

National Park Service
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Cumberland Piedmont Network **Vegetation Monitoring Protocol**

Natural Resource Report NPS/CUPN/NRR—2011/XXX



ON THE COVER

Clockwise starting with the largest photo: Beech tree and rock outcrops at Mammoth Cave National Park, canopy densiometer in use, *Aster georgianus* at King's Mountain National Battlefield, and field data collection at Cumberland Gap National Historic Site.

Photography by NatureServe.

Vegetation Monitoring Protocol for the Cumberland Piedmont Network

Natural Resource Report NPS/CUPN/NRR—2011/XXXX

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Abstract or Executive Summary

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 vegetation communities, including key communities of management concern where possible.

This protocol is intended for use by the CUPN and was designed as a way to efficiently collect, analyze, and disseminate scientifically credible information that will help park managers and researchers to understand how the vegetation communities of the parks are changing.

In order to fully implement this protocol, please read the entire document and all appendices. The appendices contain all standard operating procedures (SOPs) and other detailed information on implementation not provided in the main body of the document.

Acknowledgements

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

In addition, staff from other NPS IM networks and staff 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/or 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 IM program, for his time and patience in answering our questions regarding plot design and implications to 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 vegetation communities, this protocol will generate information on soil condition, forest pest presence, and invasive exotic plant presence. 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 and maintenance of vegetation communities is important to the mission of all the units in the CUPN. By ensuring that vegetation communities continue to exist and function at a high level, we can conserve most all of the species that rely on that community, including species which we don't already know about (Walker 1995). This approach complements the species-based approach, where land managers look to preserve the habitat of keystone species. By using both approaches, we can do a better job of not only conserving the rare and charismatic species, but also ensuring that we keep the common species common by addressing threats before they become critical.

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, some 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).

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 two to four years.* Objective 1 is the focus of this protocol which is planned for implementation in 2011. It covers park-wide vegetation and includes all 14 parks. The CUPN will be 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 protocols targeting specific communities of management concern, and will include parks with key communities that

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."*

are not covered by Objective 1. The CUPN will work with parks and other partners to accomplish this objective, and will incorporate documentation in future revisions to this protocol.

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 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 (Perles et al. 2007b, Sanders et al. 2006, Tierney et al. 2007).

This document contains detailed descriptions of how to implement the vegetation monitoring protocol, including standard operating procedures (SOPs) for field data collection, data management, data analysis and reporting, sample field datasheets, and field guide for forest pests and invasive plants. CUPN staff will read and revise the SOPs on a yearly basis to update information prior to the following field season. In addition, all staff and volunteers participating in any component of the monitoring work must read this document prior to their involvement.

Background and Objectives

Overview of Parks and Ecological Resources

The CUPN contains 14 parks with diverse cultural and natural resources that span a large geographic area crossing eight states and five ecoregions (Table 1, Figure 1). The vegetation within the parks varies with factors such as latitude, longitude, elevation, geology, and topographic position. As seen in Table 1, the parks range in size from the smallest at 91.5 hectares (226 acres) to the largest at 21,380 hectares (52,830 acres).

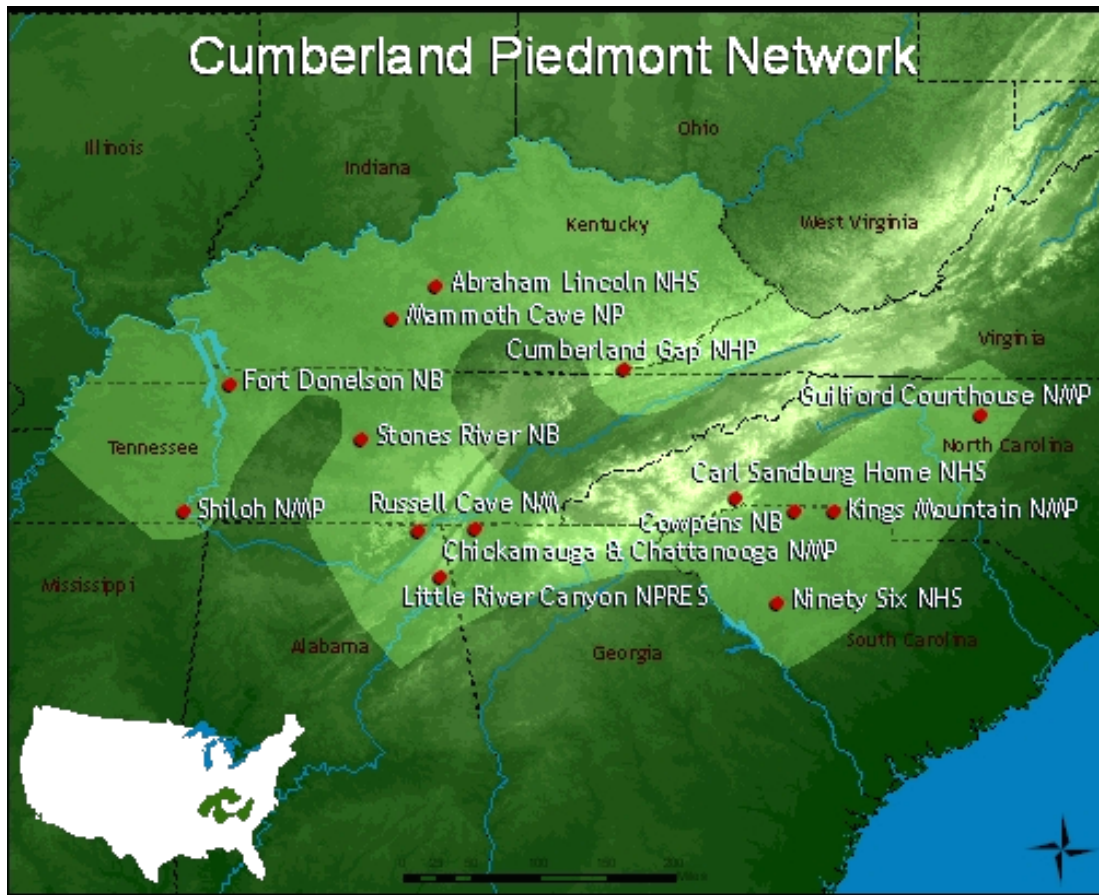


Figure 1. Location of the CUPN parks

Table 1: Cumberland Piedmont Network Parks

Park Name	Code	Size (acre)	Size (ha)	State	TNC Ecoregion
Abraham Lincoln Birthplace National Historical Park	ABLI	344	139	KY	Interior Low Plateau
Carl Sandburg Home National Historic Site	CARL	264	107	NC	Southern Blue Ridge
Chickamauga & Chattanooga National Military Park	CHCH	8,933	3,617	GA/TN	Cumberlands and Southern Ridge and Valley
Cowpens National Battlefield	COWP	842	341	SC	Piedmont
Cumberland Gap National Historical Park	CUGA	23,215	9,399	KY/TN /VA	Cumberlands and Southern Ridge and Valley
Fort Donelson National Battlefield	FODO	717	290	KY/TN	Interior Low Plateau
Guilford Courthouse National Military Park	GUCO	226	91	NC	Piedmont
Kings Mountain National	KIMO	3,945	1,597	SC	Piedmont

Park Name	Code	Size (acre)	Size (ha)	State	TNC Ecoregion
Military Park					
Little River Canyon National Preserve	LIRI	13,691	5,543	AL	Cumberlands and Southern Ridge and Valley
Mammoth Cave National Park	MACA	52,830	21,389	KY	Interior Low Plateau
Ninety Six National Historic Site	NISI	989	400	SC	Piedmont
Russell Cave National Monument	RUCA	310	125	AL	Cumberlands and Southern Ridge and Valley
Shiloh National Military Park	SHIL	5,119	2,072	TN/MS	Upper East Gulf Coastal Plain
Stones River National Battlefield	STRI	709	287	TN	Interior Low Plateau

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 (National Research Council 2000, Elzinga et al. 1998, Noon 2002). Conceptual models improve the planning process for monitoring by explicitly 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 an obvious need for conceptual modeling as a tool to help organize information and synthesize understanding of system components and interactions.

