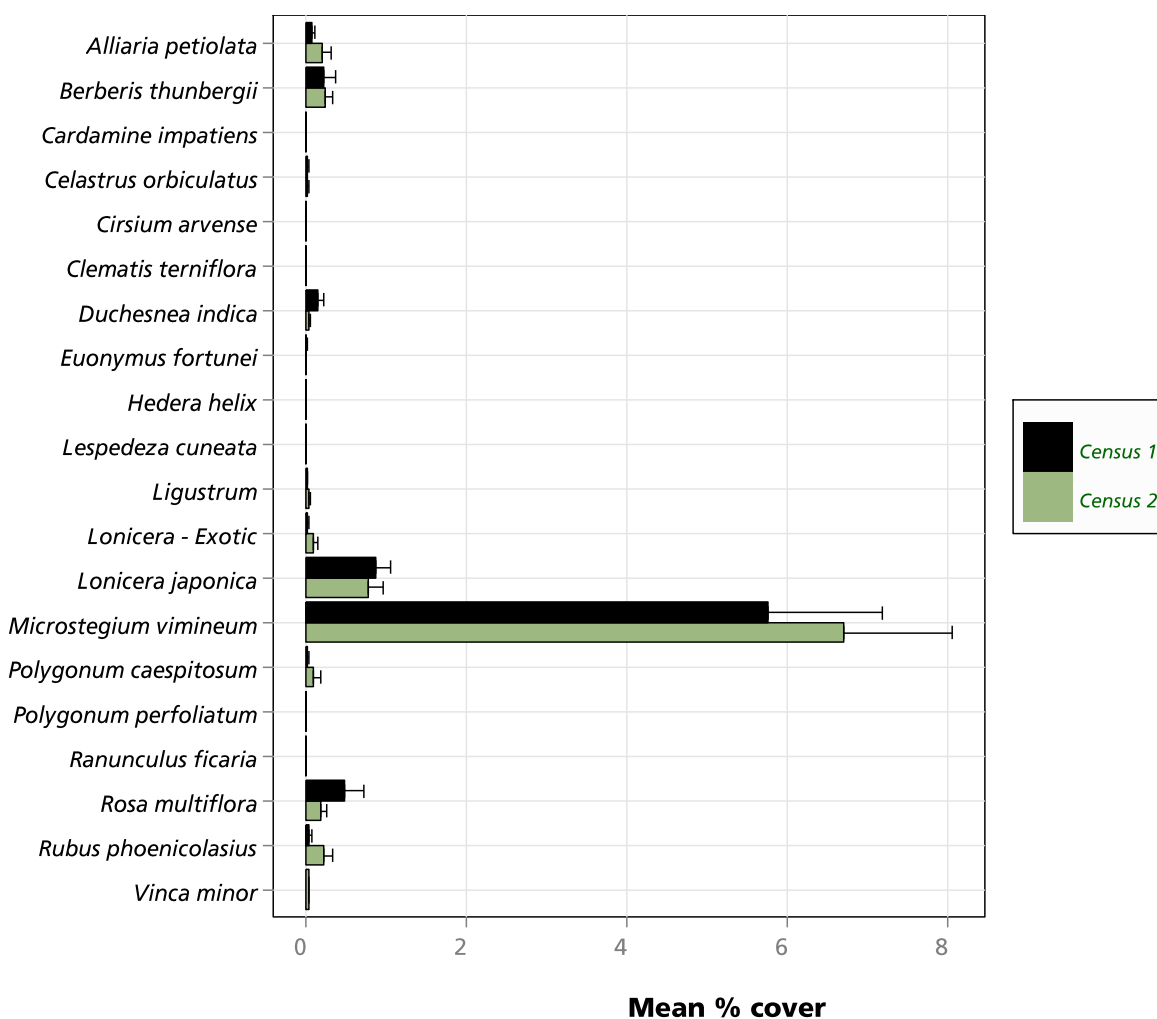


Figure 22. Mean percent cover of invasive exotic indicator species and taxa in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008 (Census 1), and remeasured in 2011 and 2012 (Census 2). Standard errors are shown for each bar. All data are based on 154 plots.

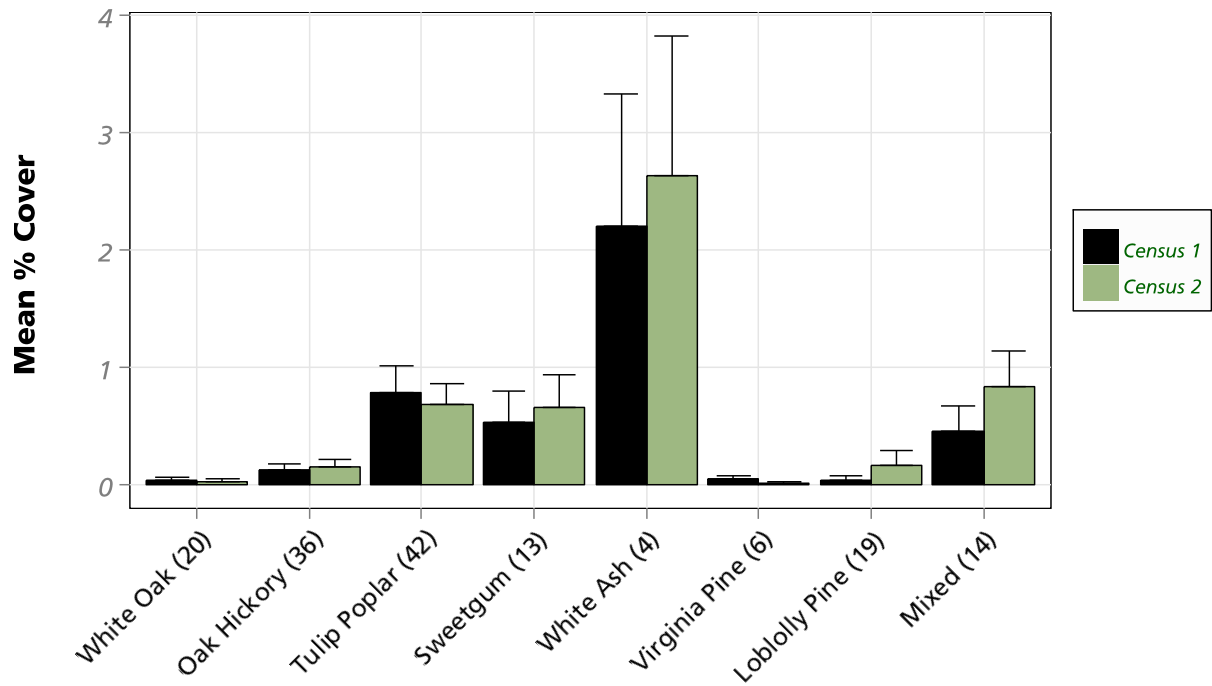


Figure 23. Mean percent cover of invasive exotic indicator species and taxa in different community types in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008 (Census 1), and remeasured in 2011 and 2012 (Census 2). Standard errors are shown for each bar and number of plots is shown in parentheses.

Deer-Browse Indicator Species

A list of 34 native deer-browse indicator species and taxa (including vines) is targeted for measurement in the 12 quadrats in each plot, and their presence is also noted if they occur in the plot only but outside the quadrats. Table 15 summarizes the results for deer-browse indicator species and taxa sampled in 2012 by park, while Table 16 summarizes species data across the Mid-Atlantic and Northeast Coastal and Barrier networks. The change in mean percent cover of deer-browse indicator species (Figure 24) and their occurrence in different community types (Figure 25) between 2007–2008 (Census 1) and 2011–2012 (Census 2) are illustrated. The 2011–2012 deer-browse indicator species data are presented as the mean number and percent cover of deer-avoided and deer-preferred herbaceous (including vines) and shrub indicator species per plot in each park (Table 17). More extensive analysis of deer-browse indicators will be conducted once more plots have been sampled.

Table 15. Deer-browse indicator species and taxa in forest vegetation monitoring plots sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.

Park	# of plots	Plots with indicator spp. ¹	% quads / plot with indicator spp.	Mean # quads / plot with indicator spp.	Total # indicator spp. ²	Mean # indicator spp. / plot ²
APCO	7	7 (0)	92.86%	11.14	14 (2)	7.86 (2.57)
BOWA	2	2 (0)	79.17%	9.50	7 (3)	5.50 (3.50)
COLO_JAMES	2	2 (0)	75.00%	9.00	6 (6)	5.00 (4.50)
COLO_YORK	10	9 (1)	48.33%	5.80	13 (2)	3.50 (3.40)
FRSP_CHWILD	13	13 (0)	75.00%	9.75	14 (3)	3.92 (1.92)
FRSP_FRED	7	7 (0)	72.62%	8.71	15 (2)	4.71 (3.43)
FRSP_SPOT	8	8 (0)	51.04%	7.00	12 (3)	3.88 (2.12)
GETT	9	9 (0)	87.04%	10.44	11 (3)	5.78 (1.33)
GEWA	2	2 (0)	50.00%	6.00	8 (2)	5.00 (1.50)
HOFU	4	4 (0)	91.67%	11.00	16 (3)	6.50 (2.25)
PETE_EAST	7	7 (0)	72.62%	8.71	13 (1)	5.86 (2.14)
PETE_FIVE	6	6 (0)	63.89%	7.67	11 (2)	4.00 (2.33)
RICH	8	8 (0)	78.12%	9.38	17 (0)	6.62 (1.50)
THST	2	2 (0)	87.50%	10.50	10 (3)	7.50 (2.50)
VAFO	7	7 (0)	63.10%	7.57	14 (3)	3.71 (1.57)

¹ Number of plots with deer-browse indicator species in quadrats. Values in parentheses are additional number of plots with indicators recorded only outside the quadrats.

² Number/Mean of deer-browse indicator species occurring in quadrats. Values in parentheses are additional number/mean of indicators found in plots only outside quadrats.

Table 16. Native deer-browse indicator species and taxa in forest vegetation monitoring plots sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.

Latin Name	Common Name	Plots ¹	Mean % Cover / Plot ²
<i>Arisaema triphyllum</i>	Indian jack in the pulpit	8 (9)	0-1%
<i>Campsis radicans</i>	trumpet creeper	11 (5)	0-1%
<i>Cyperaceae</i>	Sedges	51 (14)	0-1%
<i>Dennstaedtia punctilobula</i>	eastern hayscented fern	7 (3)	1-2%
<i>Eurybia divaricate</i>	white wood aster	2 (2)	0-1%
<i>Ferns (all families)</i>	Ferns	16 (19)	0-1%
<i>Impatiens capensis</i>	Jewelweed	3 (3)	0-1%
<i>Maianthemum racemosum</i>	feathery false lily of the valley	10 (8)	0-1%
<i>Medeola virginiana</i>	Indian cucumber	1 (3)	0-1%
<i>Orchid</i>	Orchids	0 (1)	0%
<i>Parthenocissus quinquefolia</i>	Virginia creeper	49 (16)	0-1%
<i>Poaceae</i>	grasses	43 (15)	0-1%
<i>Polygonatum biflorum</i>	Smooth Solomon's seal	9 (5)	0-1%
<i>Polystichum acrostichoides</i>	Christmas fern	10 (16)	0-1%
<i>Rubus spp.</i>	blackberry	28 (14)	0-1%
<i>Smilax spp.</i>	Common greenbrier	8 (4)	0-1%
<i>Smilax glauca</i>	cat greenbrier	43 (11)	0-1%
<i>Smilax rotundifolia</i>	roundleaf greenbrier	52 (15)	0-1%
<i>Thelypteris noveboracensis</i>	New York fern	4 (2)	0-1%
<i>Toxicodendron radicans</i>	eastern poison ivy	30 (21)	0-1%
<i>Uvularia perfoliata</i>	perfoliate bellwort	2 (1)	0-1%
<i>Vaccinium</i>	blueberries	39 (12)	2-5%
<i>Vaccinium corymbosum</i>	highbush blueberry	16(15)	0-1%
<i>Vaccinium stamineum</i>	deerberry	31(3)	0-1%
<i>Vitis spp.</i>	grape	45 (19)	0-1%
Total Species:	25		

¹ Number of plots with deer-browse indicators in quadrats. Values in parentheses are additional number of plots with indicators 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.

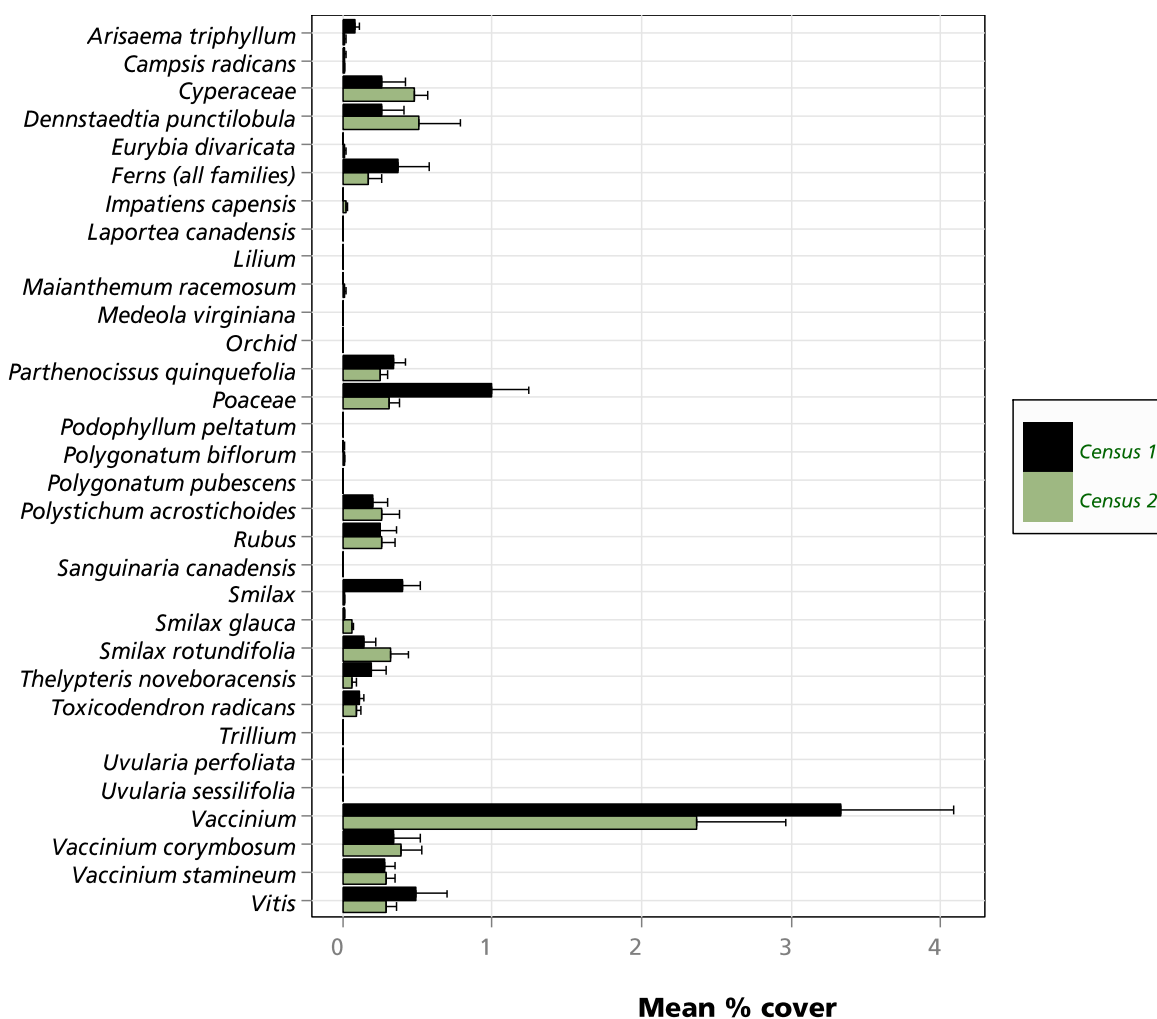


Figure 24. Mean percent cover of deer-browse indicator species and taxa in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008 (Census 1), and remeasured in 2011 and 2012 (Census 2). Standard errors are shown for each bar. All data based on 154 plots.

