



Forest Vegetation Monitoring Protocol for the Cumberland Piedmont Network

Protocol Narrative—Version 2.1

Natural Resource Report NPS/CUPN/NRR—2024/2642



ON THE COVER

Plot layout at Russell Cave National Monument.

NPS photo

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Natural Resource Report NPS/CUPN/NRR—2024/2642

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Change History

Version numbers will be incremented by a whole number (e.g., Version 1.3 to Version 2.0) when a change is made that significantly affect requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.6 to Version 1.7) when there are minor modifications that do not affect requirements or procedures for publication in the series. The following revisions have occurred to this plan since April 2011 (Version 1.0). Version 1.0 reflected changes addressed during the external review process and was implemented during the 2011 field season (May–September).

Change History

Version #	Date	Revised by	Changes
1.1	01/15/12	B. Moore and R. White	Minor editorial changes adding clarification following 2011 field season; formatted for publication in NRR series
1.2	9/20/12	R. White and B. Moore	Minor editorial changes adding clarification following 2012 field season.
2.0	3/31/13	R. White, B. Moore, and T. Leibfreid	- Revised revisit schedule to 5 years to accommodate more plots in all parks. Revised average annual budget (overall total did not change). Revised reports section to include “state of parks” symbology - Changed protocol title from vegetation monitoring to forest vegetation monitoring
2.1	4/25/23	B. Moore	- Changed cover photo - Updated network map to include ecoregions - Sampling Design: cleaned up language and tables to more clearly articulate the 5-year sampling design - Field Methods: cleaned up language and figures in attempt to more clearly summarize current activities, also removed Plot Design subsection (redundant) - Made minor updates and clarifications to Data Handling, Analysis and Reporting section - Updated Personnel Requirements and Training to more accurately reflect current operations. - Updated startup budget estimates and added numerous details to workload and equipment needs. - Removed Appendix C (Standard Operating Procedures) as these are now treated as standalone documents. - Removed Appendix D (Field Datasheets) as these are part of the appropriate SOPs - Removed Appendix E (“Field Guide” to CUPN Potential Forest Pests, Pathogens, and Invasive Plants). This subject matter was incorporated into CUPN’s Invasive Species Early Detection Protocol. - Incorporated edits/suggestions received from regional inventory and monitoring division manager

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List of SOPs Associated with this Protocol Version

SOP 1: Field Season Preparation

SOP 2: Using GPS (Based on use of the GPSMAP 64)

SOP 3: Site Selection and Plot Establishment

SOP 4: Plot Photopoints

SOP 5: Canopy Closure and Stand Height Measurements

SOP 6: Tree Measurements

SOP 7: Species Diversity and Tree Regeneration Measurements

SOP 8: Coarse Woody Debris Measurements

SOP 9: U. S. National Vegetation Classification Measure

SOP 10: Soil Measurements

SOP 11: Data Quality Assurance and Quality Control

SOP 12: Data Management: Procedures upon Return from the Field

SOP 13: Analysis and Reporting

SOP 14: Recording Species Nomenclature

SOP 15: Deviations and Summary of Major Changes

Abstract

In 2003, “vegetation communities” were selected as one of the highest priority vital signs of importance across the Cumberland Piedmont Network (CUPN) parks (Leibfreid et al. 2005). The protocol described in this document will address all aspects of monitoring this vital sign. The primary monitoring goal is to assess status and trends of ecological health for park forest vegetation communities, including key communities of management concern where possible.

By assessing status and trends for key metrics, we can obtain a more complete picture of the status of forest vegetation communities in the parks and the trends in ecological health for these communities. For instance, by repeatedly measuring one key metric of plant species composition within the same plots over the years, we can determine how quickly and profoundly invasive plant species are affecting the native vegetation and whether specific species are appearing or disappearing from plots. This information can be critical in helping land managers detect trends before they are visible qualitatively and setup more specific studies to determine the root causes of such trends.

This protocol is intended for use by the Cumberland Piedmont Network and was designed to efficiently collect, analyze, and disseminate scientifically credible information to help park managers and researchers understand how the forest vegetation communities of the parks are changing.

To fully implement this protocol, read the entire document and all appendices, as well as the standard operating procedures (SOPs; published separately). The appendices and SOPs contain detailed information on implementation not provided in the main body of the document. Datasheets have been designed so data collection is sequential starting with SOP 3: *Site Selection and Plot Establishment—Version 1.48* (CUPN 2023a) and ending with SOP 10: *Soil Measurements—Version 1.1* (CUPN 2023b). The SOPs are intended to serve as a reference for field teams implementing this protocol. It is anticipated field teams will be knowledgeable of their content and maintain a copy for reference as part of the required field equipment.

Acknowledgments

We wish to thank National Park Service (NPS) Inventory and Monitoring (I&M) Network staff from the Cumberland Piedmont Network (CUPN). All staff members supported this project through technical assistance, critical suggestions, and early reviews.

In addition, staff from other NPS I&M networks assisted us by supplying information and expertise based on their own experiences developing their networks' protocols. Without their help (and their permission to use large portions of their protocols as the basis for this document), we would not have completed this protocol design in the amount of time allotted. We especially benefited from the counsel and writings of Stephanie Perles, James Finley, and Matt Marshall, authors of the Vegetation Monitoring Protocol for the Eastern Rivers and Mountains Network (ERMN); Geri Tierney, Brian Mitchell, and Kate Miller, authors of the Long-term Forest Monitoring Protocol for the Northeast Temperate Network (NETN); and Jim Comiskey and Kristina Callahan of the Mid-Atlantic Network (MIDN). We also thank Tom Phillipi, Quantitative Ecologist with the NPS I&M program, for his time and patience in answering our questions regarding plot design and implications for analysis.

Further, we benefited from the input of other key NatureServe staff. We especially want to thank Don Faber-Langendoen for his role as advisor in developing this metric-based approach.

Finally, we thank the park superintendents, resource managers, and staff who have assisted in making the vegetation monitoring protocol a reality. They have provided excellent feedback as well as valuable logistic support during our initial testing.

Introduction

This vegetation monitoring protocol captures multiple high-priority interests of Cumberland Piedmont Network (CUPN) parks. In addition to assessing the status and trends of forest vegetation communities, this protocol will generate information on the presence of forest pests and invasive exotic plants. In future years, park managers will have access to long-term data, collected consistently, that can provide defensible results for management of park resources, public interpretation, and scientific research.

The preservation of forest vegetation communities is important to the mission of all the units in the Cumberland Piedmont Network. By ensuring vegetation communities continue to exist and function at a high level, we can conserve most of the species that rely on that community, including species whose presence was previously undetected (Walker 1995). This approach complements the species-based approach, where land managers look to preserve the habitat of keystone species. Using both approaches, we can more effectively keep the common species common and conserve the rare and charismatic species by addressing threats before they reach a critical point.

There are many reasons to monitor the vegetation communities of these parks. Primarily, managers at each park need to understand whether there are certain trends in key stressors that may be affecting the overall health of the vegetation in their park. For instance, park managers need to understand how forest pests are impacting the landscape overall (e.g., impact of the hemlock wooly adelgid [*Adelges tsugae*], at Cumberland Gap National Historical Park).

The CUPN vegetation monitoring protocol draws on a combination of methodologies and protocols including the Carolina Vegetation Survey (Lee et al. 2008), the USDA Forest Service Forest Inventory and Analysis (FIA) program (USDA 1999), ecological integrity criteria developed by NatureServe and NPS (Faber-Langendoen 2006), and the vegetation monitoring protocols of three other Inventory and Monitoring programs in the eastern United States (Sanders et al. 2007; Perles et al. 2010; Tierney et al. 2007).

This document contains detailed descriptions of how to implement the forest vegetation monitoring protocol, including references to standard operating procedures (SOPs) for field data collection, data management, data analysis and reporting, and sample field datasheets. The CUPN staff will review implementation at the conclusion of each field season and update the SOPs (as necessary) prior to initiation of the next field season (Mitchell et al. 2018). In addition, all staff and volunteers regularly participating in any component of the monitoring work must read this document prior to their involvement.

Background and Objectives

Overview of Network Parks

The Cumberland Piedmont Network contains 14 parks with diverse cultural and natural resources that span a large geographic area crossing eight states and multiple ecoregions (Figure 1, Table 1). The vegetation within the parks varies with factors such as latitude, longitude, elevation, geology, disturbance history, and topographic position. As seen in Table 1, the parks range in size from the

smallest (Guilford Courthouse National Military Park) at 91.5 hectares (226 acres [ac]) to the largest (Mammoth Cave National Park) at 21,380 hectares (52,830 ac).

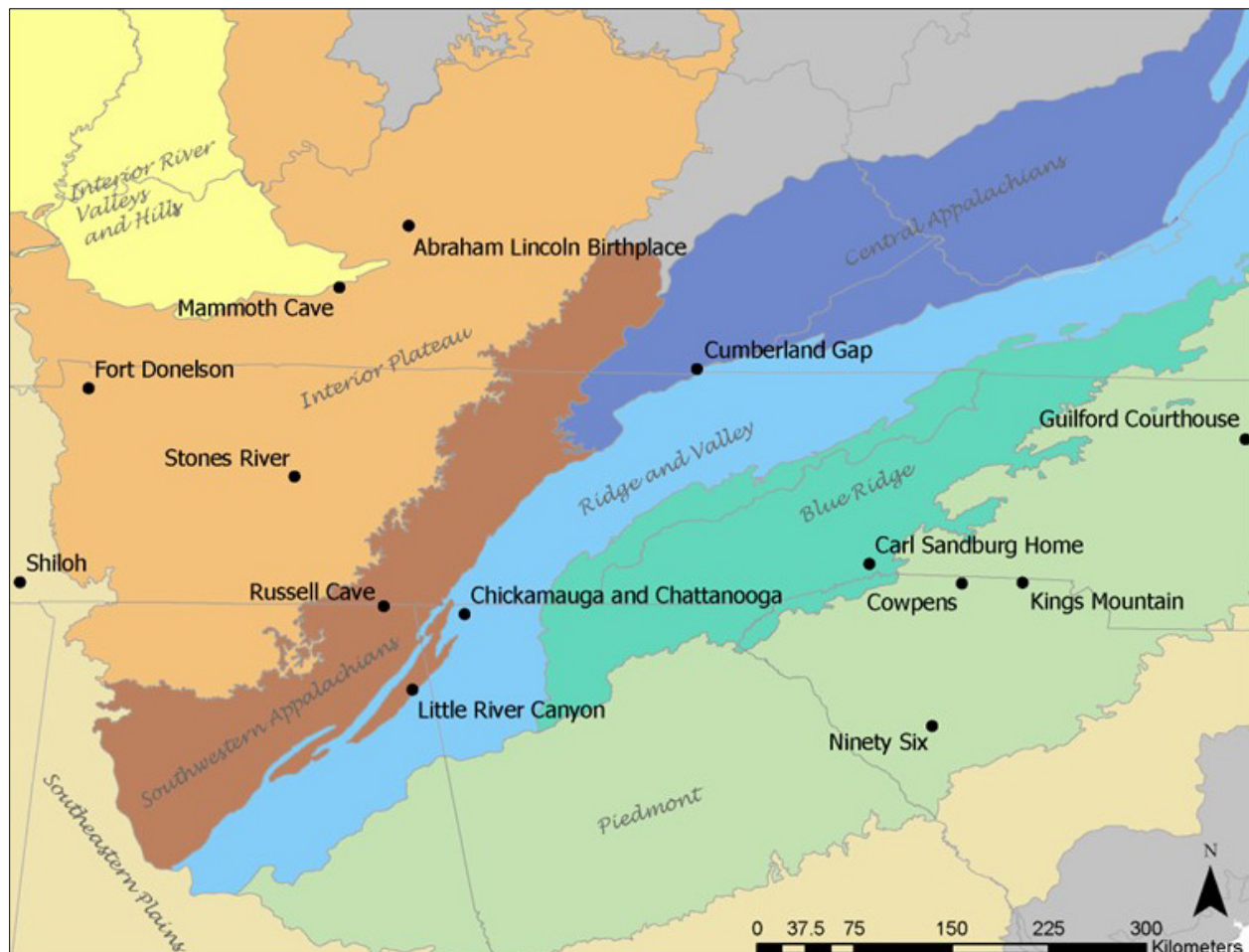


Figure 1. Cumberland Piedmont Network park locations and 2013 EPA Level III Ecoregions of the Continental United States (EPA 2013).

Table 1. Cumberland Piedmont Network parks.

Park Name	Code	Size (acre)	Size (hectare)	State(s)
Abraham Lincoln Birthplace National Historical Park	ABLI	344	139	KY
Carl Sandburg Home National Historic Site	CARL	264	107	NC
Chickamauga and Chattanooga National Military Park	CHCH	8,933	3,617	GA/TN
Cowpens National Battlefield	COWP	842	341	SC

Table 1 (continued). Cumberland Piedmont Network parks.

Park Name	Code	Size (acre)	Size (hectare)	State(s)
Cumberland Gap National Historical Park	CUGA	23,215	9,399	KY/TN/VA
Fort Donelson National Battlefield	FODO	717	290	KY/TN
Guilford Courthouse National Military Park	GUCO	226	91	NC
Kings Mountain National Military Park	KIMO	3,945	1,597	SC
Little River Canyon National Preserve	LIRI	13,691	5,543	AL
Mammoth Cave National Park	MACA	52,830	21,389	KY
Ninety Six National Historic Site	NISI	989	400	SC
Russell Cave National Monument	RUCA	310	125	AL
Shiloh National Military Park	SHIL	5,119	2,072	TN/MS
Stones River National Battlefield	STRI	709	287	TN

Conceptual Models for Ecosystems

The development of conceptual ecological models to identify key system components, linkages and processes is a critical step in the design of a long-term monitoring program. The need for conceptual ecological models has been well established (Elzinga et al. 1998; National Research Council 2000; Noon and Dale 2002). Conceptual models improve the planning process for monitoring by stating key elements of our understanding of system dynamics, which facilitates discussion, evaluation, and refinement of the monitoring program (Maddox et al. 1999). Given the complexity of natural systems and the variety of factors that influence ecological processes, there is a need for conceptual modeling as a tool to help organize information and synthesize understanding of system components and interactions.

This protocol relies on the conceptual model for terrestrial forested ecosystems developed by CUPN personnel and reproduced in Figure 2 below.