Since most of the acreage of each park is forested and terrestrial, addressing Monitoring Objective 1 for each park will, by definition, involve primarily sampling and analyzing data in these terrestrial forested communities. As a consequence, we have focused attention on the conceptual model for terrestrial forested ecosystems developed by CUPN personnel and outlined below (Figure 2):

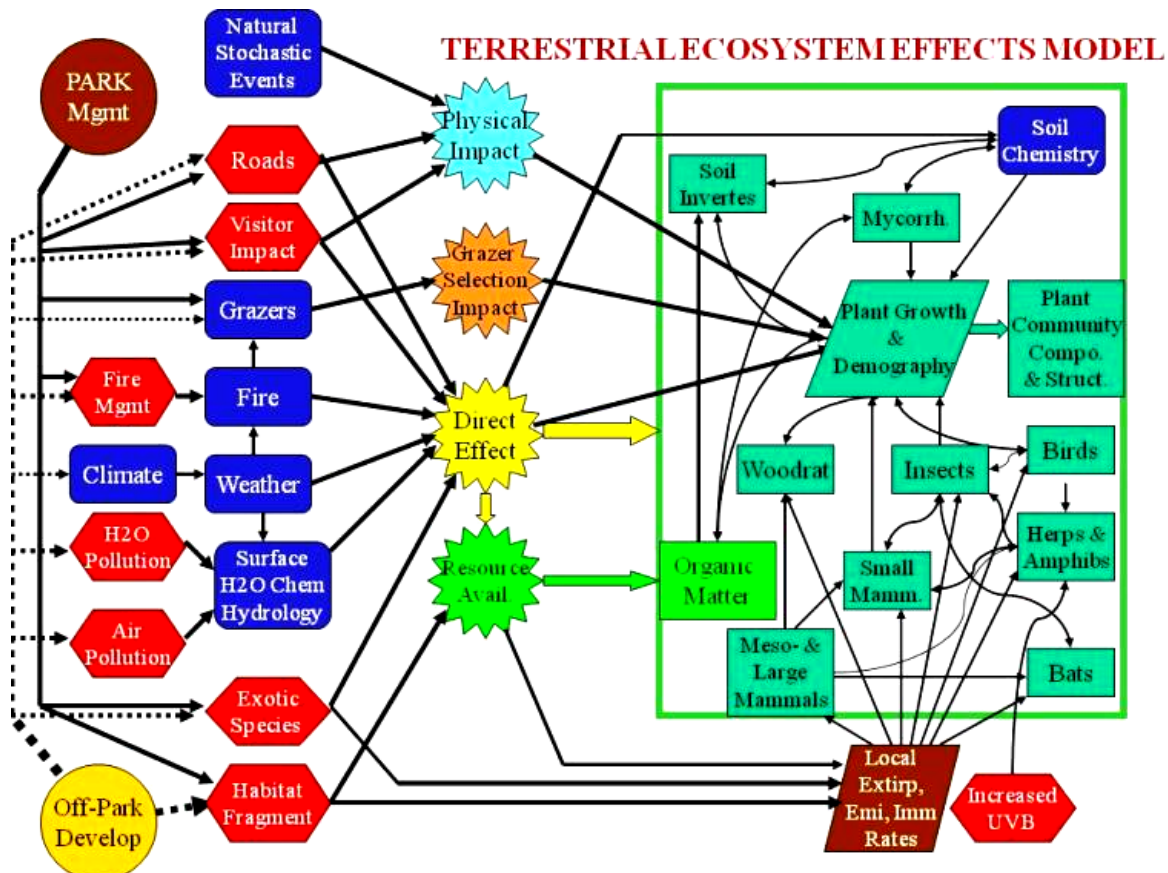


Figure 2. Ecosystem model developed for CUPN Vital Signs Monitoring Plan (Leibfreid et al. 2005)

Other inventory and monitoring networks have also 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 ecosystems 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 that are likely to be influencing change in the vegetation at CUPN parks.

The systems have been classified throughout all of the parks using both the U. S. National Vegetation Classification (FGDC 2008, Grossman et al. 1998) and NatureServe's Ecological Systems (Comer et al. 2003). Details can be found in each of the park vegetation classification reports (table 2) and in Appendix A. In order to help identify communities that span multiple parks, we have grouped them into six broad "vegetation types" (Table 3). These 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

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

In future years we hope to build conceptual models for each specific “key community” identified by individual parks as part of our effort to help those parks and the network identify the ecological health of specific communities of interest. 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 (Table 3).

Table 3. Vegetation Types for CUPN parks with estimated percent area derived from recent vegetation maps (Jordan and Madden 2010).

	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/Shrublands	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	9%	8%	11%	9%	12%	15%	10%	<1%	12%	3%	5%	3%	11%	29%

Ecosystem Drivers, Stressors, and Attributes

The CUPN Vital Signs Monitoring Plan (Leibfreid et al. 2005) describes the major drivers, stressors, and overarching ecosystem attributes associated with terrestrial ecosystems of the CUPN. We relied heavily on that document to build our final list of key ecosystem attributes and stressors of vegetation communities that we feel 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 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 can then also be considered attributes. Stressors can 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 have also considered it as a potential stressor in developing metrics and hope that some of our protocol may capture long term changes in vegetation due to changes in climate. See Appendix B for a full discussion of each key attribute and stressor.

Rationale for Monitoring Vegetation Communities

The vital sign process for CUPN 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.

Because of this interwoven relationship between vegetation and both biotic and abiotic components, this protocol incorporates the Network's monitoring plans for vegetation communities. In addition, we hope the data taken from this work can contribute to the early detection protocols for invasive exotic plants and forest pests once they are developed for the network.

For this particular project, the network is interested in 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, in the near future we hope to develop protocols to address our secondary monitoring objective: to assess the health or condition of key vegetation communities. To detect significant changes, CUPN has chosen a set of measures that can be monitored at regular intervals and used to report on change over time. Some of these 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 that have been chosen to address these monitoring objectives can be combined and used to summarize ecosystem health. Not only can we use these measures to look at quantitative change over time, we can repurpose them to determine ecological health through an ecological integrity scoring system. By measuring taxonomic, structural, and demographic features, we can look at whether or not the ecosystem's parameters fall within expected or accepted norms and ranges of variability. These metrics serve as indicators of ecological integrity that are easily explained through metric ratings (i.e. good, fair, or poor) and can be explicitly linked back to park management practices.

Sampling Design

Monitoring the vegetation in the Cumberland Piedmont Network's fourteen parks requires the development of a statistically sound sampling methodology that accounts for logistical (NPS staffing levels and resources) and scientific (year-to-year variability) factors and/or constraints. We chose to implement a flexible two year rotating panel design which maximizes the quality/quantity of scientific data collected and minimizes the stressors from logistical constraints. This design is especially useful to data consumers because of the short return interval (2 years) with which new data becomes available. This provides the data consumer with important information regarding the potentially confounding effects of inter-annual variability as well as the power of the design to detect change. 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), the design allows for the flexibility to expand the protocols to a four or eight year panel which doubles or quadruples the number of plots in each park for future sampling.

We estimate that, on average, we can complete approximately 8 plots per week of sampling with one team of two people. Therefore, we plan on sampling eight plots in each park each year.

Site Selection Overview

Relative simplicity in sampling design is highly desirable, but so is flexibility for incorporating studies with different levels of sampling intensity both now and in the future. We developed our sampling design framework to reflect both simplicity and an interest in flexibility. 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.