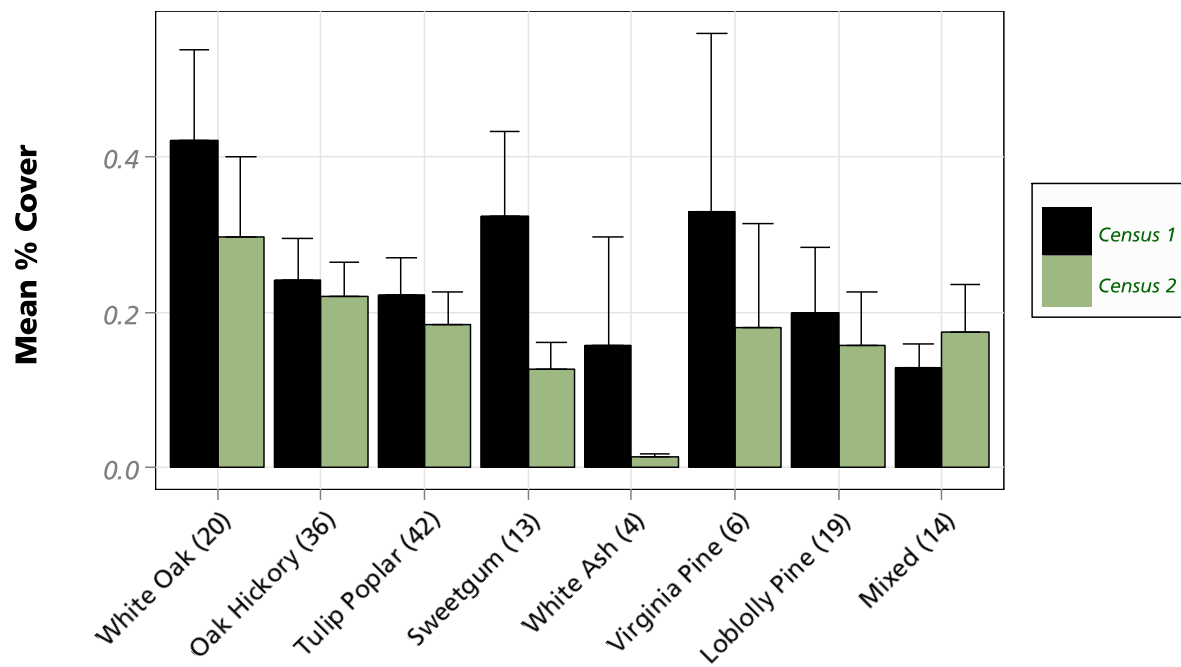


Figure 25. Mean percent cover of deer-browse indicator species and taxa in different community types in the Mid-Atlantic and Northeast Coastal and Barrier network parks for plots established in 2007 and 2008 (Census 1), and remeasured in 2011 and 2012 (Census 2). Standard errors are shown for each bar and number of plots in parentheses.

Table 17. Native deer-browse indicator herbaceous and shrub species and taxa in forest vegetation monitoring plots sampled in 2011 and 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.

Park	# of plots	Mean # of indicator species / plot				Mean % cover / plot			
		Herbaceous ¹		Shrubs		Herbaceous ¹		Shrubs	
		Avoided	Preferred	Avoided	Preferred	Avoided	Preferred	Avoided	Preferred
APCO	14	3.21	3.50	0.86	0.50	0.25	0.14	0.26	0.20
BOWA	4	4.00	4.25	0.50	0.75	0.19	0.05	0.03	0.31
COLO_JAMES	4	3.00	2.00	0.25	0.00	0.35	0.15	0.00	0.00
COLO_YORK	20	2.26	1.74	0.16	0.11	0.11	0.02	0.08	0.02
FRSP_CHWILD	24	1.04	1.83	2.04	0.13	0.10	0.02	3.61	0.06
FRSP_FRED	14	1.71	1.79	1.43	0.07	0.14	0.02	1.25	0.03
FRSP_SPOT	14	1.21	1.79	1.50	0.14	0.02	0.01	0.32	0.05
GETT	16	3.41	1.35	0.12	0.76	0.38	0.03	0.38	0.97
GEWA	4	3.50	2.50	0.00	0.50	0.41	0.05	0.00	0.11
HOFU	8	3.25	1.75	0.75	0.50	0.88	0.03	0.88	1.99
PETE_EAST	14	2.64	2.36	0.71	0.21	0.07	0.09	1.02	0.01
PETE_FIVE	12	0.92	2.50	2.25	0.08	0.01	0.04	1.40	0.00
RICH	16	3.19	2.88	0.63	0.19	0.40	0.06	0.35	0.05
THST	4	4.00	2.50	0.00	0.50	0.46	0.02	0.00	0.09
VAFO	14	2.43	0.64	0.07	0.43	0.12	0.01	0.00	0.05

¹ Including vine species.

Coarse Woody Debris

Coarse woody debris (CWD) refers to large dead branches and whole downed trees, and when compared to the proportion of live tree volume it provides an indication of wildlife habitat availability (Tierney et al. 2013). The 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).

Plots are rated based on the following criteria:

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.

Among plots sampled in 2012, both units at Colonial NHP and Gettysburg NMP had the highest mean volume of CWD (Table 18). Appomattox Court House NHP, Five Forks unit of Petersburg NB and Hopewell Furnace NHS were the only parks with proportions considered as "Significant Concern", that is, CWD was < 5% of standing live tree volume. The highest ratios of CWD to live trees were found at the Jamestown unit of Colonial NHP. Comparisons were made to the ratings from the first census in 2008. Ratings declined slightly in Appomattox Court House NHP

while they improved in Fredericksburg unit of Fredericksburg and Spotsylvania NMP, as well as in Richmond NBP and Thomas Stone NHS. As forests continue to mature, we expect to see increasing proportions of CWD in the parks.

Table 18. Coarse woody debris in forest vegetation monitoring plots sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.

Park	# of plots	Mean volume CWD (m ³ / ha)	Mean volume live trees (m ³ / ha)	Mean ratio CWD to live trees / Plot	Rating ¹	
					2008	2012
APCO	7	15.97	299.02	0.05 ²	C	SC
BOWA	2	52.42	266.28	0.21	G	G
COLO_JAMES	2	348.99	388.14	0.83	-	G
COLO_YORK	10	86.31	420.86	0.25	-	G
FRSP_CHWILD	12	20.48	348.75	0.11	C	C
FRSP_FRED	7	50.49	319.42	0.34	C	G
FRSP_SPOT	7	51.44	421.81	0.14	C	C
GETT	9	55.14	195.28	0.39	G	G
GEWA	2	36.15	527.21	0.07	C	C
HOFU	4	16.08	488.67	0.03	SC	SC
PETE_EAST	7	79.87	349.94	0.30	G	G
PETE_FIVE	6	8.39	394.95	0.02	SC	SC
RICH	8	28.20	320.45	0.10	SC	C
THST	2	27.08	415.61	0.05	SC	C
VAFO	7	41.24	454.14	0.10	C	C

¹ Rating for 2008 and 2012 as G: Good; C: Caution; SC: Significant Concern.

² Note that the ratio for APCO is actually just below 5% but is rounded up to 5%.

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 Ca:Al 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). However, we use different extractant methods to analyze our soils than those used by Cronan and Grigal. Our soil analyses provide actual soil concentrations of Ca:Al, while those used by Cronan and Grigal (1995) provide concentrations of Ca:Al in the soil water. The two methods are therefore not directly comparable, and thus, the threshold rankings may not be valid either. We have therefore stopped using the Caution and Significant Concern rankings and here we only present a ranking for those sites where Ca:Al ratios are considered to be Good, that is, they exceed a ratio of Ca:Al of 4.0.

Good: Ca:Al ratio > 4.0 in O and A horizons 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 2012. 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 networks had at least one metric that was either of “Significant Concern” or “Caution” (Table 19). Acidification was not of concern in Appomattox Court House NHP, Booker T. Washington NM, Gettysburg NMP, and Thomas Stone NHS. Nitrification was rated as “Good” only in the Five Forks unit of Petersburg NB and Chancellorsville and Wilderness unit of Fredericksburg and Spotsylvania NMP.

These data need to be interpreted with caution as soil results presented are only for samples taken in 2012. 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 19. Soil chemistry ratings for forest vegetation monitoring plots sampled in 2012 in the Mid-Atlantic and Northeast Coastal and Barrier network parks.

Unit ¹	Median Ca:Al	Ca:Al Rating	Median C:N	C:N Rating
APCO	32.55	Good	15.76	Significant Concern
BOWA	83.02	Good	16.72	Significant Concern
FRSP_CHWILD	0.17		25.60	Good
FRSP_FRED	0.71		19.25	Significant Concern
FRSP_SPOT	2.58		22.32	Caution
GETT	167.81	Good	13.82	Significant Concern
GEWA	0.41		20.40	Caution
HOFU	1.25		20.44	Caution
PETE_EAST	1.54		18.36	Significant Concern
PETE_FIVE	0.81		28.71	Good
RICH	2.46		19.29	Significant Concern
THST	14.45	Good	15.36	Significant Concern
VAFO	1.56		20.31	Caution

¹ No soil samples were collected in Colonial NHP.

Park Summaries

The following are brief summaries for each of the parks. The information presented here is directly extracted from the Forest Vegetation Monitoring Resource Briefs prepared for each park which can be found on Integrated Resource Management Applications Portal (<https://irma.nps.gov/App/Reference/Profile/2173664>).

Appomattox Court House National Historical Park

In 2012, seven plots established in 2008 at Appomattox Court House NHP (APCO) were revisited. With only one-half of the total plots in the park resampled, the following highlights of temporal trends are preliminary. However, no substantial changes have been observed with the addition of the 2012 data compared to last year's results.

All trees with a diameter at breast height (DBH) equal to or greater than 10 cm were measured and their condition was assessed. Trees that had died since the last census were noted, while recruited trees, those reaching the minimum DBH of 10 cm, were identified, measured, mapped, marked, and tagged. Most of the tree mortality occurred in the pine communities where the pines had a higher mortality than the network average. This is not uncommon due to many patches of early successional forest in the park that are currently maturing, and illustrated by the high recruitment rates of hardwood species, in particular among the oaks. Growth rates were generally higher than observed across the network among smaller trees, but larger trees appeared to have slower growth (Figure 26).

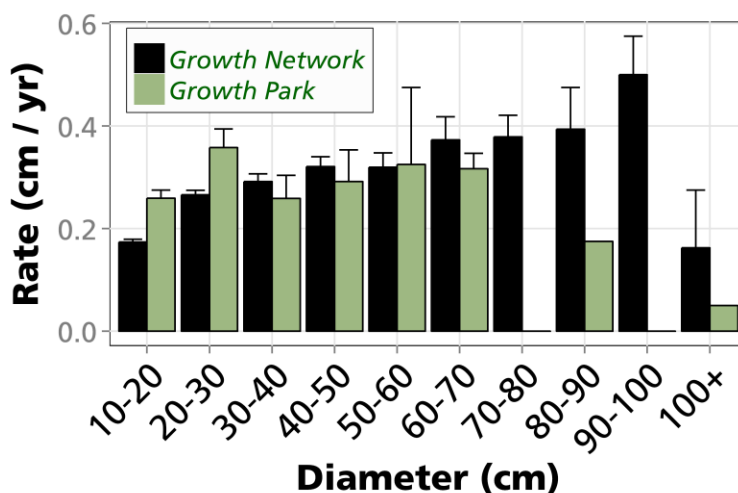


Figure 26. Growth rates of mature trees in different diameter size classes at Appomattox Court House NHP.

Three microplots in each plot were sampled for tree saplings and shrubs with diameters greater than 1 cm and less than 10 cm. The trends were similar to those observed among mature trees, with most of the recruitment occurring in the oak-hickory and mixed forests. However, growth rates in oak-hickory communities continued to be well below the network average.

Tree seedlings are identified in each of 12 quadrats, and their heights measured. The number and height of seedlings determines whether there is adequate regeneration to sustain the forest canopy. In parks where deer densities are high, a larger number of seedlings is required due to the heavier browse pressure than in parks where deer densities are low. Thus, regeneration is considered as "Good" if it exceeds the high deer density stocking index, and "Significant Concern" when it falls below the low deer density stocking index in any park. Appomattox Court House NHP is considered as "Caution" with the addition of new data this year; the stocking index is below that required under high deer-browse pressure.

Invasive exotic and native indicator species are also monitored in the quadrats. The plots sampled in 2012 had a relatively high proportion of exotic species at Appomattox Court House NHP with the most common species being Japanese honeysuckle (*Lonicera japonica*) which showed a significant decrease in cover over the previous four years. However, Japanese stiltgrass (*Microstegium vimineum*) showed a substantial increase. Among the native indicators, greenbrier (*Smilax* spp.) species were the most abundant.

In 2013, field crews will revisit plots established in 2009, adding to the data on forest dynamics and increasing our confidence in the forest health trends.

Booker T. Washington National Monument

In 2012, two plots established in 2008 at Booker T. Washington NM (BOWA) were revisited. With only one-half of the total plots in the park resampled, the following highlights of temporal trends are preliminary. However, no substantial changes have been observed with the addition of the 2012 data compared to last year's results.