Other inventory and monitoring networks have created intricate ecological models to begin the process of looking at key ecological processes and connections in each park's communities. For instance, Rentch (2006) completed ecosystems models for forested habitats of the Eastern Rivers and Mountains Network. Since these ecosystem models focused on some of the same forested habitats that dominate CUPN parks, we have used these models in conjunction with the overall CUPN ecosystem model to summarize the ecological processes that shape our vegetation communities and to supplement our own research into the most important stressors likely to influence change in the vegetation at CUPN parks.

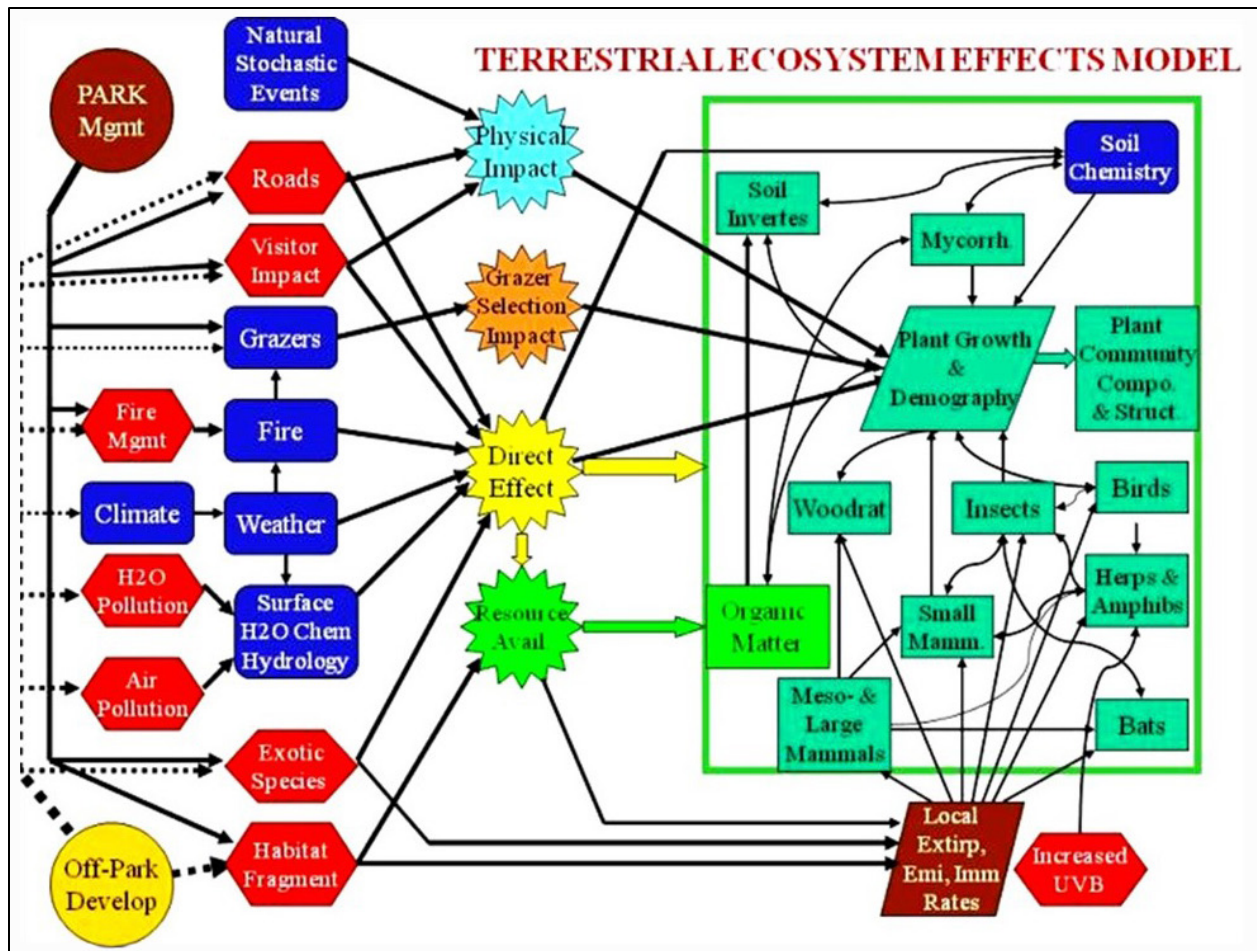


Figure 2. Ecosystem model developed for CUPN Vital Signs Monitoring Plan (Leibfreid et al. 2005).

Forested vegetation communities vary widely in composition, disturbance patterns, underlying geology, and hydrology, so we have subdivided these communities into a series of nested classes so we can more effectively look at how different types of forested communities may change over time. The communities have been classified in all parks using the U. S. National Vegetation Classification (Grossman et al. 1998; FGDC 2008) and NatureServe's Ecological Systems (Comer et al. 2003). Details can be found in each park's vegetation classification reports (Table 2) and in Appendix A. To help identify communities that span multiple parks, we grouped them into six broad "vegetation types" (Table 3). Each "vegetation type" contains multiple U.S. National Vegetation Classification communities. These "vegetation types" are very coarse in scale, but each type's communities share key traits with one another across the parks where they occur. Some parks may wish to monitor at other ecological scales, but for the purposes of our network-level monitoring these coarse ecosystem units are most appropriate for framing the overall monitoring effort.

Table 2. Community classification reports for Cumberland Piedmont Network parks. Refer to Table 1 for park codes.

Park Code	Report
ABLI	Jones, E., and M. Pyne. 2008. Vascular Plant Inventory and Plant Community Classification for Abraham Lincoln National Historic Site. NatureServe. Durham, N.C.
CARL	White, R. 2003. Vascular Plant Inventory and Plant Community Classification for Carl Sandburg Home National Historic Site. NatureServe. Durham, N.C.
CHCH	Govus, T., and R. White. 2007. Vascular Plant Inventory and Plant Community Classification for Chickamauga & Chattanooga National Military Park. NatureServe. Durham, N.C.
COWP	White, R. 2004. Vascular Plant Community Classification for Cowpens National Battlefield. NatureServe. Durham, N.C.
CUGA	White, R. 2006. Vascular Plant Inventory and Ecological Community Classification for Cumberland Gap National Historical Park. NatureServe. Durham, N.C.
FODO	White, R. 2005. Vascular Plant Inventory and Plant Community Classification for Fort Donelson National Battlefield. NatureServe. Durham, N.C.
GUCO	White, R., and M. Pyne. 2003. Vascular Plant Inventory and Plant Community Classification for Guilford Courthouse National Military Park. NatureServe. Durham, N.C.
KIMO	White, R., and T. Govus. 2005. Vascular Plant Inventory and Plant Community Classification for Kings Mountain National Military Park. NatureServe. Durham, N.C.
LIRI	Schotz, A., H. Summer, R. White. 2008. Vascular Plant Inventory and Plant Community Classification for Little River Canyon National Preserve. NatureServe. Durham, N.C.
MACA	Pyne, M., E. Jones, and R. White. 2010. Vascular Plant Inventory and Plant Community Classification for Mammoth Cave National Park. NatureServe. Durham, N.C.
NISI	White, R., and T. Govus. 2003. Vascular Plant Inventory and Plant Community Classification for Ninety Six National Historic Site. NatureServe. Durham, N.C.
RUCA	Lunsford, E. 2007. Vascular Plant Inventory and Ecological Community Classification for Russell Cave National Monument. NatureServe. Durham, N.C.
SHIL	Nordman, C. 2004a. Plant Community Classification for Shiloh National Military Park. NatureServe. Durham, N.C.
STRI	Nordman, C. 2004b. Vascular Plant Community Classification for Stones River National Battlefield. NatureServe. Durham, N.C.

Table 3. Vegetation types for CUPN parks with estimated percent area derived from recent vegetation maps (Jordan and Madden 2010). Refer to Table 1 for park codes.

Types	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Upland Forest	67%	71%	73%	52%	85%	71%	77%	94%	86%	86%	63%	91%	70%	47%
Riparian/ Wetland Forest	5%	0%	10%	11%	1%	4%	6%	4%	2%	7%	17%	2%	11%	1%
Old Fields/ Shrubland	17%	13%	6%	28%	2%	10%	7%	2%	<1%	4%	15%	4%	8%	21%
Glades/ Barrens	1%	8%	<1%	0%	<1%	0%	0%	0%	<1%	<1%	0%	0%	<1%	2%
Cliffs/Talus	<1%	0%	<1%	0%	0%	0%	0%	0%	<1%	<1%	0%	0%	0%	0%
Bogs/Fens	0%	0%	0%	0%	<1%	0%	0%	0%	<1%	0%	0%	0%	0%	0%
Other (Open Water, Developed)	9%	8%	11%	9%	12%	15%	10%	<1%	12%	3%	5%	3%	11%	29%

In future years we hope to build conceptual models for specific “key communities” identified by individual parks as part of our effort to help those parks and the network identify the ecological health of their most important resources. For now, we have identified a potential set of key communities and will work with individual parks and network personnel as resources are identified and become available to develop those conceptual models and sampling strategies (Table 3).

Ecosystem Drivers, Stressors, and Attributes

The CUPN Vital Signs Monitoring Plan (Leibfreid et al. 2005) described the major drivers, stressors, and overarching ecosystem attributes associated with terrestrial ecosystems of the Cumberland Piedmont Network. We relied on that document to build our final list of key ecosystem attributes and stressors of vegetation communities that should be part of the synthesis of vegetation community monitoring work overall. Ecosystem attributes are any biotic or abiotic feature of the environment that can be measured or estimated. Stressors are any physical, chemical, or biological entity or process that induces effects on individuals, populations, communities, or ecosystems (Noon and Dale 2002). In some cases, stressors can also be attributes. Stressors include natural processes and structures such as forms of disturbance (naturally caused fire) and may also represent anthropogenic alterations of natural processes or structures (invasion of exotic species, air pollution, climate change; Noon and Dale 2002).

Due to the increased focus on climate change, we considered it a potential stressor in developing metrics and hope some of our protocol may help to capture long-term changes in vegetation due to changes in climate. Refer to Appendix B for a full discussion of each key attribute and stressor.

Rationale for Monitoring Vegetation Communities

The vital sign process for the Cumberland Piedmont Network highlighted the importance of plant species diversity and functional plant communities with intact disturbance regimes as natural resources critical to the parks. Vegetation communities can serve as an integrated measure of terrestrial ecosystem health by exhibiting changes influenced by alterations in climate, soils, and disturbance patterns.

For this project, the network has one main monitoring objective: detecting meaningful (significant) change in vegetation community measures of forested habitats while, where possible, trying to correlate those changes to key stressors. In addition, we hope to develop additional SOPs to address our secondary monitoring objective: to assess the health or condition of key vegetation communities. To detect significant changes, the Cumberland Piedmont Network has chosen a set of measures monitored at regular intervals and used to report on change over time. Some measures relate to key stressors, others relate to specific biotic attributes of the plot, and all can be compared to other sampling events to determine whether there is significant change between sampling periods.

Certain measures chosen to address these monitoring objectives can be combined and used to summarize ecosystem health. We can use these measures to look at quantitative change over time and repurpose them to determine ecological health through an ecological integrity scoring system. By measuring taxonomic, structural, and demographic features, we can look at whether the ecosystem’s parameters fall within expected or accepted norms and ranges of variability. These metrics serve as

indicators of ecological integrity, easily explained through metric ratings (i.e., good, fair, or poor) and can be explicitly linked back to park management practices.

Monitoring Goal and Objectives

To address both network-wide and park-specific vegetation concerns, we developed a primary monitoring goal with two monitoring objectives:

***Primary Monitoring Goal: Assess status and trends of ecological health for park-wide vegetation communities, including key communities of management concern.*¹**

- Primary Objective (Monitoring Objective 1): Detect meaningful changes in species composition and vegetation structure within each park's forested habitat and determine whether these changes are correlated with trends in "key stressors" every 10 years. Objective 1 is the focus of this protocol, which was planned for implementation in 2011. It covers park-wide vegetation and includes all 14 parks. The Cumberland Piedmont Network is the lead on the accomplishment of this objective.
- Secondary Objective (Monitoring Objective 2): *Determine ecological health of key communities of importance to parks with respect to that community's reference condition.* This objective will involve future development of additional SOPs targeting specific communities of management concern, and includes parks with key communities not covered by Objective 1. The Cumberland Piedmont Network will work with parks and other partners to accomplish this objective, and will incorporate documentation in future revisions to this protocol.

¹ Ecological health is defined as: "The condition of an ecosystem in which processes and functions are adequate to maintain diversity of biotic communities commensurate with those initially found there."

Sampling Design

Monitoring the vegetation in the Cumberland Piedmont Network's 14 parks requires the development of a statistically sound sampling methodology that can be accomplished within our logistical constraints (NPS staffing levels and resources). After reviewing data from the first two years of sampling, we chose to implement a flexible five-year rotating panel design to maximize the number of plots in each park and stay within a reasonable number of plots per year from the standpoint of logistics (budget/staffing). If the design is not statistically powerful enough to detect change at the proposed level of sensitivity (i.e., the sample size is too small) for a particular park, the design allows for the flexibility to expand the number of plots for future analysis.

Site Selection Overview

Relative simplicity in sampling design is highly desirable, but so is flexibility for incorporating studies with different levels of sampling intensity now and in the future. We developed our sampling design framework to reflect simplicity and an interest in flexibility (Figure 3). Our selection of points was based on a dense grid overlay on the sampling frame and utilized the generalized random-tessellation stratified (GRTS) sampling methodology to create a spatially-balanced set of monitoring sites for each of the CUPN parks.

The GRTS technique uses reverse hierarchical ordering to map two-dimensional space (e.g., locations of plots in a park) into one-dimensional space, by giving each plot an ordered spatial address. Then, the program uses restricted randomization to order the addresses into a random, spatially-balanced list of plots (McDonald 2004; Stevens and Olsen 2004). This sampling design differs from the hexagonal sampling framework employed by the U.S. Forest Service's Inventory and Analysis (FIA) Program (Brand et al. 2000) but allows for additional flexibility in our approach over time, such as the ability to add new plots in the future without changing the random, spatially-balanced nature of the project design.