In brief, 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 US 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 that all areas within the sampling frame are represented. Second, the GRTS design allows for flexible sample size, such that sites can be added to 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 simply pick the next number on the list of plots not yet assigned to continue to have a random, spatially balanced sample. This allows potential sites to be rejected if they are determined 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 that is 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).

Selecting Sites

The sampling design framework for vegetation monitoring plot locations began with a dense base grid that spread samples evenly throughout the entire park. The size of the grid (40 m x 40 m) was based on the dimensions of our coarse woody debris transects within the vegetation plot. The starting point for this grid was randomly selected using a grid sampling program from the US Geological Survey (Gilbert, Ver. 2.9, 2007). 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. 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, as long as they are 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 still remain high as long as replacement plots are chosen from the first available point after the selected sub-sequence and as long as they are in consecutive sequence down the list. For small parks, the selected sub-sequence is the first 16 points and for large parks, the selected sub-sequence is first 32 points. Each of these sub-sequences will become the established set of the park's vegetation monitoring plot locations.

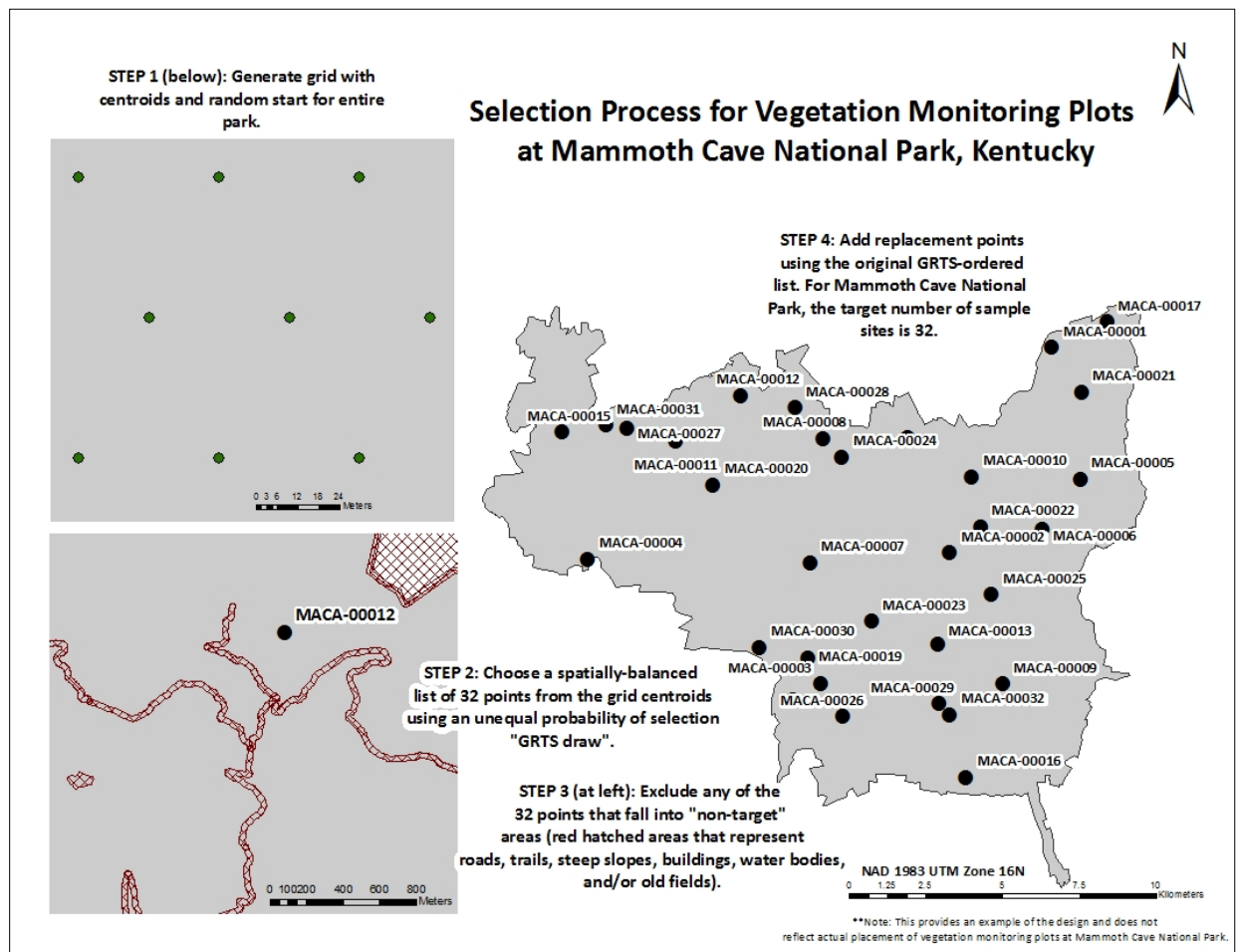


Figure 3. Map of Potential plot layout for monitoring plots at Mammoth Cave National Park

Excluding Points

In some situations, we will exclude points from the site selection sample for particularly important reasons. These include situations where points are:

- 1) on privately owned land;

- 2) on non-vegetated land, including transportation corridors, built-up land, river, pond, etc;
- 3) on intensively managed lands including regularly mowed lawns and landscaping.
- 4) on inaccessible slopes $\geq 30^\circ$ (equivalent to $\geq 58\%$ slope) as calculated from digital elevation models. In CUPN parks, slopes more than 30 degrees are extremely rare and so we feel that this exclusion is justified.
- 5) that occur directly on a trail or road to minimize possible vandalism in the plots and to avoid negative visual impacts to park visitors.
- 6) that occur directly on a park boundary in order to avoid encroachment onto privately owned land.

We have adopted the guidelines of the FIA program to define what constitutes a “forest”, whereby there is a 10 percent minimum stocking requirement of tree species. The 10 percent requirement is intended for sites that are stocked by that amount at the time of sampling, or will likely return to that percentage in the future. This would take into account natural phenomenon 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 whether or not 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 accurate assessment. 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 that even with several point removals, the spatial balance of the selected set of monitoring plots will be retained as long as the replacement sites are selected appropriately.

When plot locations are rejected for any reason, the next unsampled plot number in the ordered list is chosen to replace it (see the Site Selection and Plot Establishment Standard Operating Procedure (SOP) in Appendix C for rejection criteria and procedures).

Overview of the four step process for rejecting plots:

- 1) After generating the ordered list of GRTS centroid points, the points will be overlaid in GIS with derived slope measures, digital orthoquads and/or aerial imagery to determine whether any of the centroid points overlap with one of the situations mentioned and listed above.
- 2) If any centroids occur on roads, trails, or the park boundary or if they fall in areas that have less than 10% tree cover, they will be excluded from the selection and will be replaced by new points from the next available centroids in consecutive order from GRTS sequence of points.
- 3) Maps of the selected monitoring plot locations post a priori assessment, will sent to park managers and they will be able to “veto” any points based on the situations above or other issues that they might have with placement of particular plots
- 4) When field crews are in the field, they may either move or eliminate any points where one of the situations above applies to the centroid of the plot or where they feel that their safety is being compromised (open mine shaft present, etc.). Specific directions for moving a plot are outlined in SOP 3 of Appendix C.

Randomization Test

GRTS procedures do involve a random component (i.e. assignment of quadrant number). Therefore, it is possible for GRTS procedures to produce a random sample. It is recommended that GRTS samples be tested using a Randomization Test. The mean nearest neighbor (MNN) of the “n” GRTS selected sites is derived. MNN is also derived from a randomly selected set of “n” sites using the frame used in the GRTS selection procedure. The MNN of the random sample is compared with the MNN of the GRTS sample. If the MNN of random is greater than or equal to the MNN of GRTS, then the GRTS result is not random. Replications on the order of 100,000 to 1,000,000 will be performed of random site selection, MNN calculations, and comparisons with MNN of the GRTS sample. The proportion of replicates where MNN of random is greater than the MNN of GRTS will be recorded. This proportion is the P-value for rejecting the null hypothesis: H_0 : GRTS sample is not different from random. The alternative hypothesis is that the GRTS sample is different from random (more spatially-balanced).