All trees with a diameter at breast height (DBH) equal to or greater than 10 cm were measured and their condition was assessed. Trees that had died since the last census were noted, while recruited trees, those reaching the minimum DBH of 10 cm, were identified, measured, mapped, marked, and tagged. Most of the tree mortality occurred in the Virginia pine community. This is not uncommon due to patches of early successional forest in the park that are currently maturing, and illustrated by the high recruitment rates of early successional hardwood species such as tulip poplar (*Liriodendron tulipifera*). Growth rates were higher than observed across the network, especially among the smaller diameter size classes (Figure 27).

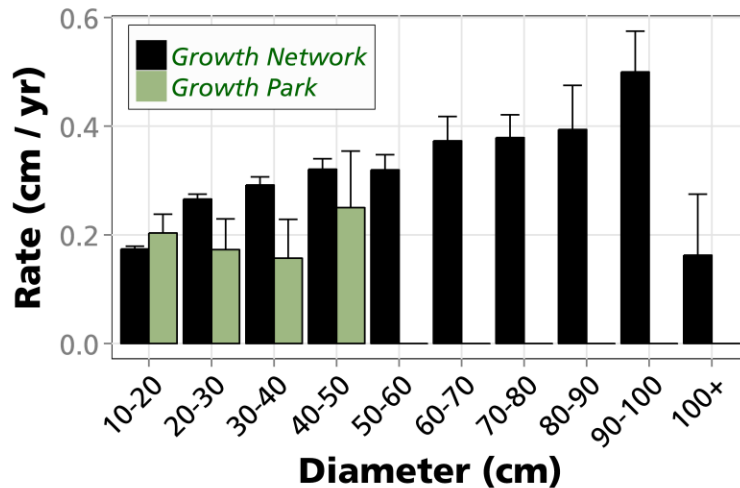


Figure 27. Growth rates of mature trees in different diameter size classes at Booker T. Washington NM.

Three microplots in each plot were sampled for tree saplings and shrubs with diameters greater than 1 cm and less than 10 cm. Trends remained similar to those observed in 2011. Sapling mortality was only documented in the pine community, but recruitment occurred in both community types. The pine community had substantially higher recruitment rates than those observed across the network. In contrast, growth rates were highest in the tulip poplar community, well above the network average.

Tree seedlings are identified in each of 12 quadrats, and their heights measured. The number and height of seedlings determines whether there is adequate regeneration to sustain the forest canopy. In parks where deer densities are high, a larger number of seedlings is required due to the heavier browse pressure than in parks where deer densities are low. Thus, regeneration is considered as "Good" if it exceeds the high deer density stocking index, and "Significant Concern" when it falls below the low deer density stocking index in any park. At Booker T. Washington NM, the addition of new plots brought down the average from 2011. However, seedling regeneration in the park is still classified as "Caution".

Invasive exotic and native indicator species are also monitored in the quadrats. Compared to the rest of the network, Booker T. Washington NM had a low average percent cover of exotics in the plots sampled with the most common species being Japanese honeysuckle (*Lonicera japonica*) and Japanese stiltgrass (*Microstegium vimineum*), both of which declined between the sampling periods. Among the native indicators, *Poaceae* (grasses) and *Cyperaceae* (sedges) were the most abundant.

In 2013, field crews will revisit plots established in 2009, adding to the data on forest dynamics and increasing our confidence in forest health trends.

Colonial National Historical Park

In 2012, 12 plots were established in Colonial National Historical Park (COLO), two in the Jamestown unit and 10 in Yorktown. With only one-half of the total plots established in the park,

the following highlights are preliminary. No plots have been revisited, so it is not possible to comment on how the forests in Colonial NHP are changing over time.

All trees with a diameter at breast height (DBH) equal to or greater than 10 cm were measured and their condition was assessed. There are more trees per plot in Yorktown than Jamestown, resulting in a greater average number of species. The total number of tree species is also greater in Yorktown largely due to a greater diversity of habitats in that unit and to the larger number of plots sampled. Forests in Yorktown also have a greater number of larger trees, probably related to higher disturbance rates in Jamestown (Figure 28).

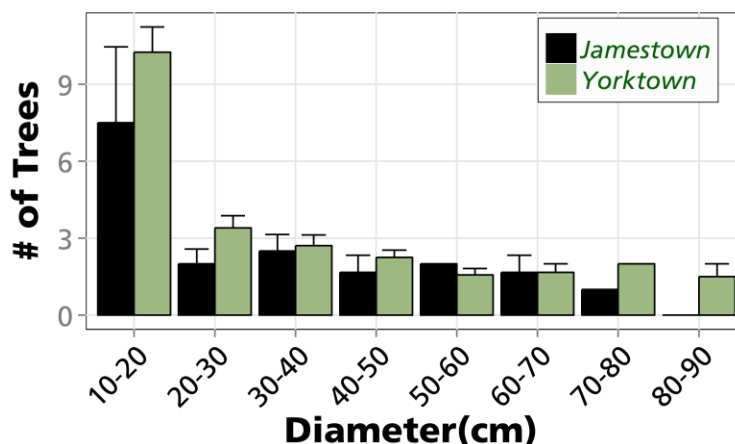


Figure 28. Distribution of mature trees in different diameter size classes at Colonial NHP.

Three microplots in each plot were sampled for tree saplings and shrubs with diameters greater than 1 cm and less than 10 cm. The forests of Jamestown had more saplings than Yorktown, but the diversity of sapling species was lower.

Tree seedlings are identified in each of 12 quadrats, and their heights measured. The number and height of seedlings determines whether there is adequate regeneration to sustain the forest canopy. In parks where deer densities are high, a larger number of seedlings is required due to the heavier browse pressure than in parks where deer densities are low. Thus, regeneration is considered as "Good" if it exceeds the high deer density stocking index, and "Significant Concern" when it falls below the low deer density stocking index in any park. Jamestown regeneration levels are ranked as "Caution" while those in Yorktown are of "Significant Concern". Additional plots in both units will help us determine if there is cause for long-term concern regarding forest regeneration.

Invasive exotic and native indicator species are also monitored in the quadrats. Japanese stiltgrass (*Microstegium vimineum*) was by the far the most common invasive exotic indicator species encountered, with it occurring in 75% of plots in Yorktown and Jamestown. In Jamestown, the average cover of stiltgrass per plot was 5-10% where it was the only invasive indicator species present. The most common native indicators were roundleaf greenbrier (*Smilax rotundifolia*) in Jamestown and grape (*Vitis* spp.) and sedges (*Cyperaceae*) were common in Yorktown.

In 2013, field crews will establish additional plots in the two units of Colonial NHP adding to our understanding of the forest composition of the park. All new plots will be established in the park by 2014 with the first revisits occurring in 2015. At that time, evaluation of trends in the parks forests will be possible.

Fredericksburg and Spotsylvania National Military Park

In 2012, 12 plots established in 2007 at the Chancellorsville and Wilderness unit (treated as one unit) of Fredericksburg and Spotsylvania NMP (FRSP) were revisited, along with seven plots in each of the Fredericksburg and Spotsylvania units. With only one-half of the plots in the park resampled, the following highlights of temporal trends are preliminary. However, no substantial changes have been observed with the addition of the 2012 data compared to last year's results.

All trees with a diameter at breast height (DBH) equal to or greater than 10 cm were measured and their condition was assessed. Trees that had died since the last census were noted, while recruited trees, those reaching the minimum DBH of 10 cm, were identified, measured, mapped, marked, and tagged. The highest tree mortality occurred in the Virginia pine community of the Fredericksburg unit, while the highest recruitment rates occurred in the sweetgum communities of the same unit. Both community types also had the highest growth rates especially among the mid-sized tree diameter classes (Figure 29).

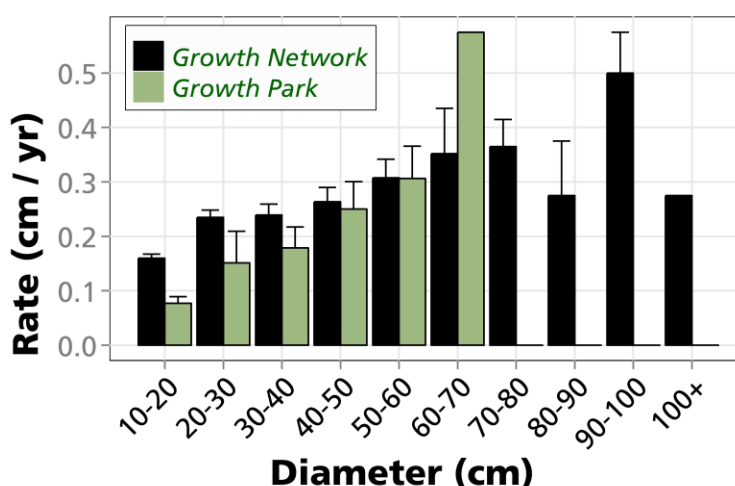


Figure 29. Growth rates of mature trees in different diameter size classes at Fredericksburg unit of Fredericksburg and Spotsylvania NMP.

Three microplots in each plot were sampled for tree saplings and shrubs with diameters greater than 1 cm and less than 10 cm. Sapling mortality was highest in the oak-hickory communities in the Fredericksburg unit, while recruitment was low. The highest recruitment rates were in the tulip poplar community of the Spotsylvania unit. American beech (*Fagus grandifolia*) growth rates were among the highest in the Fredericksburg and Spotsylvania units, while American holly (*Ilex opaca*) had higher than average growth in the Chancellorsville and Wilderness unit.

Tree seedlings are identified in each of 12 quadrats, and their heights measured. The number and height of seedlings determines whether there is adequate regeneration to sustain the forest canopy. In parks where deer densities are high, a larger number of seedlings is required due to

the heavier browse pressure than in parks where deer densities are low. Thus, regeneration is considered as "Good" if it exceeds the high deer density stocking index, and "Significant Concern" when it falls below the low deer density stocking index in any park. All three Fredericksburg and Spotsylvania NMP units showed declines in tree seedling regeneration between measurements. In the Chancellorsville and Wilderness unit the regeneration declined from "Caution" to "Significant Concern". Additional data over the coming years will help us determine if there are potential long-term impacts on the forest communities of the park.

Invasive exotic and native indicator species are also monitored in the quadrats. Compared to the rest of the network, Fredericksburg and Spotsylvania NMP had a low average percent cover of exotics in the plots sampled with the most common species being Japanese honeysuckle (*Lonicera japonica*). Among the native indicators, *Vaccinium* species (blueberries) were the most abundant.

In 2013, field crews will revisit plots established in 2009, adding to the data on forest dynamics and increasing our confidence in forest health trends.

Gettysburg National Military Park

In 2012, eight plots established in 2008 at Gettysburg NMP (GETT) were revisited. With only one-half of the total plots in the park resampled, the following highlights of temporal trends are preliminary. However, no substantial changes have been observed with the addition of the 2012 data compared to last year's results.

All trees with a diameter at breast height (DBH) equal to or greater than 10 cm were measured and their condition was assessed. Trees that had died since the last census were noted, while recruited trees, those reaching the minimum DBH of 10 cm, were identified, measured, mapped, marked, and tagged. Most of the tree mortality occurred in the tulip poplar forest community, which was significantly higher than the network average. This is not uncommon as the successional forests in the park mature. However, recruitment rates were highest in the oak-hickory forest communities, and above the network average. These two community types also had higher tree growth rates than seen across the network, particularly in the mid-size diameter classes (Figure 30).

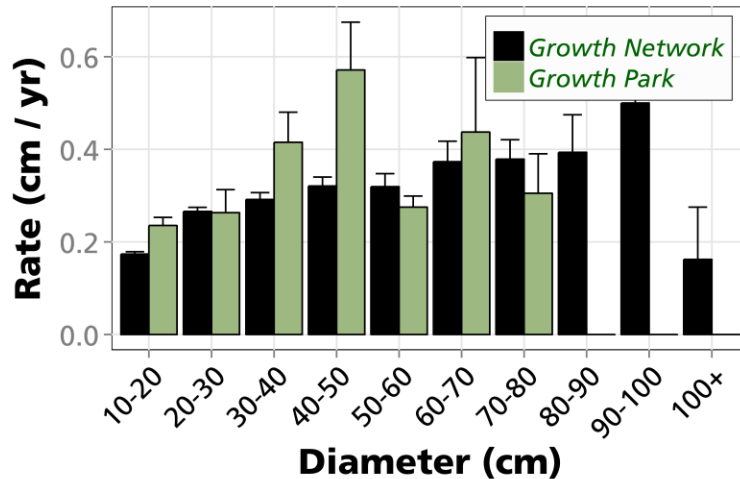


Figure 30. Growth rates of mature trees in different diameter size classes at Gettysburg NMP.

Three microplots in each plot were sampled for tree saplings and shrubs with diameters greater than 1 cm and less than 10 cm. Sapling mortality was highest in the white ash community at rates higher than the network average as were the growth rates, but recruitment was greatest in the oak and tulip poplar communities.

Tree seedlings are identified in each of 12 quadrats, and their heights measured. The number and height of seedlings determines whether there is adequate regeneration to sustain the forest canopy. In parks where deer densities are high, a larger number of seedlings is required due to the heavier browse pressure than in parks where deer densities are low. Thus, regeneration is considered as "Good" if it exceeds the high deer density stocking index, and "Significant Concern" when it falls below the low deer density stocking index in any park. Gettysburg NMP is one of the few network parks where the tree seedling regeneration score has not only increased, but has done so to a level above that required under heavy deer-browse pressure. Seedling regeneration in the park is therefore considered to be "Good".

Invasive exotic and native indicator species are also monitored in the quadrats. Compared to the rest of the network, Gettysburg NMP had a high average percent cover of exotics in the plots sampled with the most common species being Japanese honeysuckle (*Lonicera japonica*) and Japanese stiltgrass (*Microstegium vimineum*). Most exotics declined over the previous four years except Japanese honeysuckle. Among the native indicators, *Poaceae* species (grasses) and Virginia creeper (*Parthenocissus quinquefolia*) were the most abundant.

In 2013, field crews will revisit plots established in 2009, adding to the data on forest dynamics and increasing our confidence in forest health trends.

George Washington Birthplace National Monument and Thomas Stone National Historic Site

In 2012, two plots established in 2008 at George Washington Birthplace National Monument (GEWA) and Thomas Stone National Historic Site (THST), respectively, were revisited. With

only one-quarter of the total plots in the parks resampled, the following highlights of temporal trends are preliminary.

All trees with a diameter at breast height (DBH) equal to or greater than 10 cm were measured and their condition was assessed. Trees that had died since the last census were noted, while recruited trees, those reaching the minimum DBH of 10 cm, were identified, measured, mapped, marked, and tagged. Most of the tree mortality occurred in the pine communities at George Washington Birthplace NM where the pines had a higher mortality than the network average. One of the plots sampled was in an old plantation where the pines are maturing and will eventually give way to a hardwood canopy. Growth rates in the park were generally lower than observed across the network except in the largest size class category sampled at GEWA (Figure 31).