There are three main advantages to GRTS design. First, the sample points generated by GRTS are spatially balanced, wherein there is generally uniform dispersion of sampling sites over the area of interest. This ensures all areas within the sampling frame are represented. Second, the GRTS design allows for flexible sample size, so sites can be added or excluded from the sampling plan, while still maintaining the spatial balance and without compromising the integrity of the overall design. For instance, if "plot 2" is rejected using our established decision rules for plots, we can pick the next number on the list of plots not yet assigned to continue a random, spatially-balanced sample. This allows potential sites to be rejected if they are determined inaccessible or otherwise inappropriate, or additional sites to be added if funding is increased or our objectives shift. Finally, the GRTS method is a probabilistic sampling design, whereby sampling points are randomly chosen from among those in a systematic grid, eliminating site-selection bias. The GRTS design has the advantage of being spatially dispersed without the repeating interval often present in systematic samples. This provides additional flexibility for post-stratification of plots based on ecological system, vegetation association, or other criteria, as needed (Stevens and Olsen 2004).

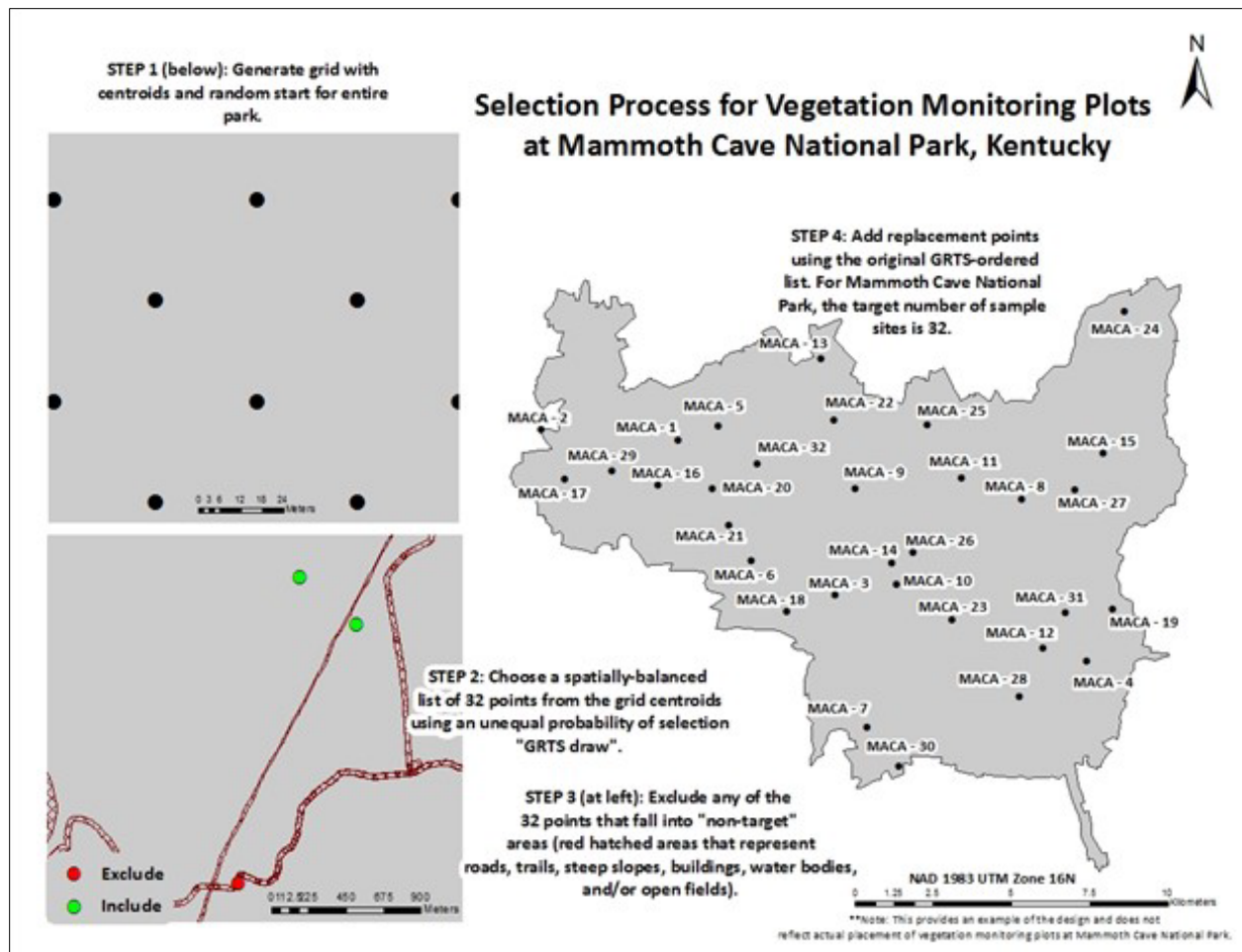


Figure 3. Map of potential plot layout for monitoring plots at Mammoth Cave National Park.

Selecting Sites

The sampling design framework for vegetation monitoring plot locations began with a dense base grid that spread samples evenly throughout a park. The size of the grid (40×40 meters [131.2×131.2 feet [ft]]) was based on the maximum dimensions of the coarse woody debris transects within the vegetation plot. The starting point for this grid was randomly selected using a grid sampling program from the U.S. Geological Survey. ArcEditor was used to manually offset every other row of the grid. The center of each cell was used as the sampling point and the list of centroids was used as input for GRTS site selection. The area available for sampling (minus any intersection with roads, trails, water, or park boundaries) was calculated for each grid cell and assigned to their centroids. These area measures became the weights used in the unequal probability design in GRTS (Table 4). Using the spsurvey library in R v2.10, we performed probabilistic GRTS selection on the centroid points, where each centroid had an area-weighted probability of being selected in the GRTS draw. The resultant shapefile contains all centroid points that fall within a park's boundary and places them in a spatially-balanced GRTS order using the addressing/ordering method mentioned above. Any sub-sample of points on the list, if selected in consecutive order, will maintain their spatial balance. If a small number of the first N points are not included because of an exclusion filter applied after the

points are selected (see below), the spatial balance will remain high if replacement plots are chosen from the first available point after the selected sub-sequence and if they are in consecutive sequence down the list.

Table 4. Example of GRTS generated points for Mammoth Cave National Park (MACA).

Park ID	Original X Coordinates*	Original Y Coordinates*	GRTS Assigned Weights
MACA-1	570370.285706999	4119919.939660000	3938.58170645
MACA-2	565986.223664000	4120231.066649990	3938.58170645
MACA-3	575404.885988999	4114941.907930000	3938.58170645
MACA-4	583437.619023000	4112848.871850000	3938.58170645
MACA-5	571643.077913000	4120344.203730000	3938.58170645
MACA-6	572717.880221000	4116044.994500000	3938.58170645
MACA-7	576394.835483000	4110727.551510000	3938.58170645
MACA-8	581372.867222000	4118024.893490000	3938.58170645
MACA-9	576027.139956000	4118336.020469990	3938.58170645
MACA-10	577356.500705000	4115309.603449990	3938.58170645
MACA-11	579421.252505999	4118675.431729990	3938.58170645
MACA-12	582023.405461000	4113244.851650000	3938.58170645
MACA-13	574924.053378000	4122493.808350000	3938.58170645
MACA-14	577215.079349000	4115960.141690000	3938.58170645
MACA-15	583975.020176999	4119495.675600000	3938.58170645
MACA-16	582560.806615000	4110218.434630000	5169.29358471
MACA-17	569719.747468000	4118477.441829990	3938.58170645
MACA-18	566721.614716000	4118647.147460000	3938.58170645
MACA-19	573820.966799000	4114432.791040000	3938.58170645
MACA-20	584286.147160999	4114489.359590000	3938.58170645
MACA-21	571473.372286000	4118364.304750000	3938.58170645
MACA-22	571982.489167999	4117176.365350000	3938.58170645
MACA-23	575433.170260000	4110670.982969990	4067.10213388
MACA-24	580665.760440999	4116469.258570000	4595.91202362
MACA-25	575348.317446999	4120542.193630000	3938.58170645

Table 4 (continued). Example of GRTS generated points for Mammoth Cave National Park (MACA).

Park ID	Original X Coordinates*	Original Y Coordinates*	GRTS Assigned Weights
MACA-26	579138.409793999	4114149.948330000	3938.58170645
MACA-27	584653.842687000	4124021.159000000	3938.58170645
MACA-28	580835.466068999	4114885.339379990	4877.84035290
MACA-29	578318.165928000	4120400.772280000	3938.58170645
MACA-30	577865.617588000	4116327.837220000	3938.58170645
MACA-31	583069.923497000	4118307.736200000	3938.58170645
MACA-32	581288.014409000	4111717.501000000	3938.58170645

*Data projected in NAD 1983 UTM Zone 16

Excluding or Moving Points

There will be circumstances where a field team will not establish a plot at one of the points selected in a park's GRTS draw. These include:

- 1) Plot falls partially or completely on privately-owned land or directly on a park boundary.
- 2) Plot falls partially or completely on non-vegetated land, including transportation corridors, built-up land, rivers, and ponds.
- 3) Plot falls partially or completely on intensively managed lands including road right-of-way, regularly mowed lawns, regularly mowed fields, and landscaping.
- 4) Plot occurs on inaccessible slopes greater than or equal to 30° (equivalent to $\geq 58\%$ slope) as calculated from digital elevation models or in the field with the aid of compass or clinometers. **In CUPN parks, slopes more than 30 degrees are extremely rare and so we feel that this exclusion will not severely limit our ability to draw park-wide conclusions based on the data.**
- 5) Plot includes heavily-used trails or roads. If trails are narrow or not heavily used, the team can use their own discretion and may place the plot there but should not place any conduit on or within 1 meter (3.3 ft) of the trail.
- 6) Plot occurs in a non-forested area. This is defined as an area that has a combined canopy and understory coverage of tree species of less than 10%.
- 7) Plot is dissected by medium to large bodies of water or streams. As a rule of thumb, plots with streams that one can jump across or streams that are shallow in normal conditions will still be sampled. Streams that are large enough to require wading or ponds with open water will be avoided.

For exclusion number six above, we have adopted the guidelines of the USDA Forest Inventory Analysis program (USFS 2007) as well as the revised hierarchy of the [U.S. National Vegetation Classification](https://usnvc.org/) (<https://usnvc.org/>) to define what constitutes a “forest/woodland,” a 10% minimum

canopy coverage of tree species. The 10% requirement is intended for sites that are stocked by that amount at the time of sampling or will likely return to that percentage soon. This would also consider natural phenomena causing forest damage (e.g., hurricanes, ice storms, or tornados). As such, areas recovering from a blowdown will be included, as will grasslands returning to a forested state. To make the determination if the site is forested, aerial images or digital orthoquads will be used and manipulated to calculate percent tree cover. If after the *a priori* analysis, the quality of the selected monitoring plot is still undetermined, ground-truthing will be required to provide a determination of the suitability of the plot for sampling. If a selected monitoring plot needs to be removed for any of the aforementioned reasons, the next unselected point in consecutive order on the overall GRTS sites list will be selected as a replacement point. A beneficial characteristic of a GRTS-based sampling design is even with several point removals, the spatial balance of the selected set of monitoring plots will be retained if the replacement sites are selected appropriately.

If more than one quarter of the plot's total area is considered a restricted category or if **any** of the plot occurs outside of the park boundary, there is an option to shift the plot up to 10 meters (32.8 ft). If a corner of the plot remains in a restricted category, then teams may still include that corner if the restricted category does not take up more than one quarter of the total plot area. Refer to SOP 3: *Site Selection and Plot Establishment—Version 1.48* (CUPN 2023a) for additional details regarding exclusion or adjustment of plots.

Future Acquisitions

Some parks will acquire tracts of land after the original site selection has been established. If the park in question was in the process of acquiring property in 2011, then the area of potential acquisition was included in our GRTS draw. If a new acquisition occurs that was not included in the 2011 GRTS draw, we will work with park managers to extend the original grid into that new acquisition area and choose a proportional number of points as sample sites within that new polygon depending upon how large the acquisition is compared to the previous acreage of the park.

Number of Sample Sites

The annual number of plots to be monitored was estimated based on consideration of forecasted time and resources available to the Cumberland Piedmont Network. There are approximately 14 weeks per field season, which is equivalent to one week at each park. Accounting for travel to-and-from each park on Mondays and Fridays, and assuming a field crew would complete an average of two plots per day, the estimated sampling effort possible is eight plots per week (112 plots each year).

From a statistical point of view, the primary consideration for determining the number of sample sites is the number of sites (plots) needed to detect change with a high level of confidence over time in our key measures. However, each measure we have developed will have a different optimal sample size based on that measure's plot-to-plot variability and the pace of change for that measure. Based on experience, we know the number of weeks in the field needed for a field crew to complete monitoring within the budget. Therefore, we chose to begin sampling with a set number of plots per park. Our methodology allows for addition of plots by expanding the number of years of the panel to increase sample size, or (for smaller parks) by expanding the number of years within the five-year panel that the park is sampled. With increased sample size, we will be able to detect smaller change

with more confidence in our key measures, though with increasing time between samples we lose some ability to tease apart long-term trends from short-term spikes caused by one-time anomalies like drought or hurricane.

In the initial two-years of this study (2011–2012), all parks had 16 plots established (eight per park per year) for a total of 224 plots network-wide. In 2013 and 2014, it was decided to establish additional plots at all parks so smaller parks (less than 2,000 hectares [4,942 ac]) will have 20–28 plots each, and the larger parks (5,000 to 20,000 hectares [12,355 to 49,421 ac]) will have 32–60 plots each. This brings the network-wide total to 392 plots. To accommodate additional plots in all parks, the decision was made to implement a five-year panel (Table 5 and 6).

In future years, as our baseline data and park boundaries expand, we will review our schedule and decide how to accommodate additional plots, if needed. The decision will be based on anecdotal evidence as well as initial calculations of the power to detect change based on the data already collected. If it is determined more plots are needed to meet our monitoring objectives, we will look at either adding additional years to our revisit cycle or ways to increase the number of plots sampled each year under the current scenario. Since the GRTS methodology is flexible, we have an ordered list of additional points for each park which will allow us to pick an introductory number of points to sample but continue to proceed down the ordered list and add new points as we need them while maintaining spatial balance and randomness.

For the fieldwork, the heaviest sampling occurs during years 1–3 of the cycle, when all parks are active, with a lighter schedule in years 4–5, when only larger parks are active. This break in years 4–5 will allow room for other types of targeted sampling/data collection that will address objective 2 (key communities) and will allow additional time for analysis and reporting.