Future Acquisitions

It is possible that some parks will acquire tracts of land after the original site selection has been established. If the park in question is in the process of acquiring property, then the area of potential acquisition will be included in our GRTS draw. If a new acquisition occurs after the site selection process, 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.

Table 4: Example of GRTS generated points for MACA.

*Data projected in NAD 1983 UTM Zone 16N.

Park ID	Original X Coordinates*	Original Y Coordinates*	GRTS Assigned Weights
MACA-00001	583560.9945	4123708.8203	2028.7813
MACA-00002	580240.9945	4117028.8203	2028.7813
MACA-00003	576040.9945	4112748.8203	2028.7813
MACA-00004	568440.9945	4116828.8203	2028.7813
MACA-00005	584480.9945	4119428.8203	2028.7813
MACA-00006	583240.9945	4117788.8203	2028.7813
MACA-00007	575680.9945	4116708.8203	2028.7813
MACA-00008	576120.9945	4120748.8203	2028.7813
MACA-00009	581960.9945	4112748.8203	2028.7813
MACA-00010	580960.9945	4119508.8203	2028.7813
MACA-00011	571320.9945	4120668.8203	2028.7813
MACA-00012	573440.9945	4122148.8203	2028.7813
MACA-00013	579840.9945	4114068.8203	2028.7813
MACA-00014	575120.9945	4112228.8203	2028.7813
MACA-00015	567600.9945	4120948.8203	2028.7813
MACA-00016	580760.9945	4109708.8203	2028.7813
MACA-00017	585360.9945	4124548.8203	2028.7813
MACA-00018	578880.9945	4120788.8203	2028.7813
MACA-00019	575600.9945	4113588.8203	2028.7813
MACA-00020	572520.9945	4119228.8203	2028.7813
MACA-00021	584520.9945	4122268.8203	2028.7813
MACA-00022	581240.9945	4117868.8203	2028.7813
MACA-00023	577680.9945	4114788.8203	2028.7813
MACA-00024	576720.9945	4120148.8203	2028.7813
MACA-00025	581600.9945	4115668.8203	2028.7813
MACA-00026	576760.9945	4111708.8203	2028.7813
MACA-00027	569720.9945	4121068.8203	2028.7813
MACA-00028	575200.9945	4121748.8203	2028.7813
MACA-00029	579880.9945	4112108.8203	2028.7813
MACA-00030	574040.9945	4113948.8203	2028.7813
MACA-00031	569040.9945	4121188.8203	2028.7813
MACA-00032	580240.9945	4111748.8203	2028.7813

Number of Sample Sites

We estimated the total number of plots to be included in this project based on consideration of forecasted time and resources available from the CUPN Inventory and Monitoring Network staff. Two teams will be available for each field season for a total of approximately 14 weeks per

season, which is roughly equivalent to one team per park per season. Accounting for travel to and from each park on Mondays and Fridays and assuming each team would complete an average of 2 plots/day, we suggested sampling at least eight plots/week (112 plots each year). This number does not include additional sampling that may occur in each park, as resources become available, to address monitoring objective two or to assist in early detection efforts for invasive exotic plant species or forest pests.

From a statistical point of view, the primary consideration for determining the number of sample sites should be the number of sites/plots needed to detect change 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 particular measure. Based on past experience, we already know the number of weeks in the field realistically needed for our field crews to complete monitoring within the budget. Therefore, we chose to begin sampling with a set number of plots per park. Our methodology allows for easy addition of plots by expanding the number of years of the panel from two to four years or from four to eight years to increase sample size. With increased sample size, generally we will be able to detect smaller change with more confidence in our key measures.

Sampling will occur every year in every park. At least eight plots will be measured in each park annually. At the beginning of this study, all parks will be on a two-year rotation, so that 16 plots will be completed for each park within a two year cycle. At the end of the two year period, CUPN network staff will continue to sample new unique plots at the largest parks (CUGA and MACA) for another two years while revisiting the original 16 plots at the other parks (see tables 5 and 6 below). This will create a plot total of 32 plots at MACA and CUGA after four years of sampling and a plot total of 16 plots measured twice at the other 12 parks after four years of sampling. To determine whether parks will need more plots, CUPN staff will look at the results of the change detection analyses after two cycles of monitoring (2014) to see whether we can detect change in key measures with the target level of confidence. If it is shown that we cannot detect change at the level of confidence that we need for key measures, then we will consider adding 16 additional plots to the sample. This will be accomplished by changing the return interval for revisiting plots from two years to four years. If it is determined that 32 plots is still not enough to meet our monitoring objectives, then we will look at either adding an additional four years and 32 plots or we will look for ways to increase the number of plots sampled each year under the current scenario. Since the GRTS methodology is flexible, we will have an ordered list of additional points for each park which will allow us to pick an introductory number of points to sample (16 points in most parks) but later continue to proceed down the ordered list and add new points as we need them while maintaining spatial balance and randomness.

Table 5. Schematic for parks where plots are revisited every 2 years (12 Smaller Parks)

Panel	Year								
	1	2	3	4	5	6	7	8	9
Year 1 plots	X		X		X		X		X
Year 2 plots		X		X		X		X	

Table 6. Schematic for parks where plots are revisited every 4 years (CUGA/MACA).

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

To determine whether the plots are being measured consistently, we will also randomly choose a portion of the plots sampled in each year for a return visit. Before the beginning of each field season, the GIS Specialist will randomly choose two plots in three of the 14 parks (5% of all plots sampled in any given year) to be resampled that field season.

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 be visiting plots more than once every 2 years (with the exception of the QA plots mentioned in the paragraph above). In addition, all plot work will be done in a way that minimizes trampling to the best of our abilities. All steps in the SOPs are planned to make the most efficient use of time spent inside the plot boundary and are meant to minimize multiple passes through an area. In many instances, the measurements we take can be taken while standing outside of the plot. Sampling will take place from (May-September).

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 actually did, is generally represented as “beta”. Power is equal to $1 - \text{beta}$. The NPS IM 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).

Unfortunately, we do not have any existing data from CUPN parks to look at the level of trend detection of our key measures over time. The Eastern Rivers and Mountains Network (ERMN) has taken data on similar key measures and in 2011 will be examining the number of plots that would be needed under different scenarios to detect change in their measures. Since our measures/metrics are very similar to those of the ERMN, we will use that information to help inform our own ideas about how many plots we may ultimately need to make the monitoring project statistically valid into the future.

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 percent change in key parameters over two to eight 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 in the smaller parks (4 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, and floristic quality/species richness).

As the monitoring is expected to continue indefinitely, 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 a number of factors carefully after the first four years when deciding whether or not to increase or decrease the number of plots in a given park.

Summary of Field Methods

The CUPN Vegetation Monitoring protocols are 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 (Perles et al. 2010), and USFS FIA protocols. The end goal for this protocol development was to create a final set of protocols that would yield summary data that could be used by the network parks internally to fulfill our objectives but that were also comparable with regional and national data collection efforts to allow for data sharing and comparison. In addition to the ERMN protocols, CUPN has referenced several other vital signs networks protocols to build this document (Schmit et al. 2006; Tierney and Faber-Langendoen 2007a,).

The standard operating procedures (SOPs, Appendix C) provide detailed instructions for the CUPN vegetation monitoring protocol. These SOPs include instructions on using the GPS, site selection and plot establishment, and specific instructions on all data collection. We plan on following all protocol instructions listed below and will clearly document any changes to protocols so that we can fully understand the impacts such changes might have to our final results and data analyses.