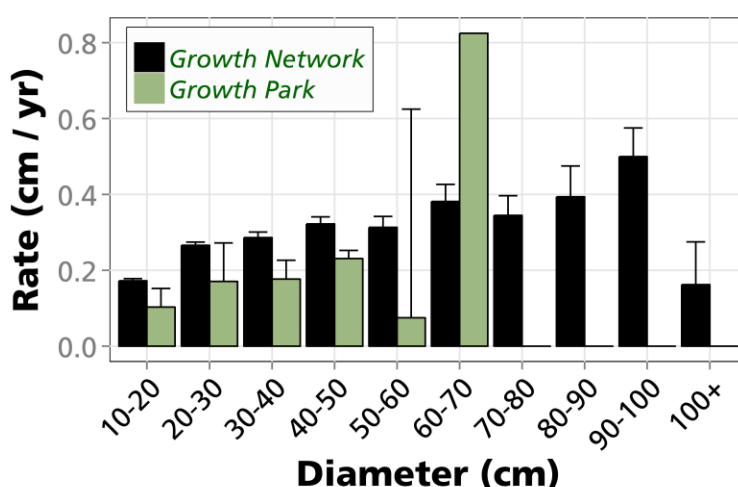


Figure 31. Growth rates of mature trees in different diameter size classes at George Washington Birthplace NM.

Three microplots in each plot were sampled for tree saplings and shrubs with diameters greater than 1 cm and less than 10 cm. At GEWA, the mortality rate was lower than the network average while the recruitment rate was higher. The smaller saplings accounted for the higher growth rates.

Tree seedlings are identified in each of 12 quadrats, and their heights measured. The number and height of seedlings determines whether there is adequate regeneration to sustain the forest canopy. In parks where deer densities are high, a larger number of seedlings is required due to the heavier browse pressure than in parks where deer densities are low. Thus, regeneration is considered as "Good" if it exceeds the high deer density stocking index, and "Significant Concern" when it falls below the low deer density stocking index in any park. Regeneration at GEWA is considered to be of "Significant Concern", however, rates improved very slightly between the two sampling years. At THST, regeneration was rated as "Concern" in 2008, but levels declined substantially by 2012. Continued monitoring will provide valuable information on the condition of forests in the two parks.

Invasive exotic and native indicator species are also monitored in the quadrats. At THST, there was a threefold increase in Japanese stiltgrass (*Microstegium vimineum*) over the four years of sampling. Though stiltgrass also increased in GEWA, the change was only minimal. Among the native indicators, greenbrier species (*Smilax* spp.) were abundant in both parks, while ferns increased in cover substantially at THST.

In 2013, field crews will revisit plots established in 2009, adding to the data on forest dynamics and increasing our confidence in the forest health trends.

Hopewell Furnace National Historic Site

In 2012, four plots established in 2008 at Hopewell Furnace NHS (HOFU) were revisited. With only one-half of the total plots in the park resampled, the following highlights of temporal trends are preliminary. However, no substantial changes have been observed with the addition of the 2012 data compared to last year's results.

All trees with a diameter at breast height (DBH) equal to or greater than 10 cm were measured and their condition was assessed. Trees that had died since the last census were noted, while recruited trees, those reaching the minimum DBH of 10 cm, were identified, measured, mapped, marked, and tagged. Recruitment was primarily in the tulip poplar and oak hickory dominated forest community. This is not uncommon due to patches of early successional forest in the park that are currently maturing, and illustrated by the high growth rate of early successional hardwood species such as tulip poplar (*Liriodendron tulipifera*). Growth rates were generally lower than observed across the network except among trees in the larger diameter size classes (Figure 32).

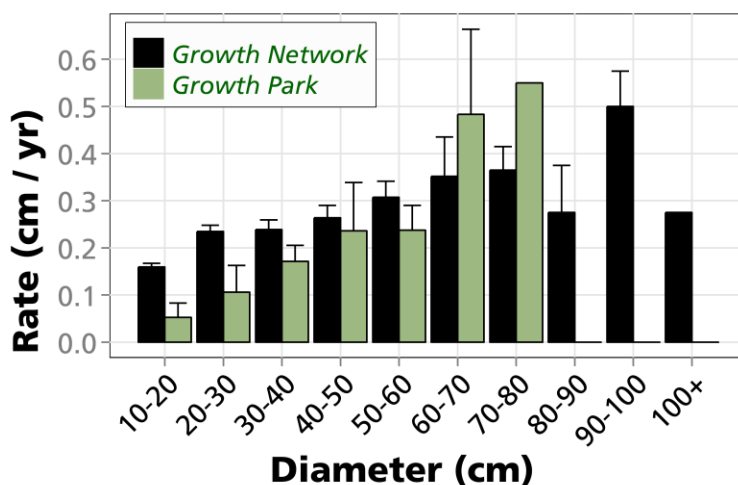


Figure 32. Growth rates of mature trees in different diameter size classes at Hopewell Furnace NHS.

Three microplots in each plot were sampled for tree saplings and shrubs with diameters greater than 1 cm and less than 10 cm. Sapling mortality was only documented in the tulip poplar community and was below the network average. No sapling recruitment was observed in any plots. Sapling growth rates were generally higher than observed across the network.

Tree seedlings are identified in each of 12 quadrats, and their heights measured. The number and height of seedlings determines whether there is adequate regeneration to sustain the forest canopy. In parks where deer densities are high, a larger number of seedlings is required due to the heavier browse pressure than in parks where deer densities are low. Thus, regeneration is considered as "Good" if it exceeds the high deer density stocking index, and "Significant Concern" when it falls below the low deer density stocking index in any park. At Hopewell Furnace NHS, the tree seedling regeneration score increased substantially between measurements. Seedling regeneration in the park based on this data is classified as "Caution". Additional data over the coming years will help us determine if regeneration in the park is in fact improving.

Indicator invasive exotic and native species are also monitored in the quadrats. Compared to the rest of the network, Hopewell Furnace NHS had a moderate percent cover of exotics in the plots sampled. The most common invasive exotic plant species was Japanese stiltgrass (*Microstegium vimineum*) which decreased in cover over the previous four years. Among the native indicators, eastern hayscented fern (*Dennstaedtia punctilobula*) and *Vaccinium* species (blueberries) were the most abundant.

In 2013, field crews will revisit plots established in 2009, adding to the data on forest dynamics and increasing our confidence forest health trends.

Petersburg National Battlefield

In 2012, 13 plots established in 2008 at Petersburg NB (PETE) were revisited, seven in the Eastern Front unit and six in the Five Forks unit. With only one-half of the total plots in the park resampled, the following highlights of temporal trends are preliminary. However, no substantial changes have been observed with the addition of the 2012 data compared to last year's results.

All trees with a diameter at breast height (DBH) equal to or greater than 10 cm were measured, and their condition was assessed. Trees that had died since the last census were noted, while recruited trees, those reaching the minimum DBH of 10 cm, were identified, measured, mapped, marked, and tagged. Most of the tree mortality and recruitment occurred in the oak-hickory community of the Five Forks unit at a rate above the network average. Growth rates were generally lower than observed across the network, except in the tulip poplar community. Larger diameter size classes at the Eastern Front unit had growth rates that were above the network average (Figure 33).

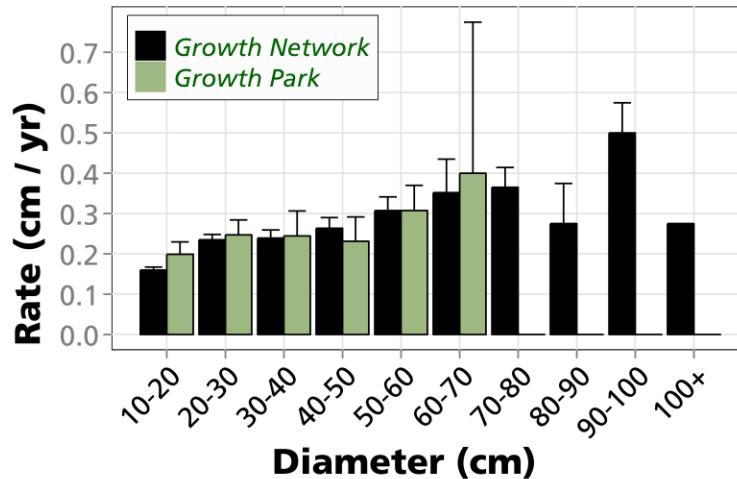


Figure 33. Growth rates of mature trees in different diameter size classes at Petersburg NB.

Three microplots in each plot were sampled for tree saplings and shrubs with diameters greater than 1 cm and less than 10 cm. Sapling mortality was substantially lower in the loblolly pine communities of Five Forks than across the network, but growth rates of sweetgum (*Liquidambar styraciflua*) saplings at Eastern Front were higher than the Mid-Atlantic Network average.

Tree seedlings are identified in each of 12 quadrats, and their heights measured. The number and height of seedlings determines whether there is adequate regeneration to sustain the forest canopy. In parks where deer densities are high, a larger number of seedlings is required due to the heavier browse pressure than in parks where deer densities are low. Thus, regeneration is considered as "Good" if it exceeds the high deer density stocking index, and "Significant Concern" when it falls below the low deer density stocking index in any park. At the Eastern Front unit, the tree seedling regeneration score decreased, being classified as "Significant Concern". However, at Five Forks the seedling score increased, and the regeneration is now classified as "Caution" in that unit. Additional data over the coming years will help us determine if there are potential long-term impacts on the forest communities of the park.

Invasive exotic and native indicator species are also monitored in the quadrats. The Five Forks unit had a very low average percent cover of exotics in the plots sampled, while the Eastern Front plots had a high percent cover of Japanese stiltgrass (*Microstegium vimineum*) that increased since the last census. Among the native indicators, *Vaccinium* species (blueberries) were the most abundant in both units.

In 2013, field crews will revisit plots established in 2009, adding to the data on forest dynamics and increasing our confidence in forest health trends.

Richmond National Battlefield Park

In 2012, eight plots established in 2008 at Richmond NBP (RICH) were revisited. With only one-half of the total plots in the park resampled, the following highlights of temporal trends are preliminary. However, no substantial changes have been observed with the addition of the 2012 data compared to last year's results.

All trees with a diameter at breast height (DBH) equal to or greater than 10 cm were measured and their condition was assessed. Trees that had died since the last census were noted, while recruited trees, those reaching the minimum DBH of 10 cm, were identified, measured, mapped, marked, and tagged. Most of the tree mortality occurred in the loblolly pine community at a rate significantly higher than the network average. In contrast, most of the recruitment occurred in the tulip poplar and sweetgum community types, though at levels below those observed across the network. The dominant species recruited was blackgum (*Nyssa sylvatica*). Growth rates were generally higher than observed across the network, especially in the smaller diameter size classes (Figure 34).

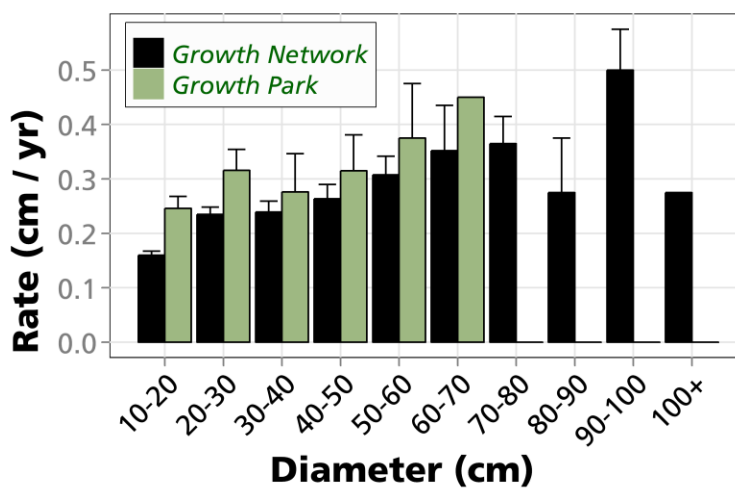


Figure 34. Growth rates of mature trees in different diameter size classes at Richmond NBP.

Three microplots in each plot were sampled for tree saplings and shrubs with diameters greater than 1 cm and less than 10 cm. Sapling mortality was substantially higher in the loblolly forest community, while recruitment was generally lower than the network average and was dominated by mockernut hickory (*Carya alba*). Likewise, growth rates were generally low compared to those observed across the network.

Tree seedlings are identified in each of 12 quadrats, and their heights measured. The number and height of seedlings determines whether there is adequate regeneration to sustain the forest canopy. In parks where deer densities are high, a larger number of seedlings is required due to the heavier browse pressure than in parks where deer densities are low. Thus, regeneration is considered as "Good" if it exceeds the high deer density stocking index, and "Significant Concern" when it falls below the low deer density stocking index in any park. In Richmond NBP the tree seedling regeneration scores declined between censuses, changing the regeneration condition from "Caution" to "Significant Concern". Additional data over the coming years will help us determine if there are potential long-term impacts on the forest communities of the park.

Invasive exotic and native indicator species are also monitored in the quadrats. Compared to the rest of the network, Richmond NBP had a moderate percent cover of exotics in the plots sampled with the most common species being Japanese stiltgrass (*Microstegium vimineum*), which

increased over the previous four years, and Japanese honeysuckle (*Lonicera japonica*) which declined in cover. Among the native indicators, percent cover showed a decline.

In 2013, field crews will revisit plots established in 2009, adding to the data on forest dynamics.

Valley Forge National Historical Park

In 2012, seven plots established in 2008 at Valley Forge NHP (VAFO) were revisited. With only one-half of the total plots in the park resampled, the following highlights of temporal trends are preliminary. However, no substantial changes have been observed with the addition of the 2012 data compared to last year's results.

All trees with a diameter at breast height (DBH) equal to or greater than 10 cm were measured and their condition was assessed. Trees that had died since the last census were noted, while recruited trees, those reaching the minimum DBH of 10 cm, were identified, measured, mapped, marked, and tagged. Most of the tree mortality occurred in the tulip poplar community, at a rate higher than the network average. Recruitment was highest in the oak hickory dominated community. Growth rates were generally higher than observed across the network, but lower than average among the smaller diameter size classes (Figure 35).