In addition to the regularly scheduled monitoring, approximately 5% of scheduled plots will be randomly selected for repeat sampling to ensure consistency in plot data collection. This means two to six additional plot sampling events each year. Refer to SOP 1: *Field Season Preparation—Version 1.53 (CUPN 2023c)* for details regarding selection of the QA/QC plots and crew.

Yearly plot measurements can affect soil compaction and understory via trampling which could bias the monitoring data (Urquhart et al. 1998). Therefore, we will not visit plots more than once every five years (except for the QA plots mentioned in the paragraph above). In addition, all plot work will be done in a way that minimizes trampling. All steps in the SOPs are planned to make the most efficient use of time spent inside the plot boundary to minimize multiple passes through an area.

Table 5. Schematic for smaller parks where plots are revisited every five years. An “X” indicates that plot was visited and endash (“–”) indicates that it was not visited for that plot and year combination.

Panel	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Year 1 Plots	X	–	–	–	–	X	–	–	–	–
Year 2 Plots	–	X	–	–	–	–	X	–	–	–
Year 3 Plots	–	–	X	–	–	–	–	X	–	–

Table 6. Schematic for larger parks where plots are revisited every five years. An “X” indicates that plot was visited and endash (“–”) indicates that it was not visited for that plot and year combination.

Panel	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Year 1 Plots	X	–	–	–	–	X	–	–	–	–
Year 2 Plots	–	X	–	–	–	–	X	–	–	–
Year 3 Plots	–	–	X	–	–	–	–	X	–	–
Year 4 Plots	–	–	–	X	–	–	–	–	X	–
Year 5 Plots	–	–	–	–	X	–	–	–	–	X

Detectable Levels of Change

Two factors that influence our ability to detect change over time are false change error (Type 1 error) and missed change error (Type 2; Irwin 2008). The probability of detecting a “false change,” or falsely detecting a change when it did not occur, is generally represented as “alpha.” The probability of “missed change,” or wrongly concluding no change occurred when it did, is generally represented as “beta.” Power is equal to $1 - \text{beta}$. The NPS I&M Program is typically more concerned about “missed change” (beta) than “false change” (alpha). Common accepted values of alpha and beta range from 0.01 to 0.2 (Irwin 2008).

We will determine realistic and appropriate values for alpha and beta as more data are collected and analyzed. Our default goal will be to detect a 20% change in key parameters over 10–15 years (i.e., two or three plot revisits), with a power of 0.80 and an alpha of 0.1. After two cycles of data collection (10 years), we will use a power analysis to determine the sample size needed to detect a set level of change in each key metric. Examples of key metrics in which we hope to use the power analysis include stocking index for seedlings, mortality statistics of canopy trees, foliage damage percentages, invasive species presence and frequency, and floristic quality or species richness.

Monitoring is expected to continue indefinitely so more data will be added and the power to detect change will increase. Even if adequate power is not attained after the first cycle of panels, adequate power may be achieved after several repetitions (Urquhart et al. 1998) or with the addition of more plots. Therefore, we will need to weigh several factors carefully after the first 10 years when deciding to increase or decrease the number of plots in a park.

Field Methods

The CUPN Forest Vegetation Monitoring protocol is designed to monitor the “vegetation communities” vital sign in a standardized, statistically valid, and cost-effective manner. Our team compiled field methods for CUPN vegetation monitoring relying heavily on a combination of Carolina Vegetation Survey (Lee et al. 2008), Eastern Rivers and Mountains Network (ERMN; Perles et al. 2010), and United States Forest Service (USFS) Forest Inventory and Analysis (FIA) protocols. The end goal for this protocol development effort was to create a final set of protocols that would yield summary data that could be used by the NPS but that were also comparable to regional and national data collection efforts to allow for data sharing and comparison. In addition to the ERMN protocols, the Cumberland Piedmont Network has referenced and heavily borrowed from other vital signs networks protocols to build this document (Schmit et al. 2006; Tierney et al. 2007).

Plot Design Rationale

Although the monitoring protocol itself is a hybrid of different protocols, the specific plot layout is a modified version of the Carolina Vegetation Survey (CVS) protocols (Lee et al. 2008; Figure 4). Since the categories of data taken using CVS are similar to FIA and the size of plots is roughly comparable to FIA and other NPS network protocols, much of the data we collect can be compared to data from other CVS projects in the region, USFS FIA Program plots, and plots associated with I&M vegetation monitoring in the Northeastern U.S.

The CVS is a collaborative, multi-institutional research program designed to document the composition and status of the natural vegetation of the Carolinas for purposes of inventory, monitoring of environmental impacts, and assessment of conservation status ([Carolina Vegetation Survey](http://cvs.bio.unc.edu/) (<http://cvs.bio.unc.edu/>)). The CVS design has been adopted by researchers throughout the eastern U.S. due to its efficiency and flexibility in different habitat types in the region (Brown and Peet 2003; Cohen et al. 2004; Albanese et al. 2007).

The USFS FIA Program has been used to monitor forest resources on a regional basis across the United States since the 1930s. Beginning in the 1990s, a Forest Health Monitoring (FHM) component was developed by several federal agencies, and later incorporated into the ground survey component of the FIA program. The FIA protocols have undergone extensive development by the USFS with academic and other government agency partners (USFS 2007). The FIA program has developed a substantial database that can be used to assess regional trends in forest resource capacity and health across the region and the country. The FIA data are collected throughout the U.S., helping us better understand regional trends outside of the parks. However, the wide geographic dispersion of FIA points makes the data inappropriate for local analyses in each of the CUPN parks (most CUPN parks contain one or fewer detailed FIA plots). Instead, we can use summarized FIA data to look at how CUPN park measures and metrics compare to regional forest data.

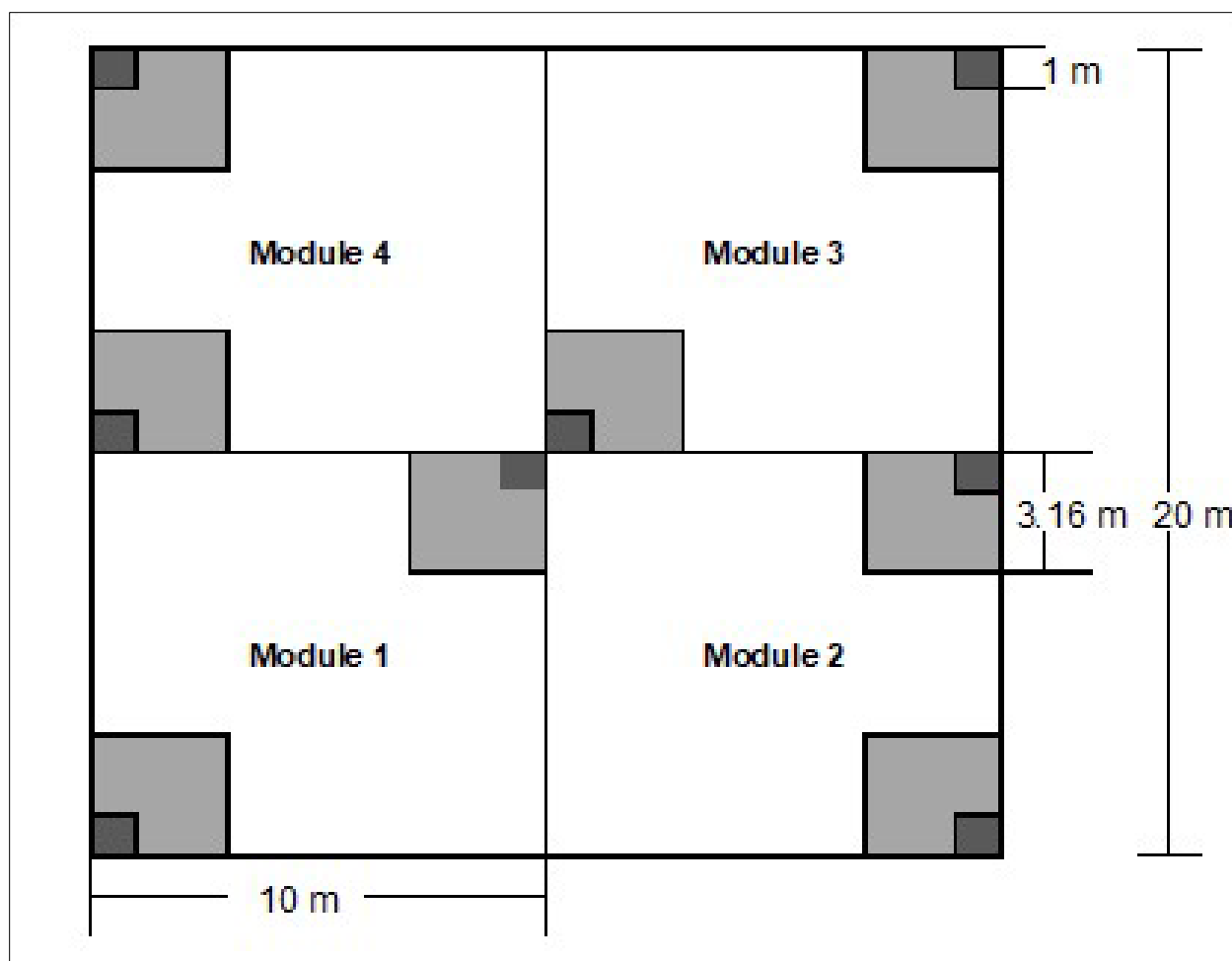


Figure 4. Basic layout of 20 × 20 meter (m; 65.6 × 65.6 ft) standard vegetation monitoring plot.

Finally, we have developed this project with the understanding it will be linked to a larger NPS effort to analyze vegetation dynamics throughout the Northeastern and Southeastern U.S. Our summarized data will be shared with Eastern Rivers and Mountains Network, Gulf Coast Network, Northeast Temperate Network, Mid-Atlantic Network, National Capital Region Network, Southeast Coast Network and South Florida / Caribbean Network to contribute to a greater understanding of regional and national vegetation trends.

Preseason Preparation and Plot Set-Up

The protocol lead and other staff begin preparing for monitoring activities in advance of each field season following steps detailed in SOP 1: *Field Season Preparation—Version 1.53* (CUPN 2023c). Fieldwork begins in late April or early May of each year. Depending on the year within the five-year sampling cycle/panel, three to 14 parks are sampled during the field season. Approximately 5% of plots sampled will be selected for a follow-up repeat QA/QC sampling event by a second crew to ensure consistency in plot data collection across crews. Field crews utilize handheld GPS units and maps to navigate to the predetermined plot centroid coordinates (SOP 2: *Using the GPS [Based on use of GPSMAP 64]—Version 1.26* [CUPN 2023d]). Plots are selected and marked per guidance

contained in SOP 3 (CUPN 2023a). Plot centroid and boundaries are “permanently” marked with cut sections of electrical metallic tubing (EMT) conduit driven in the ground. Various site characteristics such as slope are also recorded by the crew to aid in interpretation of other plot data.

Plot Sampling Methods

For each sampling event, the field crew performs several tasks including plot photopoints to qualitatively assess or document change in appearance over time (SOP 4: *Plot Photopoints—Version 1.34* [CUPN 2023e]). Canopy closure and stand height are estimated with the aid of a spherical densiometer and hypsometer (SOP 5: *Canopy Closure Measurements—Version 1.36* [CUPN 2023f]). Each tree greater than or equal to 10 centimeters (3.9 inches [in]) diameter-at-breast-height (DBH) is recorded live or dead, along with various health measures including evidence of forest pests (SOP 6: *Tree Measurements—Version 1.48* [CUPN 2023g]). The field crew also collects species diversity data and tree seedling/sapling counts in nested subplots within the 20 × 20-meter (65.6 × 65.6-ft) plot (SOP 7: *Species Diversity and Tree Regeneration Measurements—Version 1.40* [CUPN 2023h]). Most of the monitoring SOPs can be completed with basic plant identification skills. However, the protocol requires at least one team member to have demonstrated expertise and experience with the full diversity of vascular plant species in the park and be able to quickly identify each plant species as data are collected.

Coarse woody debris (CWD) includes downed trees and large branches on the ground. As logs deteriorate on the ground, they provide special habitat for many animals, fungi, bryophytes, and other forest organisms. The amount of coarse woody debris is an important indicator of ecological health or integrity. For this reason, field crews measure CWD with the aid of two 40-meter (131.2-ft) transects centered on the plot centroid and extending 20 meters (65.6 ft) in each of the four cardinal directions. Twenty meters north and 20 meters south from plot centroid delineates one of the 40-meter transects. Twenty meters west and 20 meters east from plot centroid delineates the second 40-meter CWD transect, SOP 8: *Coarse Woody Debris Measurements—Version 1.35* (CUPN 2023i).

Before leaving the plot, the field crew will select a U. S. National Vegetation Classification (USNVC) association that best describes the ecological community of the plot. They will do this with the aid of a park specific dichotomous key developed for each park unit in the Cumberland Piedmont Network. This is an important step because ecological communities will change over time. Additionally, it allows us the opportunity to post-stratify plots for analysis purposes. Full instructions are provided in CUPN Forest Vegetation SOP 9: *U.S. National Vegetation Classification Measure—Version 1.35* (CUPN 2023j).

While the tree data will help us understand long term patterns, the herbaceous data will potentially alert us to short term patterns and changes in the vegetation. As stressors affect the vegetation, seedling and herbaceous species composition and structure will respond more quickly than large trees, coarse woody debris, and other measures.

The initial version of this protocol (White et al. 2011) called for soil samples to be collected once every eight years, but soil sampling was never initiated, due largely to compliance issues (i.e., concerns of soil disturbance on battlefield parks). This issue may be re-addressed in future years

based on available resources (i.e., budget) and perceived need. For additional background on soil sampling, refer to SOP 10: *Soil Measurements—Version 1.1* (CUPN 2023k).

Data Handling, Analysis and Reporting

This section provides an overview of the procedures for data handling, analysis and reporting. Additional detail and context can be found in the CUPN Data Management Plan (Moore et. al 2005), as well as task specific SOPs for this protocol, in particular SOP 1: *Field Season Preparation—Version 1.53* (CUPN 2023c), SOP 11: *Data Quality Assurance and Quality Control—Version 2.1* (CUPN 2023k) and SOP 12: *Data Management: Procedures Upon Return from the Field—Version 1.39* (CUPN 2023l).