Plot Design Rationale

Although the monitoring protocol itself is an amalgam of a number of different protocols, the specific plot layout is a modified version of the Carolina Vegetation Survey (CVS) protocols (Lee et al. 2008). By using the CVS approach to plot layout, much of the data collected can be compared to data from other CVS projects in the region, USFS FIA Program plots, and plots associated with IM vegetation monitoring in the Northeastern U.S. This is because 1) the types

of data taken using CVS is similar to FIA and other IM project data and 2) the size of plots is roughly comparable in all three layouts.

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 (<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 (Cohen 2004, Brown 2003, Albanese 2007).

The USFS FIA Program has been monitoring 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. 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 and ongoing database that can be used to assess regional trends in forest resource capacity and health across the region and the country. FIA data are collected throughout the U.S., helping us better understand regional trends outside of the parks. However, the wide distribution of FIA points makes the data inappropriate for local analyses in each of the CUPN parks (most CUPN parks have only one or no FIA plots). We can use summarized FIA data to look at how CUPN park measures/metrics generally compare to regional forest plots.

Finally, we have developed this project with the understanding that it will be linked to a larger NPS effort to analyze vegetation dynamics throughout the Northeastern and Southeastern US. Our summarized data will be shared with Eastern Rivers and Mountains Network, Northeast Temperate Network, Mid-Atlantic Network, and the National Capital region to contribute to a greater understanding of regional and national vegetation trends.

Plot Design

Our team has completed a sampling scheme and plot design that is flexible enough to expand as needed to increase change detection for key measures and, once protocols for monitoring objective 2 have been developed, to examine particular habitat types more closely. CUPN plots will allow for measurement of a suite of key measures that will help us better understand and quantify changes that occur in vegetation communities. The plot design is based on a modified 20 m x 20 m (400 m²) plot similar to that used with the Carolina Vegetation Survey, FIA plots (673 m²), and ERMN plots (707 m²) (Figure 4). All measurements except soil samples and coarse woody debris (CWD) are taken completely within the 20 m x 20 m plot. Soil samples are taken on the outside edge of the plot and CWD samples run through the plots but also include data taken just outside of the plot. Tree seedling/sampling and overall species measurements are taken in four 10 m² modules within the 400 m² plot.

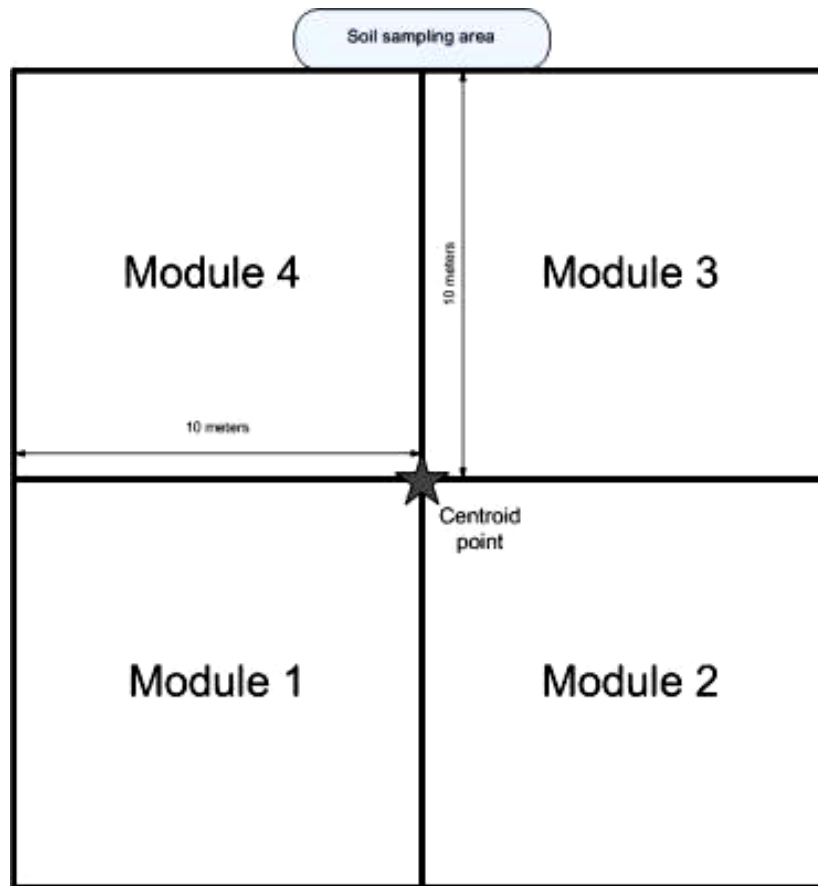


Figure 4. Basic layout of 20m by 20m standard vegetation monitoring plot

Data on coarse woody debris are collected using line intersect sampling (Van Wagner 1964) along two 40 meter transects that form an X through the plot. Total transect length in this protocol (80 m) is nearly equivalent to the total transect length for coarse woody debris used in the FIA plot design (88 m) (USFS 2007). The recommended length, number, and configuration of coarse woody debris transects has been debated in the literature, and is ultimately dependent on the amount of coarse woody debris present, the distribution of the debris, the logistical cost of sampling, and the desired precision of measurement (Pickford and Hazard 1978; Nemec and Davis 2002; Woodall and Monleon 2008).

Soil samples are taken just outside of the plot to ensure that areas within the 20 x 20 m plot are not heavily disturbed (which might affect other measures). These soil samples will be used to help understand soil chemistry baseline and change over time as well as changes in organic matter. The three (optional) soil samples are collected from sampling frames located adjacent to the plot's northern edge (Appendix C for details and more plot diagrams) and will be collected once every 8 years.

Details for Taking Measurements

Detailed instructions on data collection and definitions for all data fields are provided in the Standard Operating Procedures in Appendix C. The general types of data that will be collected are listed here:

- Site Selection/Establishment (SOP 3)
- Photopoints (SOP 4)
- Canopy Closure Measures (SOP 5)
- Tree Measurements (SOP 6)
- Herbaceous Plant and Seedling/Sapling Measurements (SOP 7)
- Coarse Woody Debris (SOP 8)
- U. S. National Vegetation Classification Measure (SOP 9)
- Soil Measurements (SOP 10)

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, as referenced.

Data and information are the basic products of scientific research (Michener and Brunt 2000). With this in mind, CUPN'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 the right data gets in the right hands, with appropriate context, so that informed decisions can be made.

Therefore, data handling procedures should be in place to ensure data are of an acceptable quality. It is important that data handling procedures not only be documented but also *implemented in a consistent manner*. To accomplish this, staff must be made aware of their assigned roles and resultant responsibilities and receive the tools and training necessary to accomplish those tasks throughout the project life cycle.

Preseason Preparation for Data Handling

Well in advance of the field season, the project leader should schedule a meeting with the data manager, GIS specialist and other relevant staff to communicate problems and suggested changes to procedures implemented 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 lay an important foundation in the realm of data quality control. Ensuring that those involved in data acquisition are properly equipped and adequately trained nullifies the need for 'alternative' modes of data collection and reduces the frequency of incorrect or incomplete data forms. Refer to **SOP 1: Field Season Preparation**, for additional details.

The GIS specialist and project lead should work together to ensure that target coordinates and data dictionaries are loaded into the GPS units prior to the onset of field work, 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 the Global Positioning System (Current document tailored to use of Garmin Map 76 or V).**

Data Acquisition and Processing

At least initially, vegetation monitoring data will be recorded in the field onto a series of customized paper field forms (Appendix D). Prior to leaving the field, the field crew leader will be responsible for reviewing datasheets for completeness and legibility. Upon returning from the field, all data entry forms will be copied, with the originals submitted to the CUPN data manager who will oversee data entry. Refer to **SOP 11: Data Quality Assurance and Quality Control** for additional details. GPS units will also be returned to the GIS specialist, who is responsible for stewardship of geospatial data.