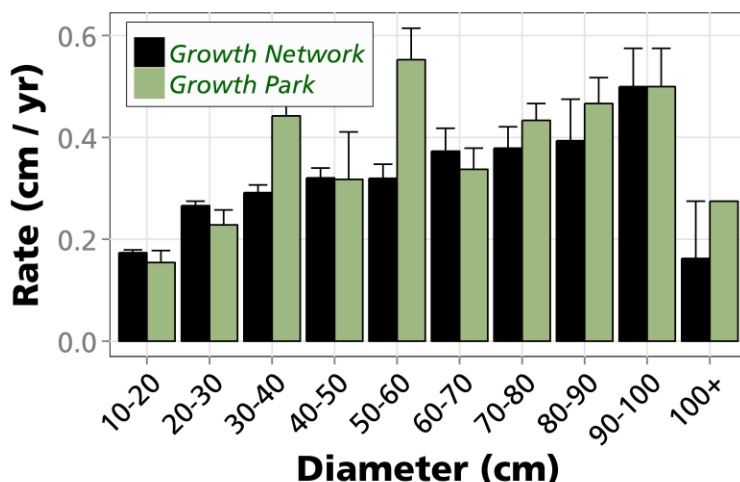


Figure 35. Growth rates of mature trees in different diameter size classes at Valley Forge NHP.

Three microplots in each plot were sampled for tree saplings and shrubs with diameters greater than 1 cm and less than 10 cm. Sapling mortality was lower than observed across the network, but recruitment was not documented in any community type. However, growth rates among saplings were mostly above average, so we anticipate increased recruitment rates in the future.

Tree seedlings are identified in each of 12 quadrats, and their heights measured. The number and height of seedlings determines whether there is adequate regeneration to sustain the forest canopy. In parks where deer densities are high, a larger number of seedlings is required due to the heavier browse pressure than in parks where deer densities are low. Thus, regeneration is considered as "Good" if it exceeds the high deer density stocking index, and "Significant Concern" when it falls below the low deer density stocking index in any park. Valley Forge NHP did show a slight increase in the tree seedling regeneration score from Census 1 (2007 and 2008)

to Census 2 (2011 and 2012). However, seedling regeneration in the park is still classified as "Significant Concern". Continued monitoring will determine whether regeneration is improving across the park.

Invasive exotic and native indicator species are also monitored in the quadrats. Compared to the rest of the network, Valley Forge NHP had a high average percent cover of exotics in the plots sampled with the most common species being Japanese stiltgrass (*Microstegium vimineum*), which showed a decline in cover over the previous four years. Wine raspberry (*Rubus phoenicolasius*) and garlic mustard (*Alliaria petiolata*) also decreased in cover. Among the native indicators, Virginia creeper (*Parthenocissus quinquefolia*) was the most abundant.

In 2013, field crews will revisit plots established in 2009, adding to the data on forest dynamics and increasing our confidence in forest health trends.

Literature Cited

- Anderson, R. C. 1994. Height of White-Flowered Trillium (*Trillium grandiflorum*) as an index of deer browsing intensity. *Ecological Applications* 4(1):104-109.
- Augustine, D. J. and L. E. Frelich. 1998. Effects of white-tailed deer on populations of an understory forb in fragmented deciduous forests. *Conservation Biology* 12(5):995-1004.
- Augustine, D. J. and P. A. Jordan. 1998. Predictors of white-tailed deer grazing intensity in fragmented deciduous forests. *The Journal of Wildlife Management* 62(3):1076-1085.
- Augustine, D. J. and D. DeCalesta. 2003. Defining deer overabundance and threats to forest communities: From individual plants to landscape structure. *Ecoscience* 10(4):472-486.
- Balgooyen, C. P. and D. M. Waller. 1995. The use of *Clintonia borealis* and other indicators to gauge impacts of white-tailed deer on plant communities in northern Wisconsin, USA. *Natural Areas Journal* 15(4):308-318.
- Blair, R. M. and L. E. Brunett. 1980. Seasonal browse selection by deer in a southern pine-hardwood habitat. *The Journal of Wildlife Management* 44(1):79-88.
- Cass, W. B., W. W. Hochstedler, and N. A. Fisichelli. 2011. Shenandoah National Park forest vegetation monitoring protocol: Version 2.3. Natural Resource Report NPS/MIDN/NRR—2011/475. National Park Service, Fort Collins, Colorado.
- Castleberry, S. B., W. M. Ford, K. V. Miller, and W. P. Smith. 1999. White-tailed deer browse preferences in a southern bottomland hardwood forest. *Southern Journal of Applied Forestry* 23(2):78-82.
- Comiskey, J. A., J. P. Schmit, and G. Tierney. 2009. Mid-Atlantic Network forest vegetation monitoring protocol. Natural Resource Report NPS/MIDN/NRR—2009/119 National Park Service, Fort Collins, Colorado.
- Conner, R. N., J. W. Via, and I. D. Prather. 1979. Effects of pine-oak clearcutting on winter and breeding birds in southwestern Virginia. *The Wilson Bulletin* 91(2):301-316.
- Cronan, C. S. and D. F. Grigal. 1995. Use of calcium/aluminum ratios as indicators of stress in forest ecosystems. *Journal of Environmental Quality* 24(2):209-226.
- Dale, V. H., L. A. Joyce, S. McNulty, R. P. Neilson, M. P. Ayres, M. D. Flannigan, P. J. Hanson, L. C. Irland, A. E. Lugo, C. J. Peterson, D. Simberloff, F. J. Swanson, B. J. Stocks, and B. Michael Wotton. 2001. Climate change and forest disturbances. *Bioscience* 51(9):723-734.
- Diefenbach, D. R. and R. S. Fritsky. 2007. Developing and testing a rapid assessment protocol for monitoring vegetation changes on state forest lands. Pennsylvania Cooperative Fish & Wildlife Research Unit, Pennsylvania State University, University Park, PA.

- Driscoll, C. T., G. B. Lawrence, A. J. Bulger, T. J. Butler, C. S. Cronan, C. Eagar, K. F. Lambert, G. E. Likens, J. L. Stoddard, and K. C. Weathers. 2001. Acidic deposition in the northeastern United States: sources and inputs, ecosystem effects, and management strategies. *Bioscience* 51(3):180-198.
- Dufrêne, M. and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological Monographs* 67(3):345-366.
- Fletcher, J. D., W. J. McShea, L. A. Shipley, and D. Shumway. 2001. Use of common forest forbs to measure browsing pressure by white-tailed deer (*Odocoileus virginianus* Zimmerman) in Virginia, USA. *Natural Areas Journal* 21(2):172-176.
- Flory, S. and K. Clay. 2010. Non-native grass invasion suppresses forest succession. *Oecologia* 164(4):1029-1038.
- Frelich, L. E. and C. G. Lorimer. 1991. Natural disturbance regimes in hemlock-hardwood forests of the Upper Great Lakes Region. *Ecological Monographs* 61(2):145-164.
- Goodell, L. and D. Faber-Langendoen. 2007. Development of stand structural stage indices to characterize forest condition in Upstate New York. *Forest Ecology and Management* 249(3):158-170.
- Heckel, C. D., N. A. Bourg, W. J. McShea, and S. Kalisz. 2010. Nonconsumptive effects of a generalist ungulate herbivore drive decline of unpalatable forest herbs. *Ecology* 91(2):319-326.
- Horsley, S. B., S. L. Stout, and D. S. DeCalesta. 2003. White-tailed deer impact on the vegetation dynamics of a northern hardwood forest. *Ecological Applications* 13(1):98-118.
- Keddy, P. A. and C. G. Drummond. 1996. Ecological properties for the evaluation, management, and restoration of Temperate Deciduous Forest Ecosystems. *Ecological Applications* 6(3):748-762.
- Kraft, L. S., T. R. Crow, D. S. Buckley, E. A. Nauertz, and J. C. Zasada. 2004. Effects of harvesting and deer browsing on attributes of understory plants in northern hardwood forests, Upper Michigan, USA. *Forest Ecology and Management* 199(2-3):219-230.
- Latham, R. E., J. Beyea, M. Benner, C. A. Dunn, M. A. Fajvan, R. R. Freed, M. Grund, S. B. Horsley, A. F. Rhoads, and B. P. Shissler. 2005. Managing white-tailed deer in forest habitat from an ecosystem perspective: Pennsylvania case study. *Deer Management Forum for Audubon Pennsylvania and Pennsylvania Habitat Alliance*, Harrisburg, Pennsylvania.
- Lorimer, C. G. and A. S. White. 2003. Scale and frequency of natural disturbances in the northeastern US: implications for early successional forest habitats and regional age distributions. *Forest Ecology and Management* 185(1-2):41-64.

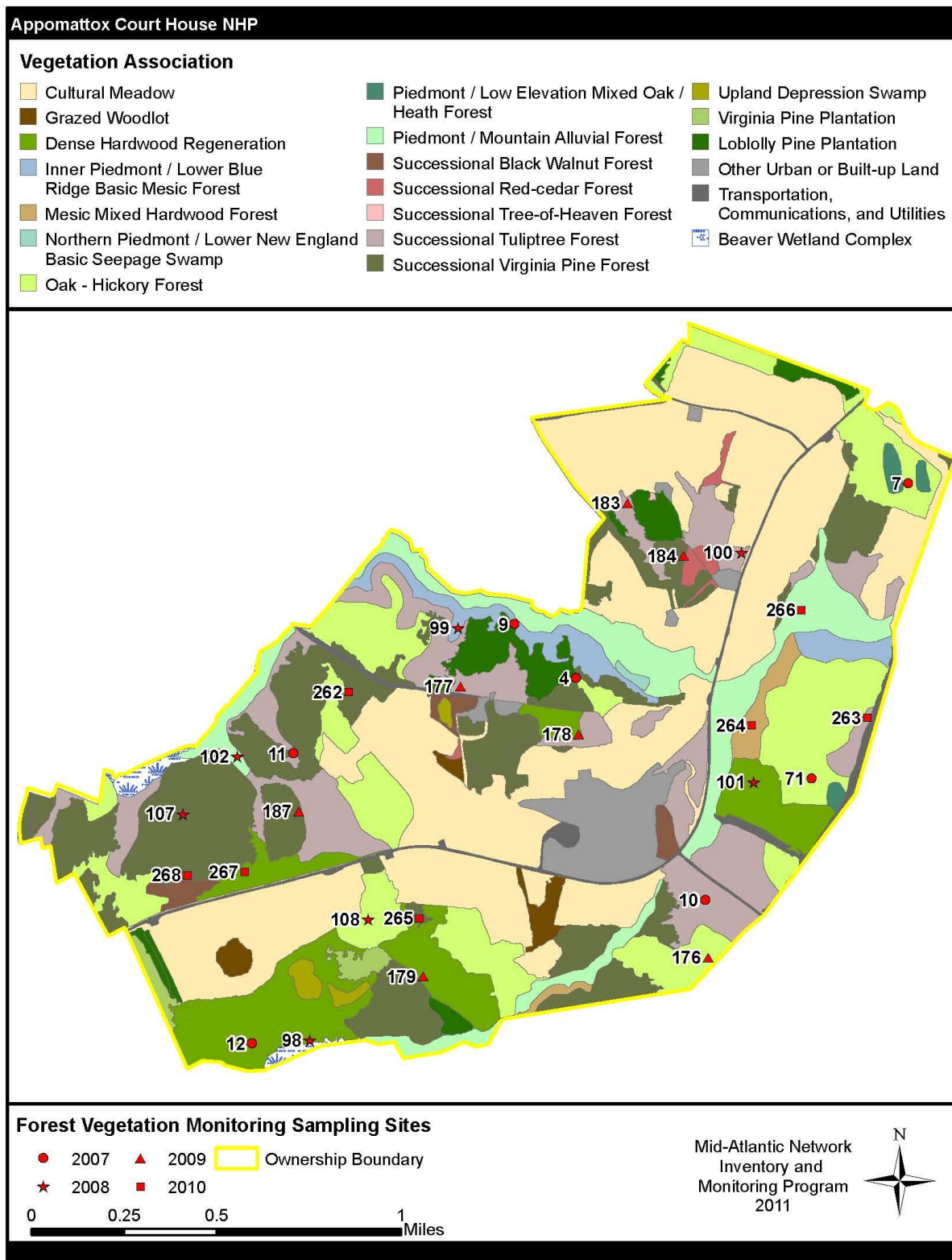
- Marshall, P. L., G. Davis, and V. M. LeMay. 2000. Using line intersect sampling for coarse woody debris. Forest Research Technical Report TR-003. British Columbia Ministry of Forests, Vancouver Forest Region, Nanaimo, British Columbia.
- Maxey, W. R. 1976. Response of greenbrier to various silvicultural treatments under oak stands. *Wildlife Society Bulletin* 4(4):186-188.
- McCune, B. and J. B. Grace. 2002. Analysis of ecological communities. MjM Software Design, Gleneden Beach, Oregon.
- McShea, W. J. and J. H. Rappole. 2000. Managing the abundance and diversity of breeding bird populations through manipulation of deer populations. *Conservation Biology* 14(4):1161-1170.
- McWilliams, W. H., T. W. Bowersox, P. H. Brose, D. A. Devlin, J. C. Finley, K. W. Gottschalk, S. Horsley, S. L. King, B. M. LaPoint, T. W. Lister, L. H. McCormick, G. W. Miller, C. T. Scott, H. Steele, K. C. Steiner, S. L. Stout, J. A. Westfall, and R. L. White 2005. Measuring tree seedlings and associated understory vegetation in Pennsylvania's forests. Pages 21-26 in *Proceedings of the fourth annual forest inventory and analysis symposium*. St. Paul, MN, 2005. Gen. Tech. Rep. NC-252. U.S. Department of Agriculture, Forest Service, North Central Research Station.
- Meiners, S. 2007. Apparent competition: An impact of exotic shrub invasion on tree regeneration. *Biological Invasions* 9(7):849-855.
- Miller, S. G., S. P. Bratton, and J. Hadidian. 1992. Impacts of white-tailed deer on endangered and threatened vascular plants. *Natural Areas Journal* 12(2):67-74.
- Mitchell, B. 2011. Forest Scorecard Reporting Database. Version: 20110328. National Park Service Woodstock, Vermont. <http://science.nature.nps.gov/im/units/netn/index.cfm>
- Mohan, J. E., L. H. Ziska, W. H. Schlesinger, R. B. Thomas, R. C. Sicher, K. George, and J. S. Clark. 2006. Biomass and toxicity responses of poison ivy (*Toxicodendron radicans*) to elevated atmospheric CO₂. *Proceedings of the National Academy of Sciences of the United States of America* 103(24):9086-9089.
- Nilsson, S. G., M. Niklasson, J. Hedin, G. Aronsson, J. M. Gutowski, P. Linder, H. Ljungberg, G. Mikusinski, and T. Ranius. 2002. Densities of large living and dead trees in old-growth temperate and boreal forests. *Forest Ecology and Management* 161(1-3):189-204.
- Petranka, J. W., M. P. Brannon, M. E. Hopey, and C. K. Smith. 1994. Effects of timber harvesting on low elevation populations of southern Appalachian salamanders. *Forest Ecology and Management* 67(1-3):135-147.
- Randall, J. A. and M. B. Walters. 2011. Deer density effects on vegetation in aspen forest understories over site productivity and stand age gradients. *Forest Ecology and Management* 261(3):408-415.