Data and information are the basic products of scientific research (Michener and Brunt 2000). With this in mind, The Cumberland Piedmont Network’s success will ultimately be judged by its ability to provide relevant high-quality data to current and future data users. The goal is not simply to collect data. The goal is to make sure high-quality data are available, with appropriate context, so that informed decisions can be made.

Therefore, data handling procedures will ensure data are of an acceptable quality. It is important that data handling procedures be documented and **implemented in a consistent manner**. To accomplish this, staff must know their assigned roles and resultant responsibilities and receive the tools and training to accomplish those tasks throughout the project life cycle.

Preseason Preparation for Data Handling

Well in advance of the field season, the program manager will schedule a meeting with the protocol lead, data manager, GIS specialist and other relevant staff to communicate problems and suggested changes to procedures implemented during the previous season(s) and to also review information management needs for the upcoming field season.

Recurring preseason activities include gathering required supplies and equipment, as well as conducting training. While these tasks are not traditionally viewed as data management tasks, they establish an important foundation for data quality control. Ensuring those in data acquisition are equipped and trained minimizes the need for “alternative” modes of data collection and reduces the frequency of incorrect or incomplete data forms. Refer to SOP 1 (CUPN 2023c), for additional details.

The GIS specialist and protocol lead work together to ensure target coordinates and data dictionaries are loaded into the GPS units and tablets prior to the onset of fieldwork, and that GPS download software is available and ready for use. Additional details on GPS use and GPS data handling are provided in SOP 2: *Using GPS (Based on use of the GPSMAP 64)—Version 1.26* (CUPN 2023d).

Data Acquisition and Processing

Vegetation monitoring data will be recorded in the field onto a series of customized paper field forms. Prior to leaving the field, the field crew leader will be responsible for ensuring datasheets are reviewed for completeness and legibility. The datasheets include a place for initials to document that this review is taking place. Upon returning from the field, all data entry forms are scanned once final species identification is completed and recorded onto the forms. Refer to SOP 12 (CUPN 2023l) for

additional details. GPS units are returned to the GIS specialist, who is responsible for stewardship of geospatial data.

A customized Microsoft Access relational database application is used for processing and storage of project data. The database design is largely based upon the Natural Resource Database Template (NRDT), which includes an established set of core tables and fields (NPS 2007). Existing I&M Network databases were also reviewed in the development of this application.

Before interacting with the data, users must log into the database. This allows the database to track when and by whom primary tasks such as entry, verification and validation are performed. Data are entered in the project database from paper field forms. Entry is performed by staff with a high level of experience and familiarity with the protocol and occurs in highly customized entry forms that mimic the field forms. Several functions and utilities are incorporated in the database design including basic look up fields and field limits, as well as more sophisticated error checks such as cross-referencing species codes with park lists and highlighting missing values. Ultimately, verification and validation steps are performed on the data to achieve a high level of data quality. Refer to SOP 11 (CUPN 2023k) for an overview of verification and validation checks, as well as standards and procedures for assessing whether plots are being measured consistently by field crews.

Data Archiving

Paper field forms are digitally scanned and uploaded to the CUPN file server along with plot photos utilizing an established naming convention. These files and other relevant materials are organized in a protocol-specific directory structure for active files. As part of the data validation process, the database will check to see that correctly named images reside in the correct folder for a plot sampling event. A similar directory structure contains archived files. Backups of all project data stored on the server are regularly conducted.

Final verified and validated data sets for vegetation monitoring are archived annually to the [NPS Integrated Resource Management Applications \(IRMA\) – Data Store](https://irma.nps.gov/Portal/) (<https://irma.nps.gov/Portal/>). These data sets and related products (e.g., reports) are uploaded and linked to an individualized IRMA reference. Each reference includes relevant metadata and keywords making the attached file available for discovery as appropriate. Discoverability for both the reference and attached file(s) can be set to public for wide accessibility or restricted to individual owners of the reference.

Metadata Procedures

All geospatial data will be documented with appropriate Federal Geographic Data Committee and NPS metadata standards.

Analysis and Reporting

Two types of reports will be produced for the CUPN Vegetation Monitoring Program at regular intervals: (1) annual resource briefs that summarize key metrics of current vegetation data, and (2) 10-year trend reports that provide information on changes in vegetation at each park. Both reports will focus on terrestrial forested ecosystems, since that is the focus of monitoring objective 1, and those habitat types make up 50–90% of acreage of all CUPN parks. The 10-year trend reports will

include a condition assessment using standard symbology (Table 7) to depict current condition and trends for parameters such as those listed in Table 8. The trend reports will also evaluate relationships between key stressors and key measures, including comparisons to regional datasets for a look at how NPS lands factor into the regional context. For more details on data analysis and reporting see SOP 13: *Data Analysis and Reporting—Version 1.1* (CUPN 2023m).

Table 7. Example of symbology used for condition assessments.

Condition Status Icon	Condition Status Icon Definition	Trend Icon	Trend Icon Definition	Confidence Icon	Confidence Icon Definition
	Resource is in Good Condition		Condition is Improving		High
	Resource warrants Moderate Concern		Condition is Unchanging		Medium
	Resource warrants Significant Concern		Condition is Deteriorating		Low

Table 8. Quantitative measures that may be used as part of a trend report every 10 years.

Metric Type	Parameter
Tree Regeneration	Stocking index
Tree Growth and Mortality	Percent growth in DBH and mortality of stems
Tree condition	Percent of vegetation of tree with foliage problems
Snag Abundance	Number of snags present in plot
Coarse woody debris volume	Amount of debris volume compared to live tree volume
Biotic homogenization/ FQI	Species richness or average coefficient of conservatism
Invasive exotic plant species	Overall richness of exotics and richness of target
Stand structural class	Successional state
Soil chemistry	Measures to be determined
Soil layering	Measures to be determined
Landscape coherence	Size of core area that is not heavily human influenced
Landscape connectivity	Mappable with NPScape pattern metrics
Patch size of occurrence	Size of core area of community type

Park superintendents and resource managers are the primary audience for both reports. The Cumberland Piedmont Network is collaborating with other networks to determine appropriate regional analyses that can be conducted with the vegetation monitoring data from multiple networks. Outside of the NPS, the target audience can include the state departments of natural resources, the USDA Forest Service, as well as the broader scientific community. The CUPN parks with additional plots designed to monitor distinct, key community types will receive additional reporting, as part of monitoring objective 2, if funds become available in the future.

After two or more complete sampling cycles, analyses can evaluate trends in the data. These analyses can be completed by using general or mixed linear models to partition spatial and temporal variability and assess temporal change, as is done by the USFS FIA program (Woodall and Williams 2005). Other potential analytical tools include paired t-tests, repeated measures ANOVA, Kolmogorov-Smirnov two-sample test, and calculating instantaneous rate of change. The statistical package, R, will likely be utilized in analyses due to its versatility and use by other I&M networks.

The Cumberland Piedmont Network also plans to collect and analyze covariate data on key stressors associated with ecosystems in the network. Data collected for other CUPN Vital Signs, such as Air Quality, Weather and Climate, and Landscape Dynamics, will provide information on climate variables, air pollution concentration, deposition rates, and land use change. It is our hope these variables will help account for the relationship between certain response variables (such as tree growth or mortality rate).

Personnel Requirements and Training

The Cumberland Piedmont Network (CUPN) program manager will be responsible for: overseeing and coordinating the development and implementation of vegetation monitoring and the other vital sign protocols. They will ensure that vegetation monitoring is aligned with and contributing toward network goals. The network program manager will also provide support in budget, personnel, and logistical matters.

During initial startup years, NatureServe, via a cooperative agreement, provided technical support and leadership in the development and implementation of this protocol. This included serving in a lead role on field crews and overseeing protocol development, plot establishment and data collection. Currently the protocol lead role is filled by a CUPN ecologist, who is responsible for coordinating and overseeing annual operations. In addition to ensuring fieldwork is successful at each park, the protocol lead is the main point of contact and has primary responsibility for all phases of the protocol. Additional support for this protocol is provided by other CUPN staff including a part-time CUPN biologist, who oversees data entry and verification, as well as various pre- and post-monitoring trip tasks. The CUPN data manager provides database administration and support and the CUPN curatorial specialist oversees processing of plant vouchers. For a timeline with specific duties refer to SOP 1: *Field Season Preparation—Version 1.53* CUPN 2023c).

In addition to the protocol lead, other CUPN staff will occasionally assist on field crews based on training and availability. However, additional personnel are regularly needed. This includes botanists, as well as summer interns. These additional personnel needs are secured via agreements or contracts as appropriate with cooperators. For a timeline and specific responsibilities for different protocol roles, see SOP 1 (CUPN 2023c).

Prior to each field season, the protocol lead must ensure all field personnel fully understand all standard operating procedures by conducting training sessions. Training will occur prior to each field season and in-season, as needed. Field crew training will include review and discussion of all standard operating procedures including job safety. Refer to SOP 1 (CUPN 2023c) for an overview of training topics.

Operational Requirements

Annual Workload and Field Schedule

Fieldwork begins in late April or early May of each year. Depending on the year within the five-year sampling cycle/panel, three to 14 parks are sampled during the field season. All parks are sampled in years 1–3, and only the larger parks are sampled in years 4–5. Years 1 and 2 are full implementation years with at least eight plots sampled at each of the 14 network parks (Mammoth Cave National Park has 12 plots sampled each year). All 14 parks are sampled in year 3 but the number of plots sampled at seven parks is reduced. In years 4 and 5, the number of parks sampled is reduced to 6 and 3 respectively (Table 9).

At minimum, crews will consist of a botanist capable of identifying all woody and herbaceous plants in a park, and at least one network staff member well versed on the forest protocol. A third crew member that assists with data recording, plot setup and other ancillary tasks makes for a much more efficient crew, though it's not required.

Assuming a crew completes on average two plots per day, approximately 60 sampling days is a good estimate for years one and two, with this estimate decreasing in years 3–5. While weather, travel time to a plot, and general plot complexity will alter the schedule, in most cases a single crew is able to complete sampling at a park within a single work week, though in many cases, longer than a 40-hour week. A second crew is typically utilized at both Mammoth Cave National Park and Cumberland Gap National Historical Park because Mammoth Cave NP has 12 plots on the schedule each year and Cumberland Gap NHP's long hikes can result in a crew only completing a single plot per day.

Because plots span seven states, travel time to parks is also an important consideration, particularly in years 1–3. If a crew member stationed at Mammoth Cave NP travels to each of the parks in the network in these years, an additional 15 days should be added to the field schedule to account for travel time. Depending on park/plot selections, QA/QC will add an additional 1–5 field sampling days and up to five travel days to the overall workload estimates for a field season.

Fieldwork will always follow a specified order and timeframe of parks being sampled, with work beginning at Chickamauga and Chattanooga National Military Park every field season in early May and concluding at Abraham Lincoln Birthplace National Historical Park in September, generally a south to north progression over the course of the field season.

The fall and winter months are when data entry and processing, data analysis, and report writing are normally completed. Data entry, verification and validation processes generally can be completed in four weeks of effort, though these “days” do not occur in one continuous block. Another two to four weeks should be accounted for in the annual schedule for analysis and reporting efforts.

Table 9. CUPN five-year sampling schedule: Number of plots sampled per park and year.

Park Code	Park Name	Year 1	Year 2	Year 3	Year 4	Year 5	Total
ABLI	Abraham Lincoln Birthplace National Historic Site	8	8	4	4	–	24
CARL	Carl Sandburg Home National Historic Site	8	8	4	–	–	20
CHCH	Chickamauga and Chattanooga National Military Park	8	8	8	8	8	40
COWP	Cowpens National Battlefield	8	8	4	–	–	20
CUGA	Cumberland Gap National Historical Park	8	8	8	8	8	40
FODO	Fort Donelson National Battlefield	8	8	8	4	–	28
GUCO	Guilford Courthouse National Military Park	8	8	4	–	–	20
KIMO	Kings Mountain National Military Park	8	8	8	–	–	24
LIRI	Little River Canyon National Preserve	8	8	8	8	–	32
MACA	Mammoth Cave National Park	12	12	12	12	12	60
NISI	Ninety Six National Historic Site	8	8	4	–	–	20
RUCA	Russell Cave National Monument	8	8	4	–	–	20
SHIL	Shiloh National Military Park	8	8	8	–	–	24
STRI	Stones River National Battlefield	8	8	4	–	–	20
Total	All parks	116	116	88	44	28	392

At the end of the field season but before the end of the calendar year, an annual review of operations is conducted to review implementation and ensure annual activities remain in sync with documented procedures (Mitchell et al. 2018). Preparations for the upcoming field season, including training, will occur in late winter and early spring. Refer to SOP 1: *Field Season Preparation—Version 1.53* (CUPN 2023c) for additional details on workload and schedules.

Facility and Equipment Needs

The logistical and equipment needs of the vegetation monitoring crew are detailed in SOP 1 (CUPN 2023c). The CUPN staff are based in Mammoth Cave NP, where park housing can be secured for seasonal crew members. Information Technology support including access to computer servers is provided by Mammoth Cave NP.

Implementation of this protocol can largely be accomplished with standard field equipment such as measuring tapes, meter sticks and handheld GPS units. Refer to SOP 1 (CUPN 2023c) for a complete list of required field equipment. Given that this equipment is already available for crews, long-term equipment costs are largely limited to occasional replacement and considered minimal.

Startup Costs and Budget Considerations

This protocol was developed through a cooperative agreement with NatureServe which initially covered the first two years (2011–12) of plot setup, training, and data collection. The 2011–2012 budget covering salary and travel for NatureServe ecologists to train and lead two teams was estimated at \$152,000 and future annual operating costs were estimated at \$192,000 (White et al. 2011).

As of 2022, the Cumberland Piedmont Network no longer has a cooperative agreement in place with NatureServe. Additionally, the network has experienced some changes in personnel and implementation approach. Following is a breakdown of the estimated annual cost of implementing this protocol in a full implementation year (see SOP 1 [CUPN 2023c]), based on FY2022 dollars (Table 10).

Table 10. CUPN forest vegetation monitoring protocol, projected full implementation year (Year 1 and 2) costs, based on 2022 dollars.