A customized Microsoft Access relational database application, for storage and manipulation of project data, will be developed in fiscal year 2011 according to NPS I&M standards ([Summary of I&M Information Standards](#)). These standards include utilization of the Natural Resource Database Template (NRDT), which includes an established set of core tables and fields (NPS 2007). Input from other existing I&M Network databases will also be used in development of this application. The CUPN data manager will be responsible for development and maintenance of the application, including QA/QC, summarization and export routines. Refer to **SOP 12: Data Management** for additional details.

Data Archiving

Final data sets for vegetation monitoring will be archived by CUPN with all supporting documentation, including documentation of data files, data management procedures, hardcopy field forms, and quality assurance data. Multiple copies of datasets will be stored, and care will be taken that all copies are updated simultaneously when additional material is added. Datasets destined for archiving will be stored locally within an object-oriented file structure established on the CUPN file server. Incremental or differential tape backups of all project databases on the server are regularly conducted. Backup copies of the data are maintained in a secure alternate location. Currently, GIS files are maintained and archived separately by the CUPN GIS specialist.

Metadata Procedures

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

Recommendations for Routine Data Summaries and Analysis

Data from the CUPN Vegetation Monitoring Program will be analyzed in multiple ways:

- Summaries (every 2 years) on the ecological integrity of vegetation communities for each park,
- Analysis of changes (repeat measures) in key measures over time, typically summarized every four years,

-Evaluations of relationships between key stressors and key measures, including comparisons to regional datasets for a look at how NPS lands factor into the regional context.

Every two years, data will be analyzed to produce a brief summary of data collected from each CUPN park. These summaries will provide park managers and the Network with an updated set of data and in some cases current status information relevant to policy and management decisions. One example of how we might report out this data is in table 7 below.

Table 7. Example of a biannual ecological integrity scorecard for terrestrial forested ecosystem. Scores are for demonstration purposes)

Major Ecological Attribute	Metric	Score
Landscape Context & Size	Landscape connectivity	Good
	Landscape buffer	Caution
Structure	Stocking index or some measure of seedling composition vs. sapling composition vs. canopy composition	Significant Concern
	Coarse woody debris volume	Good
Vegetation Composition	Species richness or floristic quality index (FQI)	Good
	Invasive Exotic Plant Species “richness”	Caution
	High priority forest pest presence	Significant Concern
Function	Soil Profile Disturbance and soil acidity	Significant Concern
Ecological Integrity Assessment Rating	Average of all metrics	CAUTION

CUPN will also analyze temporal change for parameters listed in Table 8. These analyses will typically take place every four years, after the plots in each panel are revisited at least once. After two or more complete sampling cycles, analyses can be used to evaluate any 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 possible analytical tools include paired t-tests, repeated measures ANOVA, Kolmogorov-Smirnov two-sample test, and calculating instantaneous rate of change. To run all of these analyses, we will most likely be using the R statistical package due to its versatility and its use by other networks and IM programs.

Table 8. Quantitative measures that may be used as part of a detailed report every four years (subject to revision).

Type of metric	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 invasives.
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

CUPN 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 that these variables will help account for the relationship between certain response variables (such as tree growth or mortality rate).

Furthermore, CUPN is collaborating with other NPS IM Networks to determine appropriate regional analyses that can be conducted with the vegetation monitoring data from our networks. In the future, CUPN plans to work with other regional partners, such as the USFS FIA program, on regional data analyses. Contributing towards regional analyses will provide context for conditions and trends observed in CUPN parks and strengthen our understanding of regional trends.

Recommended Reporting Schedule and Format

Two types of reports will be produced for the CUPN Vegetation Monitoring Program. **Summary reports** will be produced every 2 years that provide information on the status of the vegetation at each park, focused primarily on terrestrial forested ecosystems since those habitat types make up more than 75% of acreage of most CUPN parks. Park superintendents and resource managers are the primary audience for the summary reports. These summaries will document the efforts of the Vegetation Monitoring Program and convey findings of the previous two field seasons, including “ecological integrity assessment” measures that show whether specific metrics are classified as “good”, “caution”, or “significant concern”. CUPN parks with additional plots designed to monitor distinct, key community types will receive additional reporting.

In addition to summary reports every two years, detailed **monitoring reports** in which data are analyzed for change and synthesized will be produced on a periodic basis, typically every four years. They will follow a format appropriate for a scientific journal and will contain in-depth analyses focused on the measures identified in table 8 above. These comprehensive reports will place the observed results in both a regional and historical context by relating them to published literature, discussing the significance of the results relative to changing environmental factors, and providing management recommendations based on these findings. The target audience will be park natural resource managers, CUPN staff, and other IM Networks. Outside of the park service, the target audience can include the state departments of natural resources, the USDA Forest Service, and the broader scientific community.

Personnel Requirements and Training

Roles of staff and contractors are summarized below:

Field Crew Leaders

For the first two years, the CUPN will fill the role of “field crew leaders/ecologists” through a cooperative agreement with NatureServe. NatureServe ecologists will assist with establishment of plots and will train CUPN ecologists in procedures outlined in the SOPs. There will be two teams covering the 14 parks, but only one “**project leader**”. The “**project leader**” is the one ecologist responsible for implementing the overall project, including organization of field crews, management of data collected, communication with data manager about data entry, and data analysis. The project leader has primary responsibility for ensuring that the fieldwork is successful at each park. For a timeline with specific duties for each role, see Appendix C, SOP 1. Specific tasks that the Project leader will be responsible for include:

- Train all field crew members at beginning of field season
- Coordinate all housing and transportation needs for field teams
- Ensure field crews collect field data accurately as detailed in the Standard Operating Procedures and summarized in Appendix A
- ensure field crew work meets the desired standards of quality
- Ensure field datasheets make it to the staff performing data entry and are entered in a timely manner.
- Once all data is entered, complete summary reports for each park. In years when analyses are possible, analyze data and complete monitoring reports for network.

In addition, all field crew leaders, including lead and non-project leaders, are responsible for the following:

- Collect all data in field accurately and as outlined in the SOPs
- identify all plants accurately and/or process unknown plants for later identification
- complete QAQC steps at end of each plot data collection event
- Supervise field team crew member(s) assigned to your team and ensure they are collecting data efficiently and correctly

Field Team Crew members

The field crew members will be responsible for data collection in the field. Crew members may be recent college graduates or students who have strong interest or experience in forest ecology

and/or natural resources, experienced field workers, or even very well trained volunteers from the area if they are willing to volunteer consistently for at least one week at a time. Crew members must be able to identify common trees and shrubs of the ecoregion in which they will be assigned (preferably knowledge of Piedmont and Southern Blue Ridge plants if they are working east of the Appalachians and knowledge of Southern Blue Ridge, Cumberland Plateau, Interior Low Plateau, and Upper East Gulf Coastal Plain plants if they are working west of the Appalachians). Where possible, the crew should have knowledge or expertise in all of the following areas: forest pests and pathogens; forest soils; and identification of herbaceous and graminoid plants. Specific tasks that the crew members will be responsible for include:

- complete mandatory training
- accompany field crew leaders each day and collect data on trees and environment of each plot accurately and according to SOPs laid out in this document
- complete timesheets and expense reimbursement forms accurately and in a timely manner
- ensure all necessary equipment is assembled, clean and functional prior to each trip
- on rainy days, assist in data entry of plot data

In most cases, a field crew leader will be the lead team member, supervising the work of the field crew members on that team.