- Rooney, T. P. 2001. Deer impacts on forest ecosystems: A North American perspective. *Forestry* 74(3):201.
- Rooney, T. P. and D. M. Waller. 2003. Direct and indirect effects of white-tailed deer in forest ecosystems. *Forest Ecology and Management* 181(1-2):165-176.
- Rosenberg, D. K., J. D. Fraser, and D. F. Stauffer. 1988. Notes: Use and characteristics of snags in young and old forest stands in Southwest Virginia. *Forest Science* 34(1):224-228.
- Royo, A. A., S. L. Stout, D. S. deCalesta, and T. G. Pierson. 2010. Restoring forest herb communities through landscape-level deer herd reductions: Is recovery limited by legacy effects? *Biological Conservation* 143(11):2425-2434.
- Ruhren, S. and S. Handel. 2000. Considering herbivory, reproduction, and gender when monitoring plants: A case study of Jack-in-the-Pulpit (*Arisaema triphyllum* [L.] Schott). *Natural Areas Journal* 20(3):261-266.
- Stevens, D. L. and A. R. Olsen. 2004. Spatially Balanced Sampling of Natural Resources. *Journal of the American Statistical Association* 99(465):262.
- Tierney, G., B. Mitchell, K. Miller, J. Comiskey, A. Kozlowski, and D. Faber-Langendoen. 2009. Long-term forest monitoring protocol and SOPs for the Northeast Temperate Network. Natural Resources Report NPS/NETN/NRR—2009/117. National Park Service, Fort Collins, Colorado.
- Tierney, G., B. Mitchell, K. Miller, J. Comiskey, A. Kozlowski, and D. Faber-Landendoen. 2012. Northeast Temperate Network Long-term Forest Monitoring Protocol: 2012 Revision. Natural Resource Report NPS/NETN/NRR—2012/507. National Park Service, Fort Collins, Colorado.
- Tierney, G., B. Mitchell, K. Miller, J. Comiskey, A. Kozlowski, and D. Faber-Langendoen. 2013. Northeast Temperate Network long-term forest monitoring protocol: 2013 revision. Natural Resource Report NPS/NETN/NRR—2013/639. National Park Service, Fort Collins, Colorado.
- U.S. Department of Agriculture, Forest Service. 2010. Forest Inventory and Analysis National Core Field Guide: field data collection procedures for phase 2 plots. Version 5.0. Unpublished information on file at <http://www.fia.fs.fed.us/library/field-guides-methods-proc/>.
- U.S. Department of Agriculture, Natural Resources Conservation Service. 2011. The PLANTS Database. National Plant Data Team, Greensboro, NC 27401-4901 USA. <http://plants.usda.gov> Accessed 16 June 2011.
- Van Wagner, C. E. 1982. Practical aspects of the line intersect method. Petawawa National Forestry Institute Information Report PI-X-12. Canadian Forestry Service, Chalk River, Ontario.

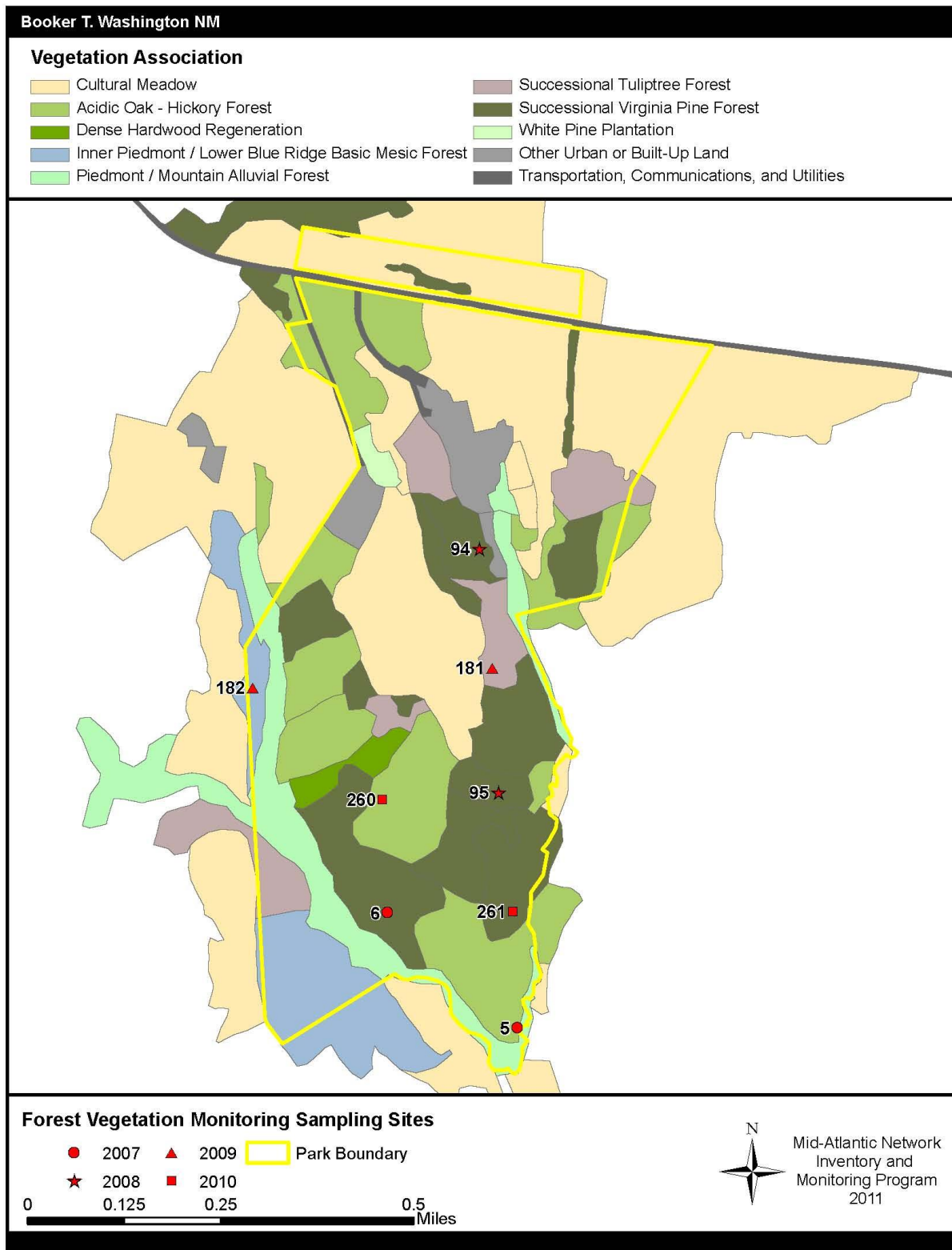
- Webster, C. and G. Parker. 2000. Evaluation of *Osmorhiza claytonii* (Michx.) C. B. Clarke, *Arisaema triphyllum* (L.) Schott, and *Actaea pachypoda* Ell. as potential indicators of white-tailed deer overabundance. *Natural Areas Journal* 20(2):176-188.
- Webster, C. R., M. A. Jenkins, and J. H. Rock. 2005. Long-term response of spring flora to chronic herbivory and deer exclusion in Great Smoky Mountains National Park, USA. *Biological Conservation* 125(3):297-307.
- Williams, C. E., E. V. Mosbacher, and W. J. Moriarity. 2000. Use of turtlehead (*Chelone glabra* L.) and other herbaceous plants to assess intensity of white-tailed deer browsing on Allegheny Plateau riparian forests, USA. *Biological Conservation* 92(2):207-215.

Appendix A. Maps of forest vegetation monitoring plots established between 2007 and 2010 and sampled in 2011 and 2012 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. Plots measured in 2012 were those established in 2008.

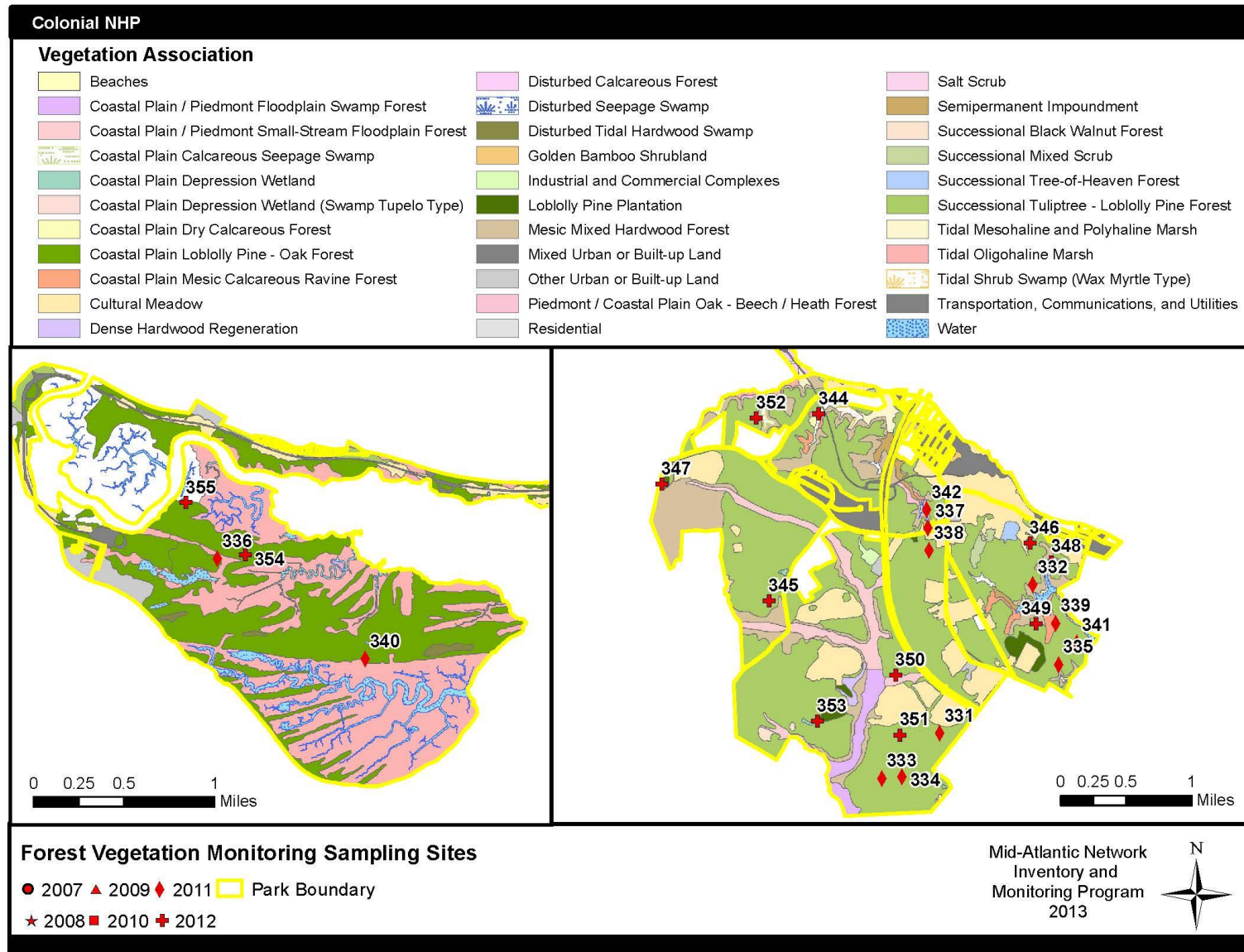


Appendix A2. Forest vegetation monitoring plots established between 2007 and 2010 at Booker T. Washington NM. Plots measured in 2012 were those established in 2008.

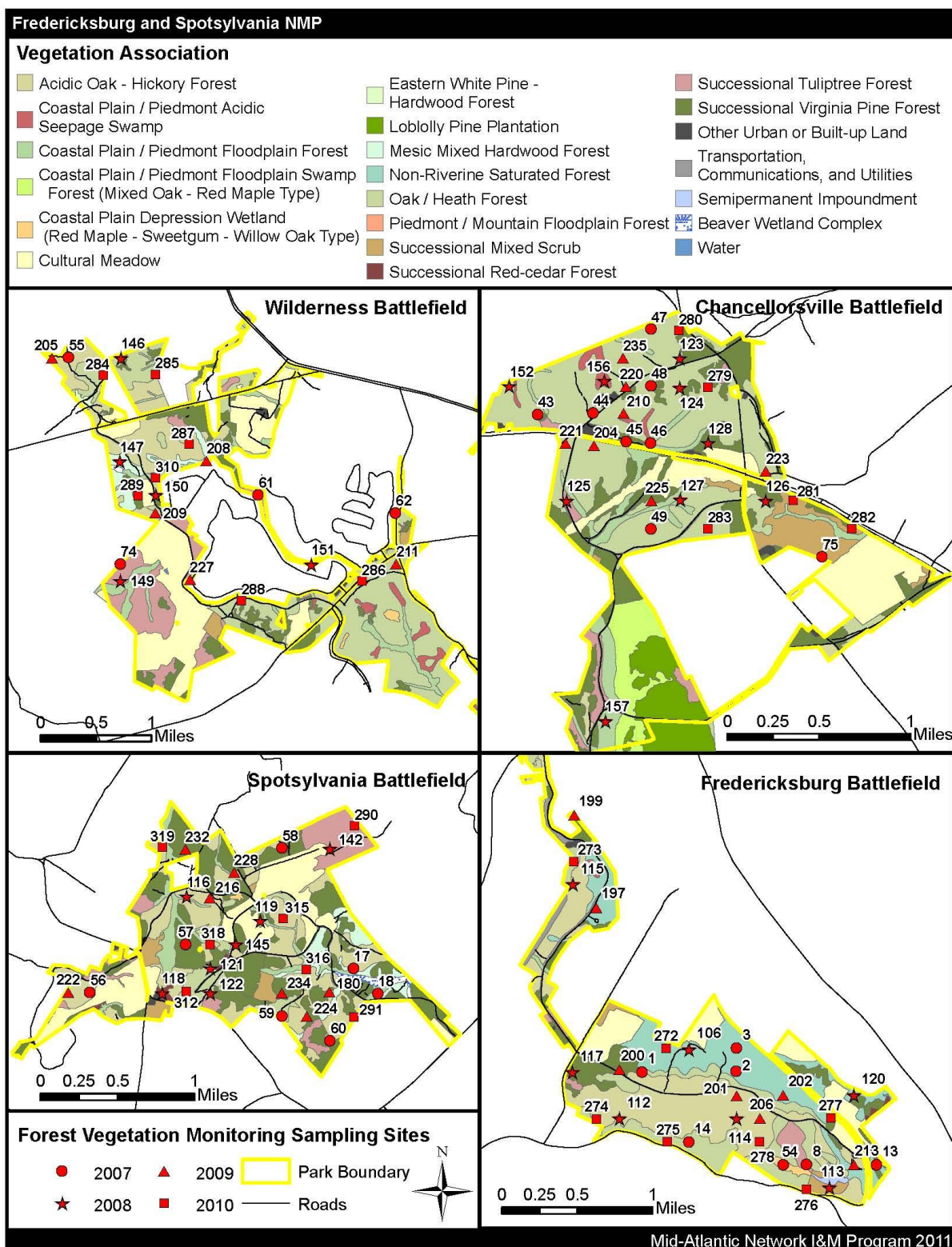


Appendix A3. Forest vegetation monitoring plots established in 2012 at Colonial NHP.