Category	Type	Cost/Day ¹	# Days - Years 1 and 2 ²	Estimated Cost - Years 1 and 2 ²	Notes
Personnel	CUPN Ecologist (GS-12)	\$482.72	97	\$46,823.84	53 field, 14 travel, 15 data management, and 15 analysis and reporting days
	Botanist (GS-9 or equivalent)	\$332.86	78	\$25,963.08	58 field, 15 travel, and 5 specimen ID and processing days
	CUPN Biologist (GS-9)	\$332.86	67	\$22,301.62	20 field, 5 travel, 27 data management, 5 specimen processing, 5 preseason preparations, and 5 analysis and reporting days
	Biotech/Intern (GS-7 or equivalent)	\$272.16	93	\$25,310.88	58 field, 15 travel, 10 data management, and 10 equipment repair and prep days
	CUPN Data Manager	\$482.72	10	\$4,827.20	10 data management days
	Contract Botanical Support	—	—	\$18,000.00	QAQC and assistance with logistically challenging parks (2nd team)
Equipment and Supplies	Field Gear	—	—	\$6,250.00	Field kit for 1 crew
	Vehicle Fuel and Maintenance	\$40.00	60	\$2,400.00	—
Travel	All types of travel	—	—	\$24,000.00	Largely based on actual FY22 costs of travel to 10 parks for 3-person crew (with some added buffer)
Total	All types	—	—	\$175,876.62	—

¹ Daily personnel cost based on 2022 General Schedule (GS) Locality Pay Table for Rest of United States (RUS). Step 5 and a 40% benefits rate was used as basis for all GS estimates. <https://www.opm.gov/policy-data-oversight/pay-leave/salaries-wages/2022/general-schedule/>

² Years 1–2 or “full implementation years” of 5-year cycle, see SOP 1: *Field Season Preparation—Version 1.53* (CUPN 2023c)

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Appendix A. Cumberland Piedmont Network Vegetation Associations

Park codes for the following tables include: ABLI=Abraham Lincoln Birthplace National Historic Site; CARL=Carl Sandburg Home National Historic Site; CHCH=Chickamauga & Chattanooga National Military Park; COWP=Cowpens National Battlefield; CUGA=Cumberland Gap National Historical Park; FODO=Fort Donelson National Battlefield; GUCO=Guilford Courthouse National Military Park; KIMO=Kings Mountain National Military Park; LIRI=Little River Canyon National Preserve; MACA=Mammoth Cave National Park; NISI=Ninety Six National Historic Site; RUCA=Russell Cave National Monument; SHIL=Shiloh National Military Park; and STRI=Stones River National Battlefield.

Table A-1. Upland Forest. X=Classified by NatureServe and mapped by UGA (Jordan and Madden 2010). Y=Classified by NatureServe but not mapped by UGA (in this instance, community is usually too small to map).

Group	Association	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Appalachian and Interior Mesophytic Forest	Beech - Maple Unglaciaded Forest	2411	2	X	–	–	–	–	–	–	–	–	X	–	–	–	–
	Montane Grape Opening	3890	1	–	–	–	–	X	–	–	–	–	–	–	–	–	–
	Piedmont Mesic Basic Oak - Hickory Forest	3949	1	–	–	–	–	–	–	–	X	–	–	–	–	–	–
	Piedmont Beech / Heath Bluff	4539	1	–	–	–	–	–	–	–	–	X	–	–	–	–	–
	Interior Low Plateau Mesic Sugar Maple - Hickory Forest	4741	2	X	–	–	–	–	–	–	–	–	X	–	–	–	–
	Northern Mixed Mesophytic Forest	5222	1	–	–	–	–	X	–	–	–	–	–	–	–	–	–
	Southern Piedmont Mesic Subacidic Oak-Hickory Forest	6227	1	–	–	–	X	–	–	–	–	–	–	–	–	–	–
	Southern Appalachian Eastern Hemlock Forest (Typic Type)	7136	1	–	–	–	–	X	–	–	–	–	–	–	–	–	–
	Southern Mesic Beech - Tuliptree Slopes	7201	1	–	–	–	–	–	–	–	–	–	–	–	–	X	–
	Rich Low-Elevation Appalachian Oak-Hickory Forest	7233	2	–	–	X	–	–	–	–	–	–	–	–	X	–	–
	Southern Appalachian Acidic Cove Forest (Typic Type)	7543	1	–	X	–	–	–	–	–	–	–	–	–	–	–	–
	Rich Appalachian Red Oak - Sugar Maple Forest	7698	1	–	–	–	–	–	–	–	–	–	X	–	–	–	–
	Central Interior Beech - White Oak Forest	7881	4	–	–	–	–	X	X	–	–	–	X	–	–	X	–

Table A-1 (continued). Upland Forest. X=Classified by NatureServe and mapped by UGA (Jordan and Madden 2010). Y=Classified by NatureServe but not mapped by UGA (in this instance, community is usually too small to map).

Group	Association	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Appalachian and Interior Mesophytic Forest (continued)	Cumberland/Appalachian Hemlock - Hardwood Cove Forest	8407	1	–	–	–	–	X	–	–	–	–	–	–	–	–	–
	Cumberland-Southern Ridge and Valley Mesic White Oak Forest	8428	1	–	–	–	–	–	–	–	–	X	–	–	–	–	–
	Piedmont Acidic Mesic Mixed Hardwood Forest	8465	1	–	–	–	–	–	–	X	–	–	–	–	–	–	–
	Piedmont Basic Mesic Mixed Hardwood Forest	8466	1	–	–	–	–	–	–	–	–	–	–	X	–	–	–
	Southern Ridge and Valley Basic Mesic Hardwood Forest	8488	1	–	–	–	–	–	–	–	–	X	–	–	–	–	–
Appalachian Oak - Chestnut Forest	Interior Low Plateau Chestnut Oak Forest	5022	1	–	–	–	–	–	–	–	–	–	X	–	–	–	–
	Appalachian Montane Oak - (Hickory) Forest (Red Oak Type)	6192	2	–	X	–	–	X	–	–	–	–	–	–	–	–	–
	Chestnut Oak Forest (Subxeric Ridge Type)	6271	2	–	X	–	–	X	–	–	–	–	–	–	–	–	–
	Chestnut Oak Forest (Mesic Slope Heath Type)	6286	2	–	X	–	–	X	–	–	–	–	–	–	–	–	–
	Appalachian Montane Oak-Hickory Forest (Typic Acidic Type)	7230	1	–	X	–	–	–	–	–	–	–	–	–	–	–	–

Table A-1 (continued). Upland Forest. X=Classified by NatureServe and mapped by UGA (Jordan and Madden 2010). Y=Classified by NatureServe but not mapped by UGA (in this instance, community is usually too small to map).

Group	Association	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Appalachian Oak - Chestnut Forest (continued)	Dry-Mesic Southern Appalachian White Oak - Hickory Forest	7231	1	–	–	X	–	–	–	–	–	–	–	–	–	–	–
	Ridge and Valley Dry-Mesic White Oak - Hickory Forest	7240	2	–	–	Y	–	X	–	–	–	–	–	–	–	–	–
	Appalachian Montane Oak-Hickory Forest (Chestnut Oak Type)	7267	2	–	X	–	–	X	–	–	–	–	–	–	–	–	–
	Chestnut Oak - Shagbark Hickory - Sugar Maple Forest	7268	1	–	–	–	–	–	–	–	–	–	–	–	X	–	–
	Appalachian White Pine - Subxeric Oak Forest	7519	1	–	X	–	–	–	–	–	–	–	–	–	–	–	–
	Appalachian Montane Oak-Hickory Forest (Rich Type)	7692	1	–	–	–	–	X	–	–	–	–	–	–	–	–	–
	Interior Low Plateau Chestnut Oak - Mixed Oak Forest	7700	2	–	–	X	–	–	–	–	–	–	X	–	–	–	–
	Cumberland Plateau Dry-Mesic White Oak Forest	8430	2	–	–	X	–	–	–	–	–	X	–	–	–	–	–
	Subxeric Ridgetop Chestnut Oak Forest	8431	4	–	–	X	–	–	–	–	X	X	–	–	X	–	–
	White Oak - Post Oak Subcalcareous Forest	8443	1	–	–	X	–	–	–	–	–	–	–	–	–	–	–
Chinkapin Oak - Ash - Red-cedar Alkaline Forest	Interior Plateau Shingle Oak - Shumard Oak - Chinquapin Oak Forest	3876	2	–	–	–	–	–	–	–	–	–	X	–	–	–	X

Table A-1 (continued). Upland Forest. X=Classified by NatureServe and mapped by UGA (Jordan and Madden 2010). Y=Classified by NatureServe but not mapped by UGA (in this instance, community is usually too small to map).

Group	Association	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Chinkapin Oak - Ash - Red-cedar Alkaline Forest (continued)	Chinquapin Oak Unglaciaded Bluff Woodland	4267	1	–	–	–	–	–	–	–	–	–	X	–	–	–	–
	Ridge and Valley Limestone Oak - Hickory Forest	4793	1	–	–	–	–	X	–	–	–	–	–	–	–	–	–
	Appalachian Sugar Maple - Chinkapin Oak Limestone Forest	6017	1	–	–	X	–	–	–	–	–	–	–	–	–	–	–
	Interior Low Plateau Chinquapin Oak - Mixed Oak Forest	7699	2	–	–	X	–	–	–	–	–	–	–	–	–	–	X
	Interior Plateau Chinquapin Oak - Shumard Oak Forest	7808	2	–	–	X	–	–	–	–	–	–	–	–	–	–	X
	Shumard Oak - Chinkapin Oak Mesic Limestone Forest	8442	2	–	–	–	–	–	–	–	–	–	X	–	X	–	–
	Dry Calcareous Forest/Woodland (White Ash - Shagbark Hickory Type)	8458	1	–	–	–	–	X	–	–	–	–	–	–	–	–	–
Northern and Central Conifer and Hardwood Plantation	Virginia Pine Plantation	4730	1	–	–	X	–	–	–	–	–	–	–	–	–	–	–
	White Pine Plantation	7178	1	–	–	Y	–	–	–	–	–	–	–	–	–	–	–
	Successional Virginia Pine Forest	2591	7	X	–	–	–	X	–	X	X	X	X	–	–	X	–
	Southern Blue Ridge Successional Sassafras Forest	4096	1	–	–	–	–	X	–	–	–	–	–	–	–	–	–
	Southeastern Successional Black Cherry Forest	4133	1	X	–	–	–	–	–	–	–	–	–	–	–	–	–

Table A-1 (continued). Upland Forest. X=Classified by NatureServe and mapped by UGA (Jordan and Madden 2010). Y=Classified by NatureServe but not mapped by UGA (in this instance, community is usually too small to map).

Group	Association	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Northern and Central Conifer and Hardwood Plantation (continued)	Virginia Pine - Red-cedar Successional Forest	7121	1	–	–	–	–	–	–	–	–	–	X	–	–	–	–
	Successional Tuliptree Bottomland Forest	7184	1	–	–	Y	–	–	–	–	–	–	–	–	–	–	–
	Successional Black Walnut Forest	7879	5	–	–	X	–	Y	–	–	Y	–	X	X	–	–	–
	Successional Eastern White Pine Forest	7944	1	–	X	–	–	–	–	–	–	–	–	–	–	–	–
	East-central Hemlock Hardwood Forest	5043	1	–	–	–	–	–	–	–	–	–	X	–	–	–	–
	Southern Appalachian Acidic Mixed Hardwood Forest	8558	1	–	–	–	–	X	–	–	–	–	–	–	–	–	–
Piedmont and Central Atlantic Coastal Plain Oak Forest	Piedmont Chestnut Oak - Blackjack Oak Woodland	3708	1	–	–	–	–	–	–	–	X	–	–	–	–	–	–
	Piedmont Granitic White Oak - Black Oak Savanna	3722	1	–	–	–	Y	–	–	–	–	–	–	–	–	–	–
	Piedmont Chestnut Oak / Heath Bluff	4415	1	–	–	–	–	–	–	–	X	–	–	–	–	–	–
	Felsic Monadnock Forest	6281	1	–	–	–	–	–	–	–	Y	–	–	–	–	–	–
	Dry Acidic Eastern Coastal Plain Oak - Hickory Forest	7246	1	–	–	–	–	–	–	–	–	–	–	–	–	X	–
	Piedmont Dry-Mesic Acidic Oak - Hickory Forest	8475	3	–	–	–	–	–	–	X	X	–	–	X	–	–	–

Table A-1 (continued). Upland Forest. X=Classified by NatureServe and mapped by UGA (Jordan and Madden 2010). Y=Classified by NatureServe but not mapped by UGA (in this instance, community is usually too small to map).

Group	Association	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Shortleaf Pine - Oak Forest	Appalachian Shortleaf Pine - Post Oak Woodland	3765	1	–	–	–	–	–	–	–	X	–	–	–	–	–	–
	Appalachian Low-Elevation Mixed Pine / Hillside Blueberry Forest	7119	3	–	–	–	–	–	–	–	Y	X	X	–	–	–	–
	Southern Blue Ridge Escarpment Shortleaf Pine - Oak Forest	7493	3	–	–	X	–	–	–	–	X	X	–	–	–	–	–
	Appalachian Shortleaf Pine - Xeric Oak Forest	7500	1	–	–	–	–	–	–	–		X	–	–	–	–	–
	Appalachian Shortleaf Pine - Mesic Oak Forest	8427	3	–	X	–	–	–	–	–	X	X	–	–	–	–	–
South-Central Coastal Plain Mesophytic Forest	Highland Rim White Oak - Tuliptree Mesic Lower Slope Forest	7709	1	–	–	X	–	–	–	–	–	–	–	–	–	–	–
South-Central Interior Oak Forest	White Oak - Red Oak Dry-Mesic Acidic Forest	2067	1	–	–	–	–	–	–	–	–	–	–	–	–	Y	–
	White Oak - Mixed Oak Dry-Mesic Alkaline Forest	2070	4	X	–	–	–	–	X	–	–	–	X	–	X	–	–
	Central Interior Upland Cherrybark Oak Forest	3871	2	–	–	–	–	–	X	–	–	–	–	–	–	X	–
	Upper East Gulf Coastal Plain Chinkapin Oak - Hickory Forest	3903	1	–	–	–	–	–	–	–	–	–	–	–	–	X	–

Table A-1 (continued). Upland Forest. X=Classified by NatureServe and mapped by UGA (Jordan and Madden 2010). Y=Classified by NatureServe but not mapped by UGA (in this instance, community is usually too small to map).