Data Manager

The Data Manager will be responsible for maintaining the Vegetation Monitoring Database and will oversee database management. Data entry will be conducted at the main CUPN office after field sheets/electronic files are turned in by field teams. Along with the project leader, s/he will ensure that all individuals involved in the project are aware of their data management responsibilities. Specific tasks for which the data manager will be responsible include:

- create, update, and maintain the structure and functionality of the Vegetation Monitoring Database, including a standard client data entry tool.
- integrate data with other databases (e.g., NPSpecies, ICMS)
- provide database training and support as needed
- oversee data entry and data verification procedures
- coordinate data archival procedures

GIS Specialist

The GIS Specialist will be responsible for coordinating GPS data/equipment and maintaining all geospatial data related to the vegetation monitoring efforts as well as reporting out on remotely sensed metrics such as landscape context and size for each plot. Tasks include archiving of plot locations to be visited and those that have been thrown out, creation of maps for field crews and reports, and linkages to photos and vegetation monitoring databases. Geospatial data will be uploaded to the NPS Natural Resource Information Portal (NRInfo), as appropriate, and will be documented with appropriate Federal Geographic Data Committee and NPS metadata standards. Specific tasks for which the GIS Specialist will be responsible include:

- maintain the full list of all plots chosen using the original GRTS draw and any actions taken on each plot
- Develop and disseminate maps to field teams at each park prior to each park's fieldwork that include all points they need to visit and layers that will make it easy to navigate to those points (especially roads, trails (where available) and either drg or aerial photography

- Maintain geodatabase with information about all plot locations, updated yearly.

Program Manager

The Network Program Manager will be responsible for overseeing and coordinating the development and implementation of the Vegetation Monitoring Program and the other vital sign protocols. S/he will ensure that the Vegetation Monitoring Program is aligned with and contributing towards network goals. The Network Program Manager will also provide support in budget, personnel, and logistical matters. Other duties are spelled out in Appendix C, SOP 1.

Curatorial Specialist

Final hard-copy data sets and specimens resulting from vegetation monitoring will be processed by the curatorial specialist according to NPS guidelines. S/he will be responsible for processing specimens, entry into NPS Interior Collection Management System (ICMS) database, and generation of loan agreements (if needed). The curatorial specialist will work with parks to ensure records are uploaded into their master NPS-ICMS database and that specimens/archives are delivered to park-designated repositories.

Training Procedures

Prior to each field season, field crew leaders must ensure that all field personnel fully understand all standard operating procedures (Appendix C) by conducting training sessions. Training will occur in late April/early May and will last for at least one week (including initial plot data collection for one of the parks). Field crew training should involve careful review and discussion of all standard operating procedures, in addition to field sessions in which training plots are established and measured. Specific topics covered during training are detailed in the Field Season Preparation SOP (Appendix C, Field Season Preparation SOP).

Operational Requirements

Annual Workload and Field Schedule

Plot sampling will begin in late April/early May and extend through the end of September. All plot resampling should occur with 2 weeks (14 days) of the original plot sampling effort for that park. Data entry will occur throughout the summer as data is taken and at the end of the season once data collection is complete.

The fall and winter months are used for the last steps of QA/QC, data analysis, and report writing. In addition, each winter this document will be reviewed and updated to prepare for the next field season and to take into account any lessons learned from the previous field season and data analysis. Preparations for the upcoming field season will occur in late winter and early spring.

Facility and Equipment Needs

The logistical and equipment needs of the vegetation monitoring crew are detailed in the Field Season Preparation SOP (Appendix C). Ideally, the crew will stay in park housing while they

are conducting field work, although not all parks have available park housing. The Lead Ecologist should coordinate housing and transportation needs with park staff.

Startup Costs and Budget Considerations

This protocol was developed through a cooperative agreement with NatureServe which covers the first two years 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. Future costs associated with the vegetation monitoring protocol are detailed in Table 9. This estimate includes salary, travel costs, soils analysis, and supplies.

Table 9: Vegetation Monitoring Annual Budget Estimate

		%Budget	\$Amount	Estimate Basis
Salary	Field Leads	34.40%	66,000	1/3 salary of two GS-11/12 ecologists
	Field Interns	23.40%	45,000	two SCA's or interns plus hiring costs
	GIS/Data Mgt/ Analysis & Reporting	33.90%	65,000	1/3 budget rule estimate from IM program
Travel		6.30%	12,000	team of two with overnight travel (approx 10 weeks); some park trips will not require overnight lodging
Supplies		1.00%	2,000	After initial supply & equipment purchase, this is placeholder for replacement costs.
Soil Analysis		1.00%	2,000	Placeholder for soils analysis
	TOTAL	100.00%	192,000	

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Appendix A: Cumberland Piedmont Network Vegetation Associations

ASSOCIATION NAME	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
UPLAND FOREST CATEGORY																
Appalachian & Interior Mesophytic Forest Group																
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				

ASSOCIATION NAME	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Central Interior Beech - White Oak Forest	7881	4					X	X				X			X	
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 Group																
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												
Dry-Mesic Southern Appalachian White Oak - Hickory Forest	7231	1			X											

ASSOCIATION NAME	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
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 Group																
Interior Plateau Shingle Oak - Shumard Oak - Chinquapin Oak Forest	3876	2										X				X
Chinquapin Oak Unglaciaded Bluff Woodland	4267	1										X				
Ridge and Valley Limestone Oak -	4793	1					X									

ASSOCIATION NAME	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Hickory Forest																
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 & Central Conifer & Hardwood Plantation Group																
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													
Virginia Pine - Red-cedar Successional Forest	7121	1										X				
Successional Tuliptree Bottomland Forest	7184	1			Y											
Successional Black	7879	5			X		Y			Y		X	X			

ASSOCIATION NAME	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Walnut Forest																
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 & Central Atlantic Coastal Plain Oak Forest Group																
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			
Shortleaf Pine - Oak Forest Group																
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					

ASSOCIATION NAME	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
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 Group																
Highland Rim White Oak - Tuliptree Mesic Lower Slope Forest	7709	1			X											
South-Central Interior Oak Forest Group																
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	
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 -	7795	1										X				

ASSOCIATION NAME	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Hickory Forest																
Southeast Hardwood & Conifer Ruderal Forest Group																
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				
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	

	ASSOCIATION NAME	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
	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 Group [Placeholder]																	
	Wisteria Vineland	8568	2							X				X			
Virginia Pine & Table Mountain Pine Woodland & Barrens Group																	
	Blue Ridge Table Mountain Pine - Pitch Pine Woodland (Typic Type)	7097	2		X			X									
Wet Loblolly Pine & Hardwood Flatwoods Group																	
	Southern Red Oak Flatwoods Forest	4412	2										X			X	
RIPARIAN AND WETLAND FOREST CATEGORY																	
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 Group																	
	Pin Oak Mixed Hardwood Depression Forest	2432	1										X				
Central Seepage Swamp Group																	
	Piedmont Low- Elevation Headwater Seepage	4426	1								X						

ASSOCIATION NAME	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Swamp																
Appalachian Forested Acidic Seep	7443	2									X	Y				
Eastern Cottonwood - Black Willow Flooded & Swamp Group																
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 Group																
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					
Southern Interior Oak Bottomland Forest	8487	2			X								X			
Silver Maple - Green Ash - Sycamore Floodplain Group																
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	

ASSOCIATION NAME	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
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					
Rich Levee Mixed Hardwood Bottomland Forest	8429	4	X		X							X		X		
South-Central Coastal Plain Mesophytic Forest Group																
East Gulf Coastal Plain Beech Floodplain Forest	4745	1													X	
Southeastern Ruderal Flooded & Swamp Forest Group																
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					
RIPARIAN & WETLAND SHRUBLANDS [PLACEHOLDER]																
Bald-cypress - Tupelo Floodplain Forest Group																
Southern Buttonbush Pond	2191	1													X	
Central Depression Pond Group																
Buttonbush	4742	1										X				