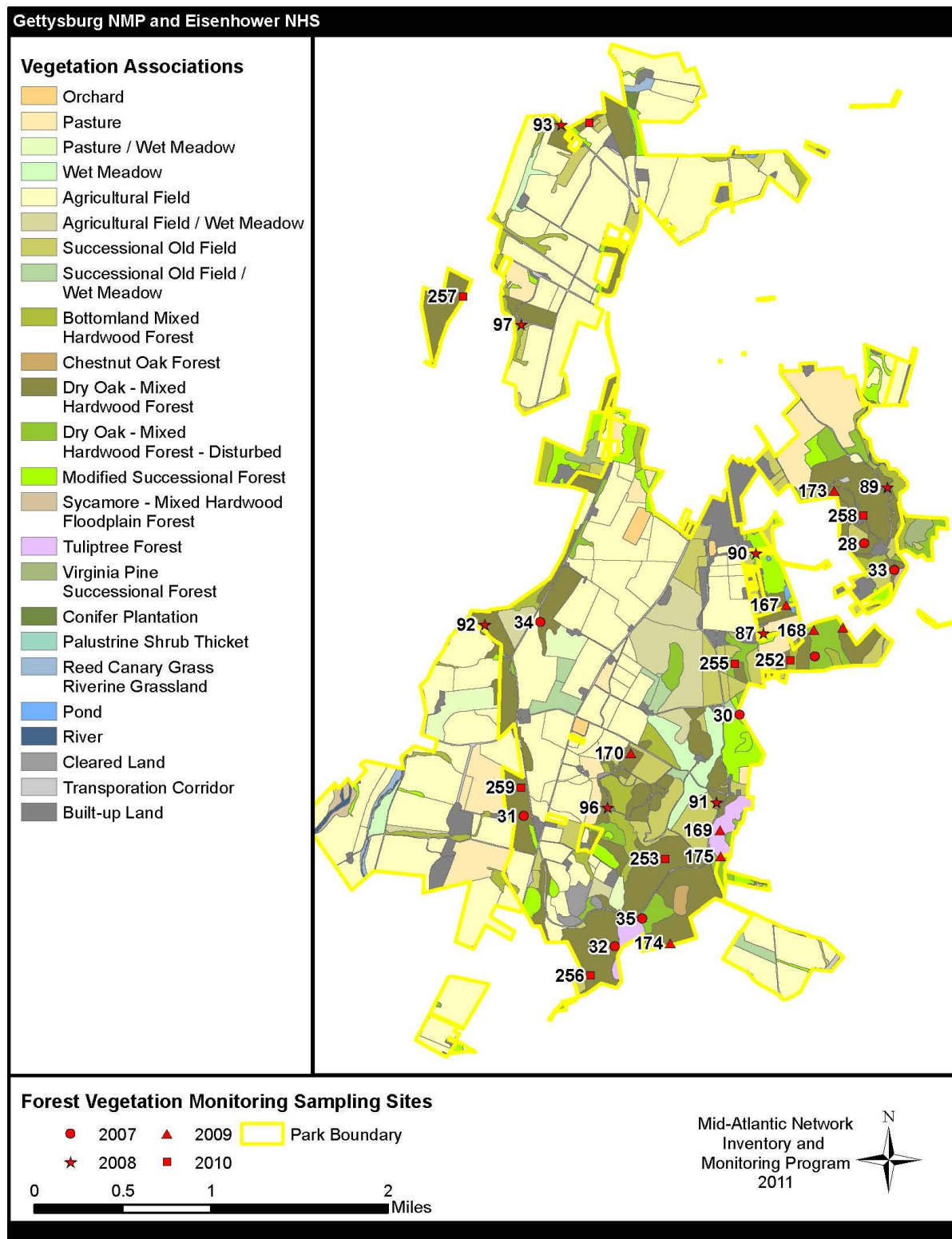
74



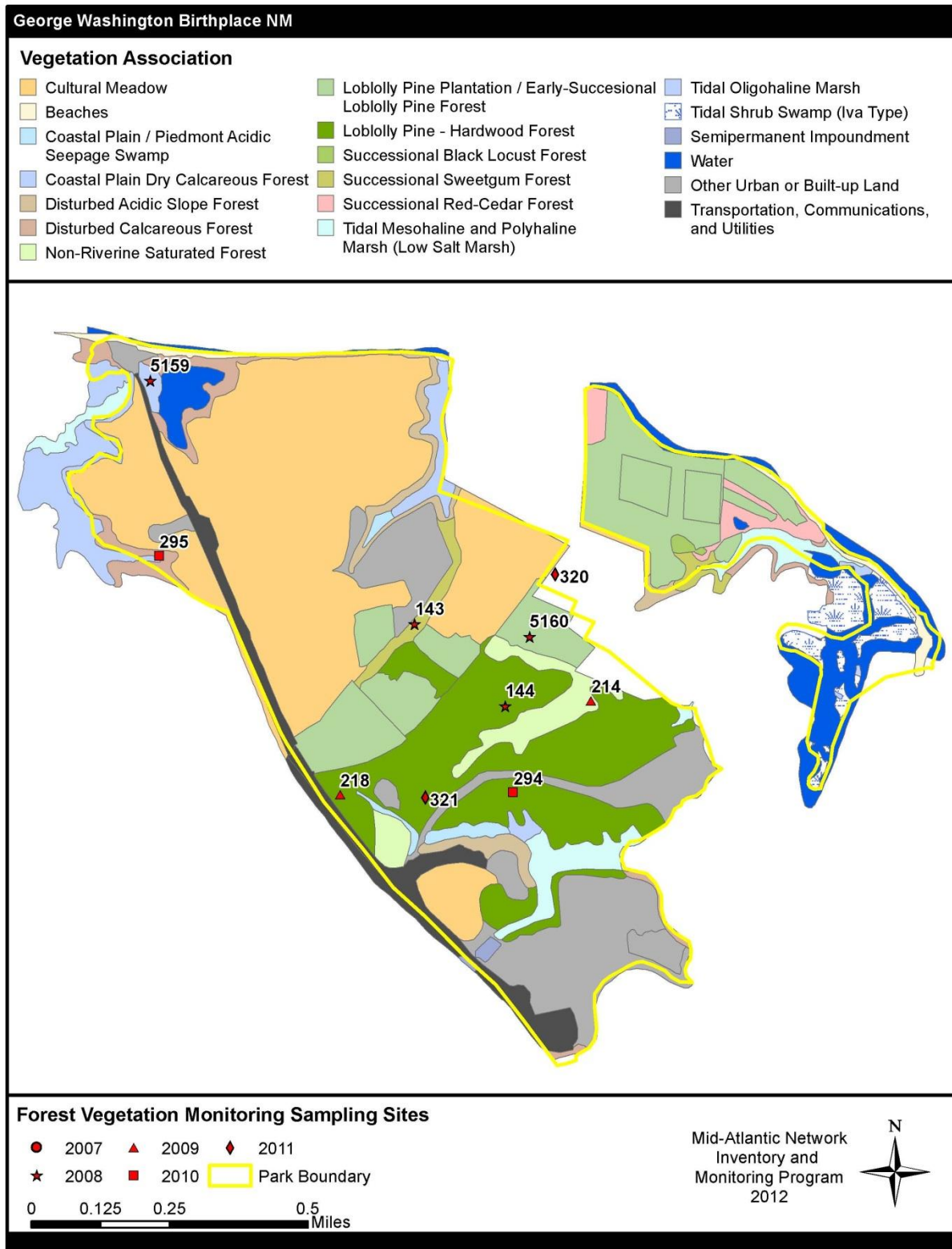
Appendix A4. Forest vegetation monitoring plots established between 2007 and 2010 at Fredericksburg and Spotsylvania NMP. Plots measured in 2012 were those established in 2008.



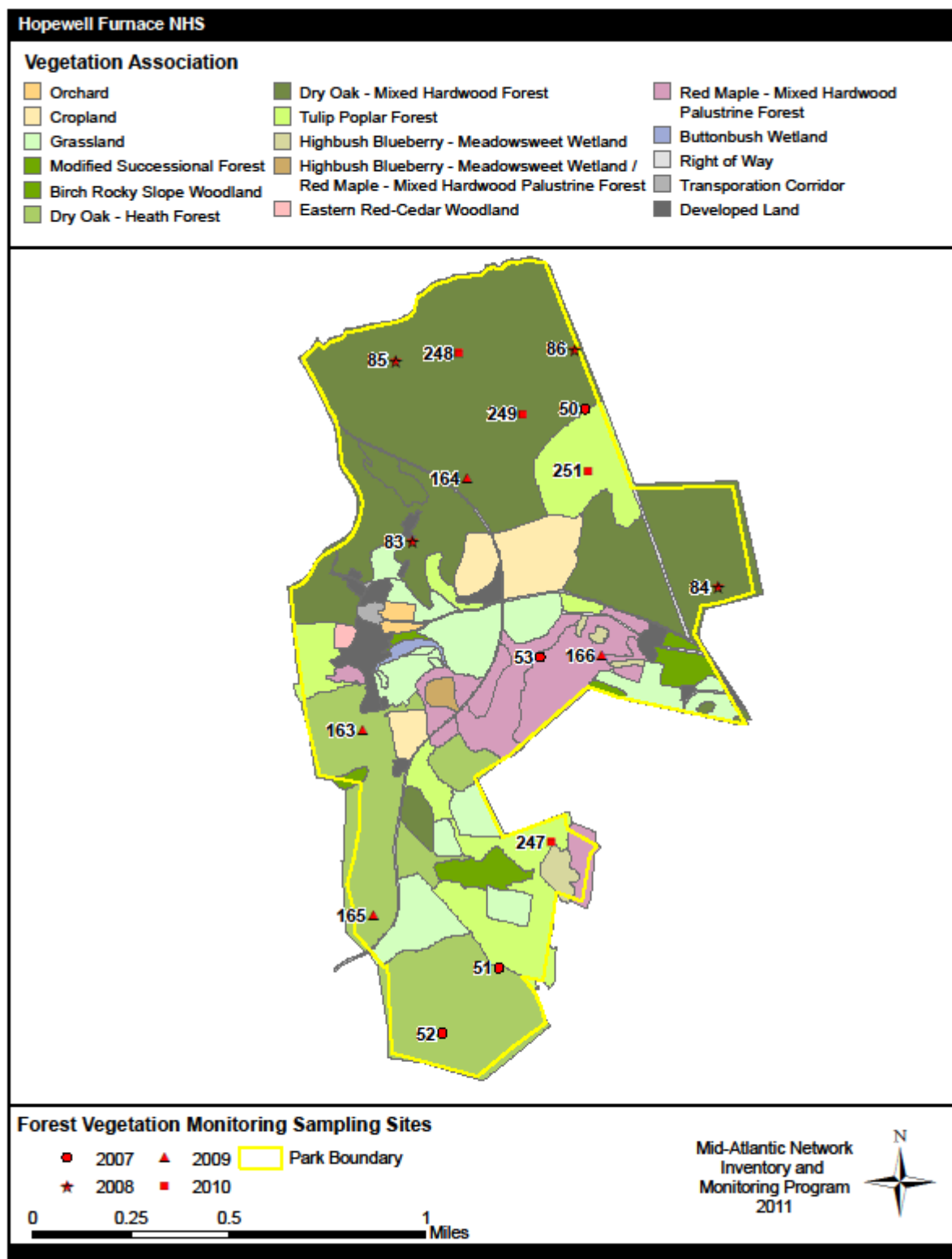
Appendix A5. Forest vegetation monitoring plots established between 2007 and 2010 at Gettysburg NMP. Plots measured in 2012 were those established in 2008.



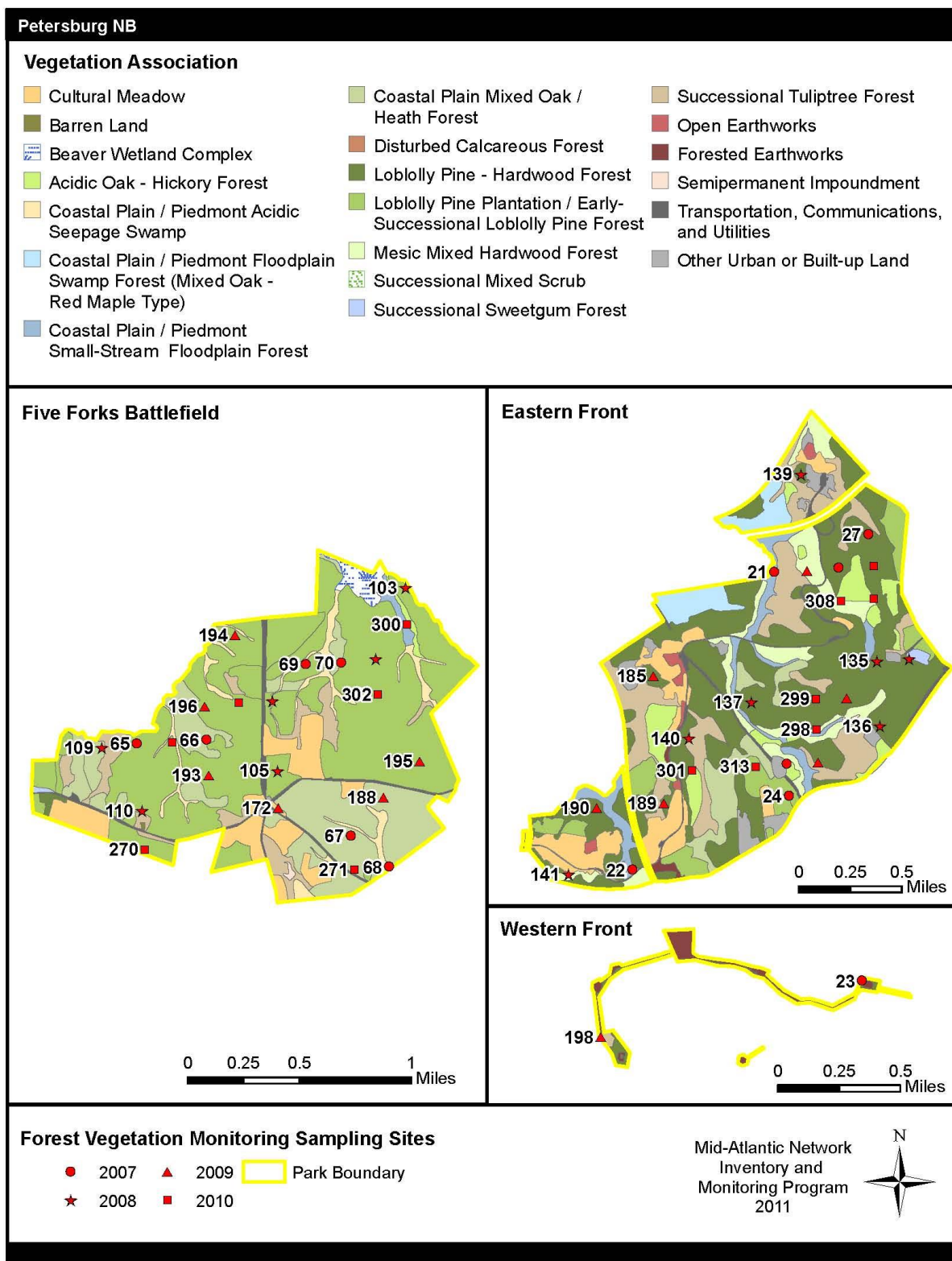
Appendix A6. Forest vegetation monitoring plots established between 2008 and 2011 at George Washington Birthplace NM. Plots measured in 2012 were those established in 2008.