Group	Association	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
South-Central Interior Oak Forest (continued)	Southern Cumberland High-Energy River Oak Terrace Forest	4098	1	–	–	–	–	–	–	–	–	X	–	–	–	–	–
	Southern Red Oak - Mixed Oak Forest	5018	2	X	–	–	–	–	–	–	–	–	X	–	–	–	–
	Interior Southern Red Oak - White Oak Forest	7244	6	–	–	–	X	–	–	X	X	X	–	X	–	X	–
	Southeastern Interior Southern Red Oak - Post Oak Forest	7247	2	–	–	X	–	–	–	–	–	Y	–	–	–	–	–
	Interior Dry-Mesic White Oak - Hickory Forest	7795	1	–	–	–	–	–	–	–	–	–	X	–	–	–	–
Southeast Hardwood and Conifer Ruderal Forest	Loblolly Pine - Shortleaf Pine Managed Woodland	3618	1	–	–	–	–	–	–	–	–	X	–	–	–	–	–
	Successional Water Oak Forest	4638	2	–	–	–	X	–	–	–	–	–	–	X	–	–	–
	Interior Low Plateau Sugarberry, Northern Hackberry Successional Forest	4697	1	–	–	–	–	–	–	–	–	–	–	–	–	–	X
	Highland Rim Semi-natural Red-cedar - Oak Forest	4731	1	–	–	X	–	–	–	–	–	–	–	–	–	–	–
	Early- to Mid-Successional Loblolly Pine Forest	6011	1	–	–	–	X	–	–	–	–	–	–	–	–	–	–
	Early-Successional Shortleaf Pine Forest	6327	5	–	–	–	X	–	–	X	X	X	X	–	–	–	–

Table A-1 (continued). Upland Forest. X=Classified by NatureServe and mapped by UGA (Jordan and Madden 2010). Y=Classified by NatureServe but not mapped by UGA (in this instance, community is usually too small to map).

Group	Association	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Southeast Hardwood and Conifer Ruderal Forest (continued)	Interior Mid- to Late-Successional Loblolly Forest	7105	2	–	–	X	–	–	X	–	–	–	–	–	–	–	–
	Successional Eastern Red-cedar Forest	7124	9	X	–	X	–	X	X	–	X	–	X	–	X	X	X
	Successional Silktree Forest	7192	1	–	–	–	–	–	–	–	–	X	–	–	–	–	–
	Successional Sweetgum Forest	7216	4	–	–	X	X	–	–	–	Y	–	–	X	–	–	–
	Interior Mid- to Late-Successional Sweetgum - Oak Forest	7217	2	–	–	–	–	–	X	–	–	–	–	–	–	X	–
	Successional Tuliptree Forest (Rich Type)	7220	5	X	–	X	–	X	X	–	–	–	X	–	–	–	–
	Successional Tuliptree Forest (Typic Type)	7221	8	–	X	–	X	X	–	X	X	–	X	X	–	X	–
	Mid- to Late-Successional Loblolly Pine - Sweetgum Forest	8462	5	–	–	X	–	–	–	X	Y	X	–	X	–	–	–
	Golden Bamboo Shrubland	8560	3	–	–	–	X	–	–	–	X	–	–	X	–	–	–
Southeastern Old Field	Wisteria Vineland	8568	2	–	–	–	–	–	–	X	–	–	–	X	–	–	–
Virginia Pine and Table Mountain Pine Woodland & Barrens	Blue Ridge Table Mountain Pine - Pitch Pine Woodland (Typic Type)	7097	2	–	X	–	–	X	–	–	–	–	–	–	–	–	–
Wet Loblolly Pine & Hardwood Flatwoods	Southern Red Oak Flatwoods Forest	4412	2	–	–	–	–	–	–	–	–	–	X	–	–	X	–

Table A-2. Riparian and Wetland Forest. X=Classified by NatureServe and mapped by UGA (Jordan and Madden 2010). Y=Classified by NatureServe but not mapped by UGA (in this instance, community is usually too small to map).

Group	Association	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Bald-cypress - Tupelo Floodplain Forest Group	Water Tupelo Swamp Forest	2419	1	–	–	–	–	–	–	–	–	–	–	–	–	X	–
	Bald-cypress Swamp	2420	1	–	–	–	–	–	–	–	–	–	–	–	–	Y	–
Central Depression Pond Group	Cumberland Plateau Willow Oak Pond	8441	1	–	–	X	–	–	–	–	–	–	–	–	–	–	–
Central Flatwoods	Pin Oak Mixed Hardwood Depression Forest	2432	1	–	–	–	–	–	–	–	–	–	X	–	–	–	–
Central Seepage Swamp	Piedmont Low-Elevation	4426	1	–	–	–	–	–	–	–	X	–	–	–	–	–	–
	Headwater Seepage Swamp	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Appalachian Forested Acidic Seep	7443	2	–	–	–	–	–	–	–	–	X	Y	–	–	–	–
Eastern Cottonwood - Black Willow Flooded and Swamp	Black Willow Riparian Forest	2103	3	–	–	X	–	–	X	–	–	–	–	–	–	–	X
	Southern Interior BoXelder Riparian Forest	4690	1	–	–	–	–	–	–	–	–	–	–	–	–	–	X
	Interior Low Plateau Willow Pond Forest	7703	1	–	–	–	–	–	–	–	–	–	Y	–	–	–	–
Oak - Sweetgum Floodplain Forest	Upper Southeast Small Stream Sweetgum - Tuliptree Forest	4418	3	–	–	–	X	–	–	X	X	–	–	–	–	–	–
	Sweetgum - Cherrybark Oak Floodplain Forest	7353	1	–	–	–	–	–	–	–	–	–	–	–	–	X	–
	Upland Sweetgum - Red Maple Pond	7388	1	–	–	–	–	–	–	–	–	X	–	–	–	–	–

Table A-2 (continued). Riparian and Wetland Forest. X=Classified by NatureServe and mapped by UGA (Jordan and Madden 2010). Y=Classified by NatureServe but not mapped by UGA (in this instance, community is usually too small to map).

Group	Association	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Oak - Sweetgum Floodplain Forest (continued)	Southern Interior Oak Bottomland Forest	8487	2	–	–	X	–	–	–	–	–	–	–	X	–	–	–
Silver Maple - Green Ash - Sycamore Floodplain	Southern Green Ash - Elm - Sugarberry Forest	2427	2	–	–	–	–	–	–	–	–	–	–	–	–	X	X
	Interior Forested Acidic Seep	4425	1	–	–	–	–	–	–	–	–	–	–	–	–	X	–
	Boxelder Floodplain Forest	5033	2	–	–	X	–	–	–	–	–	–	–	–	–	Y	–
	River Birch Levee Forest	7312	1	–	–	–	–	–	–	–	–	–	–	–	–	X	–
	Sycamore - Silver Maple Calcareous Floodplain Forest	7334	4	–	–	X	–	–	X	–	–	–	X	–	–	X	–
	Gulf Coastal Plain Sycamore - Sweetgum Floodplain Forest	7335	1	–	–	–	–	–	–	–	–	–	–	–	–	X	–
	Sycamore - Sweetgum Streambottom Forest	7340	2	–	–	–	–	X	–	–	–	–	Y	–	–	–	–
	American Sycamore - Sugarberry - Green Ash Floodplain Forest	7730	1	–	–	–	–	–	–	–	–	–	–	X	–	–	–
	Montane Sweetgum Alluvial Flat	7880	1	–	–	–	–	–	–	–	–	Y	–	–	–	–	–
South-Central Coastal Plain Mesophytic Forest	Rich Levee Mixed Hardwood Bottomland Forest	8429	4	X	–	X	–	–	–	–	–	–	X	–	X	–	–
	East Gulf Coastal Plain Beech Floodplain Forest	4745	1	–	–	–	–	–	–	–	–	–	–	–	–	X	–

Table A-2 (continued). Riparian and Wetland Forest. X=Classified by NatureServe and mapped by UGA (Jordan and Madden 2010). Y=Classified by NatureServe but not mapped by UGA (in this instance, community is usually too small to map).

Group	Association	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Southeastern Ruderal Flooded and Swamp Forest	Chinese Privet Temporarily Flooded Shrubland	3837	1	–	–	–	–	–	–	–	–	–	–	–	–	–	Y
	Successional Sweetgum Floodplain Forest	7330	6	–	–	–	X	–	Y	–	X	X	X	–	–	X	–
	Loblolly Pine - Tuliptree Successional Bottomland Forest	7546	2	–	–	–	–	–	–	–	Y	X	–	–	–	–	–

Table A-3. Riparian and Wetland Shrublands [Placeholder]. X=Classified by NatureServe and mapped by UGA (Jordan and Madden 2010). Y=Classified by NatureServe but not mapped by UGA (in this instance, community is usually too small to map).

Group	Association	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Bald-cypress - Tupelo Floodplain Forest	Southern Buttonbush Pond	2191	1	–	–	–	–	–	–	–	–	–	–	–	–	X	–
Central Depression Pond	Buttonbush Sinkhole Pond Swamp	4742	1	–	–	–	–	–	–	–	–	–	X	–	–	–	–
Florida Rivershore and Freshwater Marsh	Carolina Willow Shrubland	3899	1	–	–	–	–	–	–	–	–	–	–	–	–	–	X
Northern and Central Riverscour Wetland	Alabama St. John's-wort - Alder Shrubland	8495	1	–	–	–	–	–	–	–	–	X	–	–	–	–	–
Oak Sweetgum Floodplain Forest	Floodplain Canebrake	3836	3	Y	–	–	Y	–	–	–	–	–	–	Y	–	–	–

Table A-3 (continued). Riparian and Wetland Shrublands [Placeholder]. X=Classified by NatureServe and mapped by UGA (Jordan and Madden 2010). Y=Classified by NatureServe but not mapped by UGA (in this instance, community is usually too small to map).

Group	Association	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
River Birch - Sycamore - Willow Riverscour Scrub	Rocky Bar and Shore (Alder - Yellowroot Type)	3895	1	–	–	–	–	–	–	–	–	X	–	–	–	–	–
	Black Willow Riverbank Shrubland	3901	1	–	–	Y	–	–	–	–	–	–	–	–	–	–	–
South-Central Appalachian Seepage Fen	Saturated Alder Thicket	3912	2	–	–	–	–	Y	–	–	Y	–	–	–	–	–	–

Table A-4. Old Fields and Successional Shrublands. X=Classified by NatureServe and mapped by UGA (Jordan and Madden 2010). Y=Classified by NatureServe but not mapped by UGA (in this instance, community is usually too small to map).

Group	Association	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Southeast Hardwood and Conifer Ruderal Forest	Chinese Privet Upland Shrubland	3807	4	–	–	Y	–	–	–	–	–	Y	–	X	–	–	X
Southeastern Old Field Group [Placeholder]	Kudzu Vineland	3882	1	–	–	–	–	X	–	–	–	–	–	–	–	–	–
	Successional Broomsedge Vegetation	4044	9	Y	–	–	X	–	X	–	X	X	X	X	–	X	X
	Cultivated Meadow	4048	13	X	X	X	X	X	X	X	X	–	X	X	X	X	X
	Successional Blackberry - Greenbrier Shrubland Thicket	4732	7	–	–	–	X	X	–	X	X	–	X	X	–	–	X

Table A-5. Glades and Barrens. X=Classified by NatureServe and mapped by UGA (Jordan and Madden 2010). Y=Classified by NatureServe but not mapped by UGA (in this instance, community is usually too small to map).

Group	Association	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Eastern Interior Patch Prairie	Kentucky Mesic Tallgrass Prairie	4677	1	–	–	–	–	–	–	–	–	–	Y	–	–	–	–
	Little Bluestem - Bluestem Grassland	7707	1	–	–	–	–	–	–	–	–	–	Y	–	–	–	–
Northern and Central Acidic Glade	Alabama Cumberland Sandstone Glade	4622	1	–	–	–	–	–	–	–	–	X	–	–	–	–	–
	Cumberland Sandstone Glade Heath Shrubland	8470	1	–	–	–	–	X	–	–	–	–	–	–	–	–	–
	Southern Limestone Glade Margin Shrubland	3938	2	–	–	X	–	–	–	–	–	–	–	–	–	–	X
	Limestone Seep Glade	4169	1	–	–	Y	–	–	–	–	–	–	–	–	–	–	–
	Southern Ridge and Valley Annual Grass Glade	4339	1	–	–	Y	–	–	–	–	–	–	–	–	–	–	–
	Limestone Annual Grass Glade	4340	1	–	–	–	–	–	–	–	–	–	–	–	–	–	X
	Interior Low Plateau Limestone Glade Ephemeral Pool	4346	1	–	–	–	–	–	–	–	–	–	–	–	–	–	Y
	Central Limestone Glade	5131	4	X	–	X	–	–	–	–	–	–	Y	–	–	–	X
Northern and Central Alkaline Glade	Limestone Cliff Fragrant Sumac Shrubland	4393	1	–	–	–	–	Y	–	–	–	–	–	–	–	–	–
Southern Appalachian Rocky Outcrop	Appalachian Low-Elevation Granitic Dome	7690	1	–	X	–	–	–	–	–	–	–	–	–	–	–	–

Table A-6. Bogs and Fens. X=Classified by NatureServe and mapped by UGA (Jordan and Madden 2010). Y=Classified by NatureServe but not mapped by UGA (in this instance, community is usually too small to map).

Group	Association	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Northern and Central Conifer and Hardwood Acidic Swamp	Swamp Forest-Bog Complex (Typic Type)	7565	1	–	–	–	–	X	–	–	–	–	–	–	–	–	–
South-Central Appalachian Seepage Fen	Southern Appalachian Low Mountain Seepage Bog	3914	1	–	–	–	–	–	–	–	–	X	–	–	–	–	–
	Nodding Sedge Seepage Fen	7771	1	–	–	–	–	X	–	–	–	–	–	–	–	–	–

Table A-7. Cliffs and Talus. X=Classified by NatureServe and mapped by UGA (Jordan and Madden 2010). Y=Classified by NatureServe but not mapped by UGA (in this instance, community is usually too small to map).