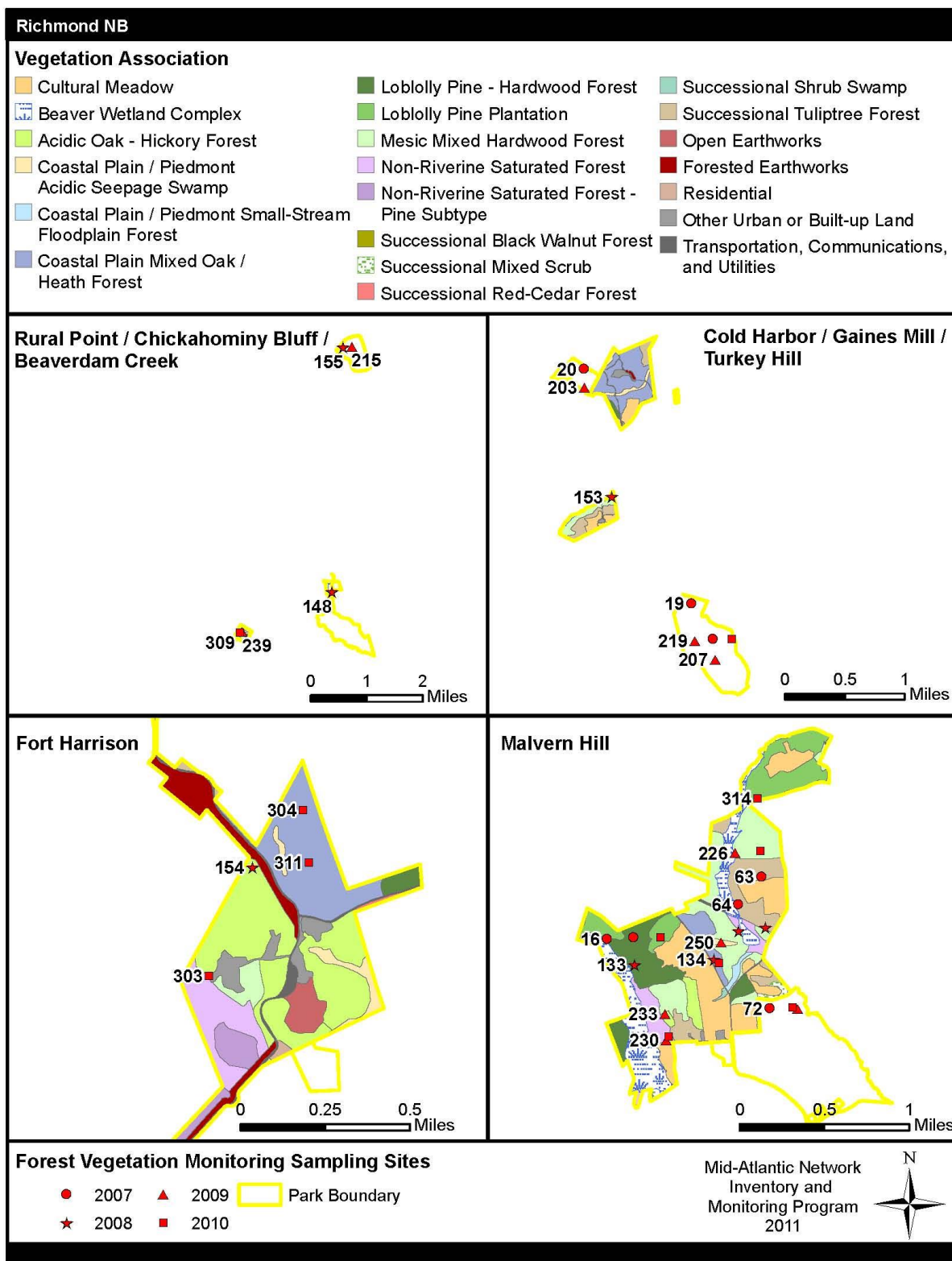
Appendix A7. Forest vegetation monitoring plots established between 2007 and 2010 at Hopewell Furnace NHS. Plots measured in 2012 were those established in 2008.



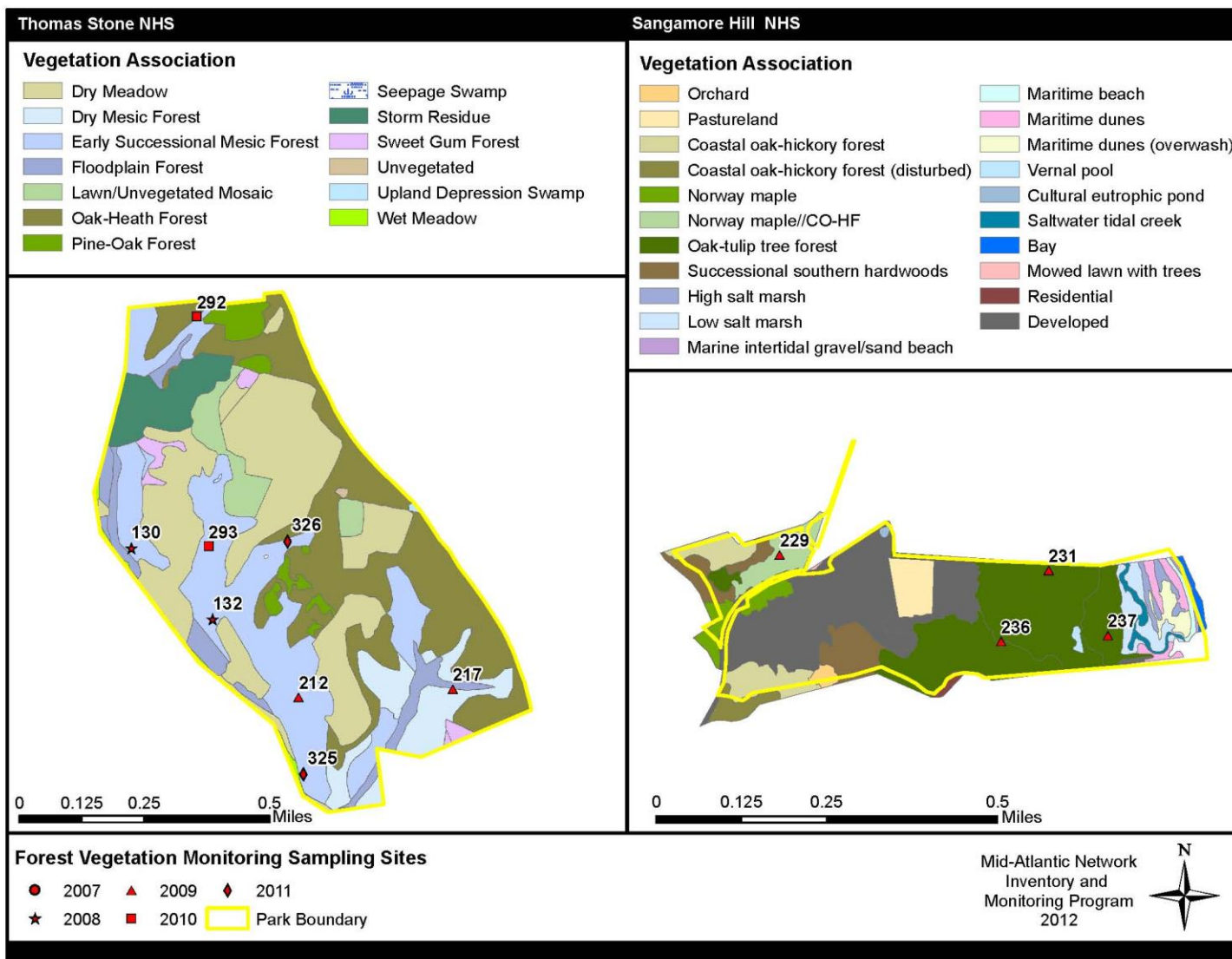
Appendix A8. Forest vegetation monitoring plots established between 2007 and 2010 at Petersburg NB. Plots measured in 2012 were those established in 2008.



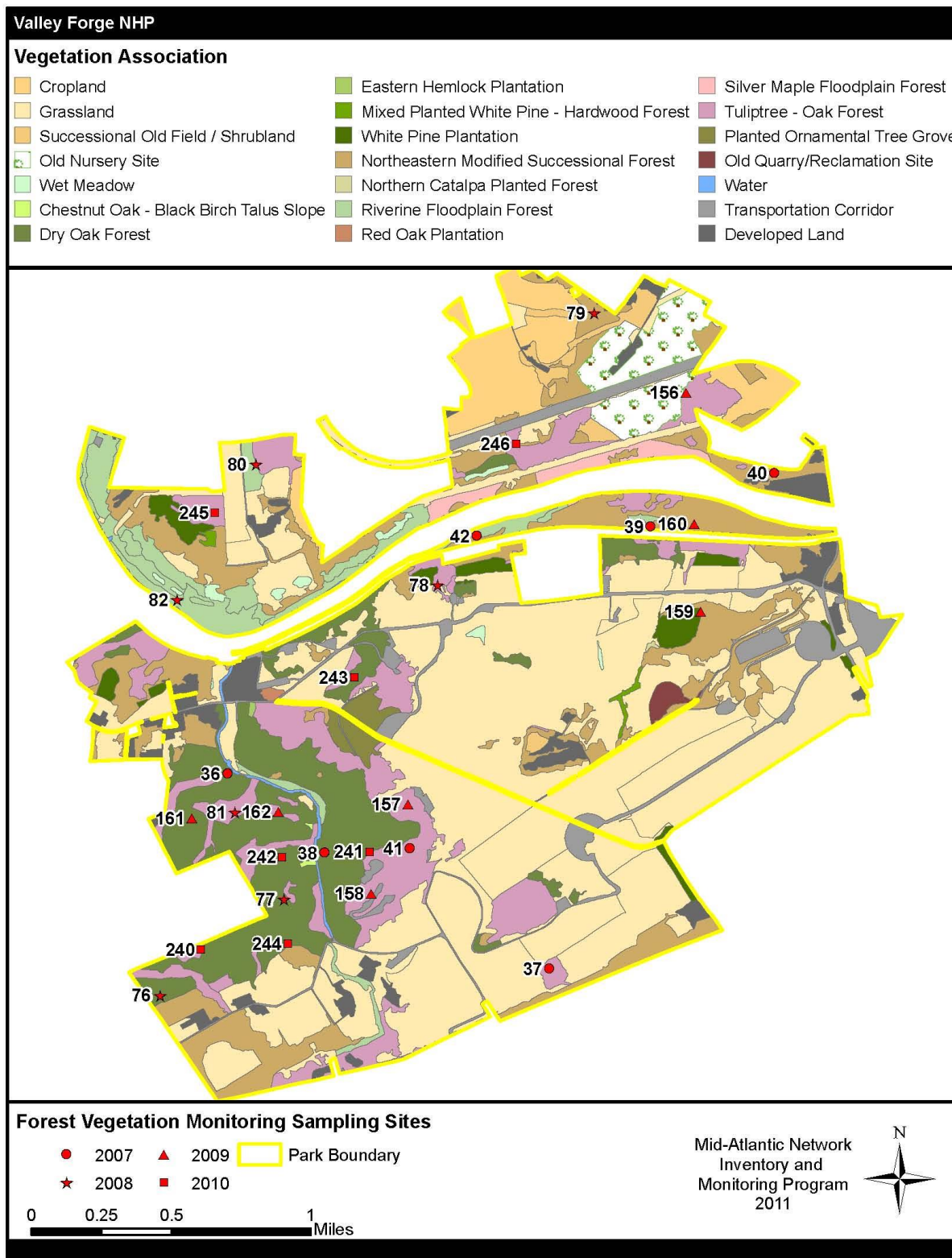
Appendix A9. Forest vegetation monitoring plots established between 2007 and 2010 at Richmond NBP. Plots measured in 2012 were those established in 2008.



Appendix A10. Forest vegetation monitoring plots established between 2008 and 2011 at Thomas Stone NHS and Sagamore Hill NHS. Plots measured in 2012 were those established in 2008.



Appendix A11. Forest vegetation monitoring plots established between 2007 and 2010 at Valley Forge NHP. Plots measured in 2012 were those established in 2008.



Appendix B. List of shrub species sampled in forest vegetation monitoring plots between 2007 and 2012 in Mid-Atlantic and Northeast Coastal and Barrier networks.

Latin Name	Common Name	Measurement Type ^{1,2}
<i>Alnus serrulata</i>	hazel alder	DRC
<i>Berberis thunbergii</i> ⁱ	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> ⁱ	autumn olive	DRC
<i>Euonymus alata</i> ⁱ	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> ⁱ	European privet	DRC
<i>Lindera benzoin</i>	northern spicebush	DRC
<i>Lonicera</i> spp.	honeysuckle	Cover
<i>Lonicera</i> — Exotic ⁱ	honeysuckle - exotic	Cover
<i>Lonicera</i> — Native	native - exotic	Cover
<i>Lonicera maackii</i> ⁱ	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> ⁱ	multiflora rose	Cover
<i>Rubus</i> spp.	blackberry	Cover
<i>Rubus occidentalis</i>	black raspberry	Cover
<i>Rubus phoenicolasius</i> ⁱ	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

ⁱ Invasive exotic species.

¹ Measurement types are: diameter at breast height (DBH), diameter at root crown (DRC), and percent cover (Cover).

² All species with DRC measurement type were changed to cover only in 2011.

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

NPS 962/122395, September 2013

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA TM