Group	Association	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Eastern North American Temperate Cliff, Talus & Scree [Placeholder]	Cumberland Plateau Rockhouse	4301	1	–	–	–	–	–	–	–	–	Y	–	–	–	–	–
	Cumberland Plateau Sandstone Cliff (Dry Type)	4392	2	–	–	X	–	–	–	–	–	–	–	–	Y	–	–
	Appalachian Mafic Cliff (Low-Elevation Type)	4395	1	–	–	–	–	–	–	–	–	–	–	–	Y	–	–
	Appalachian Talus Slope	4454	1	–	–	Y	–	–	–	–	–	–	–	–	–	–	–
	Highland Rim Limestone Cliff/Talus Seep	4708	2	X	–	–	–	–	–	–	–	–	X	–	–	–	–

Table A-8. Other. X=Classified by NatureServe and mapped by UGA (Jordan and Madden 2010). Y=Classified by NatureServe but not mapped by UGA (in this instance, community is usually too small to map).

Group	Association	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Atlantic and Gulf Coastal Plain Freshwater Tidal Marsh	Southern Cattail Marsh	4150	2	–	–	–	–	–	–	–	–	–	Y	X	–	–	–
Central Depression Pond	Sinkhole Pond Marsh	2413	1	–	–	–	–	–	–	–	–	–	X	–	–	–	–
	Common Rush Marsh	4112	1	–	X	–	–	–	–	–	–	–	–	–	–	–	–
	Southern Blue Ridge Beaver Pond Marsh	8433	1	–	–	–	–	Y	–	–	–	–	–	–	–	–	–
Eastern North American Freshwater Aquatic Vegetation	Water-lily Aquatic Wetland	2386	1	–	X	–	–	–	–	–	–	–	–	–	–	–	–
	Water-willow Rocky Bar and Shore	4286	3	–	–	–	–	–	–	–	–	Y	X	–	–	–	Y
	Smartweed - Cutgrass Beaver Pond	4290	2	–	–	X	–	–	–	–	–	–	–	–	–	Y	–
	Floating Water-primrose Aquatic Marsh	7835	1	–	–	–	–	–	–	–	–	–	–	–	–	–	Y
Florida Rivershore and Freshwater Marsh	Piedmont/Mountain Semipermanent Impoundment (Montane Boggy Type)	4510	1	–	–	Y	–	–	–	–	–	–	–	–	–	–	–
Northern and Central Riverscours Wetland	Piedmont / Central Appalachian Riverbank Tall Herbaceous Vegetation	6480	1	–	–	–	–	–	–	–	–	–	Y	–	–	–	–
Southeastern Ruderal Wet Meadow and Marsh	Tennessee Valley Impoundment Mudflat	4049	1	–	–	–	–	–	X	–	–	–	–	–	–	–	–
Southern Appalachian Grass and Shrub Bald	Southern Appalachian Mountain Laurel Bald	3814	1	–	–	–	–	X	–	–	–	–	–	–	–	–	–

Appendix B. Key Ecosystem Attributes, Drivers, and Stressors (modified based on information provided in Leibfreid et al. 2005)

Overview

Ecosystem attributes are any biotic or abiotic feature of the environment that can be measured or estimated. Stressors are defined as any physical, chemical, or biological entity or process that induces effects on individuals, populations, communities, or ecosystems (Noon and Dale 2002). In some cases, stressors that are measured quantitatively can then also be considered attributes. Stressors can include natural processes and structures such as forms of disturbance (naturally caused fire, windstorms or flooding) and may also represent anthropogenic alterations of natural processes or structures (invasion of exotic species, air pollution, climate change; Noon and Dale 2002).

Major Ecosystem Attributes

Our monitoring objective includes a goal to use attributes or measures that represent some key drivers and stressors, where data are easily available, for potential correlation of vegetation changes evident in data collected for this project. Below are some key ecosystem attributes and their descriptions:

Weather and Climate

Weather and climate is a volatile key attribute increasingly influenced by the stressor of climate change. Weather and climate affect the structure, composition, and function of all ecological systems. Change in average seasonal temperature, altered dates for first and last frost, increased drought, increased severity and frequency of storms, and other extreme weather events associated with global climate change are expected to heavily impact vegetation in national parks over the next century (Leibfreid et al. 2005; IPCC 2007). Areas of Alaska are already seeing heavy impacts due to climate change, including permafrost thaw and sea ice melt (Stroeve et al. 2008). In Southeastern parks, we expect possible changes in wildland fire occurrence, shifting of species ranges of both native and non-native species, changes in phenology, and even fluctuations in the productivity and growth rates of forests with increases in atmospheric CO₂.

For each detailed monitoring report analysis, we will use local and regional average maximum and minimum temperatures, mean temperature, and precipitation from the National Weather Service as well as measures of ground level concentrations of CO₂ in various parts of the CUPN region, taken from EPA monitoring stations, to understand how climate change might correlate with vegetation community changes observed from the data we collect on these NPS units using the vegetation monitoring protocols.

Landscape Patterns

Landscape scale patterns are significantly influenced by land use change stressors within and outside the park. Changes in land use brought on by specific stressors continue to greatly affect vegetation communities, even as these changes occur mostly outside park boundaries. Loss of adjacent ecosystems due to change in land use type both in and out of park boundaries can reduce the gene

pool for rare plants and animals such as the population of largeflower skullcap (*Scutellaria montana*) at Chickamauga and Chattanooga National Military Park, thereby potentially impacting future reproductive success (Cruzan 2001). Furthermore, adjacent land use changes that may occur quite a distance away can lead to more invasive exotic seed and forest pest pressure onsite, changes in micro-environment, and other unforeseen effects. Some land use changes can lead to hydrological changes as well as increased water and air pollution (Leibfreid et al. 2005), especially in parks where watersheds originate outside of the park boundary.

We will incorporate metrics produced from the Cumberland Piedmont Network's landscape dynamics reporting into our final land use stressor measurement. Those data may help us understand changes in landscape dynamics and how they may be correlated with changes in vegetation metrics over time. In addition, we will examine potential correlations between landscape level changes and changes in vegetation communities within the parks.

Air Quality

Air quality is affected by the stressor of air pollution and can affect vegetation in many different forms, the most conspicuous being through ozone damage to leaves. As part of our monitoring or change analysis reporting, we will use data collected as part of the network-wide ozone damage vital sign to determine air quality related changes over time and how those changes might correlate with vegetation changes in each park documented by this project. In addition, we will look at regional data on air quality trends and how those trends might correlate with the vegetation changes we observe.

Soil Chemistry

Acid deposition resulting from the stressor of air pollution can have significant effects on soils including depletion of base cations such as calcium and magnesium, mobilization of aluminum and manganese, and the accumulation of sulfur and nitrogen in soils (Driscoll et al. 2001). The reduction in basic cations and the toxicity of mobile aluminum and manganese have been linked to the decline in sugar maple (*Acer saccharum*) in Pennsylvania (Drohan and Sharpe 1997; Kogelmann and Sharpe 2006), although it is not clear what other species might be affected by changes in soil chemistry due to pollution.

We will use regional data on acid deposition, park-wide soil samples, and park-wide water quality data, collected as part of a separate vital sign, to determine soil chemistry related changes over time and how the changes might correlate with vegetation changes in each park.

Water quality and quantity

Hydroperiod (the frequency and duration of soil inundation) defines the hydrology of a specific wetland and largely determines the type of wetland that will develop in a particular setting. Wetland hydroperiod is influenced by basin morphometry, wetland size, connection of the wetland to ground-water resources, and long-term climatic conditions (Larson 1995; Lent 1997; Kirkman et al. 1999; Brooks and Hayashi 2002). Hydroperiod is the most important physical factor driving the composition and diversity of the wetland floral and faunal communities and wetland productivity (Semlitsch et al. 1996; Schneider 1999; Mitsch and Gosselink 2000; Brooks 2004). Therefore, monitoring wetland hydroperiod provides detailed information about wetland condition, structure,

and function and can be used as a corollary to better understand the ecological effects of changing weather patterns on both uplands and wetlands.

We hope to use data collected from the water quality and quantity monitoring effort or data from meteorological monitoring stations such as [SCAN stations](https://www.nrcs.usda.gov/wps/portal/wcc/home/) (<https://www.nrcs.usda.gov/wps/portal/wcc/home/>) to understand any changes that may be occurring in hydroperiod or water quality over time. Although we aren't specifically targeting wetlands on objective one of our monitoring, in some parks with large, forested wetland areas (like Ninety Six National Historic Site) we should have enough data points in forested wetlands to look at change over time in those wetland areas and compare to change over time in hydroperiod and water quality or quantity.

Key “stressors” To Be Considered as Part of the Vegetation Monitoring Protocol

Since our monitoring objective is to detect meaningful changes in vegetation of forested habitat, we have an interest in measuring key stressors (either directly or indirectly) that affect the vegetation communities. Below are key ecosystem stressors based on abiotic and biotic drivers identified in the original CUPN Vital Signs Monitoring Plan (Leibfreid et al. 2005). Most of these stressors can be quantified using publicly available regional scale data. Other stressors may require some original data taken as part of our vegetation monitoring approach.

Invasive Exotic Plants and Forest Pests

The introduction and spread of invasive exotic plants and insects are a serious threat to the parks' vegetation. Both invasive exotic plants and forest pests can actively kill or outcompete native species, changing the structure, function, or composition of vegetation communities, sometimes in a drastic way.

Some prominent exotic forest pests already established in or near CUPN parks include dogwood anthracnose (*Discula destructiva*), emerald ash borer (*Agrilus planipennis*), chestnut blight fungus (*Cryphonectria parasitica*), and hemlock woolly adelgid (*Adelges tsugae*). Other pathogens and insects such as sudden oak death (*Phytophthora ramorum*), Asian longhorned beetle (*Anoplophora glabripennis*), and European gypsy moth (*Lymantria dispar*) may pose significant future threats to CUPN parks. The network's exotic invasive plant and forest pest early detection effort is a separate project tasked with quickly identifying and reporting outbreaks of invasive exotic species, including invasive plants. We will use results from the early detection effort to quantify new forest pest pressure (change in number of high priority forest pest species in each park) and use it to help understand potential correlations between vegetation change and forest pest outbreaks.

Invasive exotic plant species often compete with native plant species or dramatically change the vegetation structure of a site, thereby affecting habitat for plant and animal species. Invasive plants can also disrupt ecosystem-level processes by altering resource utilization, trophic structures, and disturbance regimes. These disruptions may result in altered fire regimes, nutrient cycling, or changes in soil development (Vitousek 1990; Mack et al. 2000; Pimentel et al. 2000). Further, new invasives continue to become established in our region, meaning that lists of priority species may change year-to-year as new and more aggressive species ranges begin to overlap with CUPN parks.

Thus, exotic invasive plants present difficult challenges to NPS resource managers. As mentioned above, a separate “early detection” project will identify important outbreaks as they occur. In contrast to the early detection effort, our vegetation monitoring effort will look at how invasive exotic species frequency and presence or absence within the plots that we sample, are increasing or decreasing over time, thereby giving us some idea as to how invasive exotic species are affecting the park as a whole and whether exotic species richness and density per unit area are changing.

Grazers and Deer Herbivory

Deer density increases and potential overpopulation have been documented throughout the Cumberland Piedmont Network (Harlow and Hooper 1972; Rooney 2001). Changes in land use and land management as well as changes in hunting patterns over the previous decades have led to expanded populations in some areas (Rooney 2001; Latham et al. 2005). Browse pressure from deer is not equal for all species (Masters 2002). Instead, deer preferentially target some specific families (Fabaceae spp., Orchidaceae spp., and Araceae spp.) and genera (*Scutellaria* spp., *Arundinaria* spp., *Dichanthelium* spp.) (Anderson 1994; Augustine and Frelich 1998; Masters 2002; Ruhren and Handel 2003; Kirschbaum and Anacker 2005). Tree seedlings are particularly impacted by deer browse effects, leading to changes in midstory and overstory composition over time. Other effects of selective browsing by deer on forest ecosystems include reduced overall species richness, altered species composition toward dominance of non-preferred and browse-resilient species, regional biotic homogenization, and reduction in plant growth rates (Russell et al. 2001; Horsley et al. 2003; Rooney et al. 2004; Kirschbaum and Anacker 2005; Latham et al. 2005). We will use data collected from our seedling and sapling protocol to look at change in seedling and sapling species composition. We hope to document whether woody species preferentially grazed by deer are increasing, decreasing, or maintaining their populations in each park and help managers understand whether deer populations in their parks may affect future forest composition.

Visitor Use/Impacts/Management Activities

Each park has its own set of goals and challenges and resource management actions can affect vegetation communities. Some management activities (invasive exotic species removal, restoration or revitalization activities) may negatively affect some species and benefit others. We will document new management activities in plots surveyed and use these data as a proxy to look at management activity changes and their possible correlation to changes in vegetation communities. We will also document any negative visitor use impacts within any plots that we sample. These visitor impacts will potentially affect plant species richness and other measures, so we will examine whether there is a correlation between these visitor impacts and changes in vegetation community measures.

Natural Disturbance Regimes/Succession

Succession and other natural processes (such as gap formation) play a large role in changes in vegetation communities. For instance, secondary succession on abandoned agricultural lands can create forests where old fields or shrublands once stood, significantly changing the species types and species richness numbers for that stand. We will use landscape scale measures from each park to determine if any large-scale changes in successional state are correlated with vegetation change.

Most ecosystems in our current landscape have severely altered disturbance regimes compared to their historic disturbance return intervals and intensity. In many cases, areas that were subject to occasional fire are no longer burned, leading to a relatively rapid change in species composition and vegetation structure. Where data is available, we will use “acres burned” to look at whether fire is correlated with vegetation changes that we document at each park.

Acid Deposition

We do not currently have a plan to directly measure acid deposition but we will plan on using soil samples to look at soil pH changes over time that will indirectly measure this stressor.

Climate Change

Climate change is considered a stressor because it can potentially affect weather and temperature patterns of each park. We will use regional climate information for each park to better understand changes in temperature and precipitation and changes in climate patterns over time.

Interacting Stressors

In some cases, changes in vegetation can be linked to multiple interactions among stressors. For instance, it is suggested that the increased regeneration of red maples (*acer rubrum*) at the expense of oak regeneration may be due to a combination of deer overabundance, climate change, and changes in fire regime (Abrams 1998). In addition to red maple, one U.S. Forest Service model predicts large shifts in suitable potential habitat for many of our parks’ common tree species under the various climate change scenarios (Iverson et al. 1999). Interaction between stressors will be considered as part of our overall analysis of vegetation changes over time.

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