ASSOCIATION NAME	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Sinkhole Pond Swamp																
Florida Rivershore & Freshwater Marsh Group																
Carolina Willow Shrubland	3899	1														X
Northern & Central Riverscour Wetland Group																
Alabama St. John's- wort - Alder Shrubland	8495	1									X					
Oak - Sweetgum Floodplain Forest Group																
Floodplain Canebrake	3836	3	Y			Y							Y			
River Birch - Sycamore - Willow Riverscour Scrub Group																
Rocky Bar and Shore (Alder - Yellowroot Type)	3895	1									X					
Black Willow Riverbank Shrubland	3901	1			Y											
South-Central Appalachian Seepage Fen Group																
Saturated Alder Thicket	3912	2					Y			Y						
OLD FIELDS AND SUCCESSIONAL SHRUBLANDS CATEGORY																
Southeast Hardwood & Conifer Ruderal Forest Group																
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	4732	7				X	X		X	X		X	X			X

ASSOCIATION NAME	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Shrubland Thicket																
GLADES AND BARRENS CATEGORY																
Eastern Interior Patch Prairie Group																
Kentucky Mesic Tallgrass Prairie	4677	1										Y				
Little Bluestem - Bluestem Grassland	7707	1										Y				
Northern & Central Acidic Glade Group																
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 & Central Alkaline Glade Group																
Limestone Cliff Fragrant Sumac Shrubland	4393	1					Y									
Southern Appalachian Rocky Outcrop Group																
Appalachian Low- Elevation Granitic Dome	7690	1		X												

	ASSOCIATION NAME	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
BOGS AND FENS CATEGORY																	
Northern & Central Conifer & Hardwood Acidic Swamp Group																	
	Swamp Forest-Bog Complex (Typic Type)	7565	1					X									
South-Central Appalachian Seepage Fen Group																	
	Southern Appalachian Low Mountain Seepage Bog	3914	1									X					
	Nodding Sedge Seepage Fen	7771	1					X									
CLIFFS AND TALUS CATEGORY																	
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				
OTHER CATEGORY																	
Atlantic & Gulf Coastal Plain Freshwater Tidal Marsh Group																	
	Southern Cattail Marsh	4150	2										Y	X			
Central Depression Pond Group																	
	Sinkhole Pond Marsh	2413	1										X				
	Common Rush Marsh	4112	1		X												

ASSOCIATION NAME	CEGL code	Total # of Parks	ABLI	CARL	CHCH	COWP	CUGA	FODO	GUCO	KIMO	LIRI	MACA	NISI	RUCA	SHIL	STRI
Southern Blue Ridge Beaver Pond Marsh	8433	1					Y									
Eastern North American Freshwater Aquatic Vegetation Group																
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 & Freshwater Marsh Group																
Piedmont/Mountain Semipermanent Impoundment (Montane Boggy Type)	4510	1			Y											
Northern & Central Riverscours Wetland Group																
Piedmont / Central Appalachian Riverbank Tall Herbaceous Vegetation	6480	1										Y				
Southeastern Ruderal Wet Meadow & Marsh Group																
Tennessee Valley Impoundment Mudflat	4049	1						X								
Southern Appalachian Grass & Shrub Bald Group																
Southern Appalachian Mountain Laurel Bald	3814	1					X									
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)																

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 2002).

Major Ecosystem Attributes

Our monitoring objective includes a goal to use attributes/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.

Weather and Climate

Weather/climate is a volatile key attribute that is increasingly influenced by the stressor of **climate change**. Weather/climate affects 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 (IPCC 2007, Leibfreid et al. 2005). 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 (see findings of MAPSS project at <http://www.fs.fed.us/pnw/mdr/mapss/about/findings.shtml>).

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 of the 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 CHCH, 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).

We will incorporate metrics produced from the CUPN'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. 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 Al and Mn 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/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 not only provides detailed information about wetland condition, structure, and function but also can be used as a corollary to better understand the ecological effects of changing weather patterns.

We hope to use data collected from the water quality/quantity monitoring effort and/or data from meteorological monitoring stations such as SCAN stations (<http://www.wcc.nrcs.usda.gov/scan/>) to understand any changes that may be occurring in hydroperiod and/or water quality over time. Although we aren't specifically targeting wetlands for our monitoring objective one work, in some parks with large wetland areas (like NISI) 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/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 is a serious threat to the parks' vegetation. Both invasive exotic plants and forest pests can actively kill or outcompete native species, thereby changing the structure, function, and/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 CUPN exotic invasive plant and forest pest early detection effort is a separate protocol 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 relative 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 and/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, making their prioritization a moving target. Thus, exotic invasive plants present difficult challenges to NPS resource managers. As mentioned above, a separate “early detection” protocol 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 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 / Deer Herbivory

Deer overpopulation has been documented throughout the regions that encompass CUPN (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 these expanded populations in some areas (Latham et al. 2005, Rooney 2001). 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.) (Masters 2002, Anderson 1994, Augustine and Frelich 1998, Ruhren and Handel 2003, Kirschbaum and Anacker 2005). Tree seedlings are particularly impacted by deer browse effects, leading to changes in overstory composition over time. Other effects of selective browsing by deer on forest ecosystems include reduced overall species richness, altered species composition towards 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. In this way, we hope to document whether woody species that are 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/challenges and their resource management actions can often affect vegetation communities. Some management activities (invasive exotic species removal, restoration/revitalization activities) may cost 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. In addition, we will document any negative visitor use impacts within any plots that we sample. These visitor impacts will also potentially affect plant species richness and other measures, so we will be able to look at 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-day 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” as a way 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 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 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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Appendix C: Standard Operating Procedures

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Overview of fieldwork and standard operating procedures for a typical plot

This section provides an overview of the chronology of plot sampling as a “checklist” to provide an easier way for field workers to see the progression of steps from beginning to end for each plot sampled. For a detailed discussion and explanation for any of the steps outlined here, please refer to the complete SOP for that step. If a step has a number and a letter, it means that the team of 2-3 field workers can split up and complete those steps or substeps simultaneously. This overview is merely a suggestion, so team members may choose to do the steps in a different order.

Note: TM1 is team member 1, usually the project leader. TM2 is the assistant field worker/team member. If there is a third or fourth team member, then the two team members with the lowest level of plant id knowledge should work on SOP3-6 while the one-two team members with the most plant knowledge should immediately skip to SOP 7.

SOP 3: Site Selection and Plot Establishment

- 1) **Navigate to selected plot (Any).**
- 2) **A) Mark center of plot with conduit, select and mark two tag trees, and record tag numbers, DBH on plot sheet (TM2)**
B) Stand at center of plot and record distance and compass bearing from tag tree to center of plot as well as GPS coordinates for plot. (TM1)
- 3) **Lay out plot tapes (All).**
- 4) **Mark the module outside corners as per Fig. 11 (pg 86) with seven pieces of conduit, and place flagging to help quickly locate them during data collection (All)**
- 5) **Fill out remainder of plot data sheet including GPS coordinate information. Draw plot layout on the datasheet and ensure that all other data is filled out for this section before moving on (TM1).**

SOP 4: Plot Photopoints

- 1) **A) Fill out dry board marker and hold up for camera (TM2)**
B) Take all photos and record data on images on data sheet (TM3 if available. Otherwise, TM1)

SOP 5: Canopy Closure Measures

- 1) **Take spherical densiometer measurements in center of four 10 m x 10 m modules and record values (TM2 or TM3)**

SOP 6: Tree Measurements

- 1) **Identify trees and measure dbh of all live and dead standing trees ≥ 10 cm throughout the 20 m x 20 m plot. This is done one (10 m x 10 m) module at a time (TM1 (but TM2 can do this if TM3 is recording data))**

- 2) Record tree species, dbh, location by module #, and all of the tree condition classes on data sheet (TM2 (or TM3 if available)) – for dead standing trees record decay class and snag height
- 3) Map on graph of plot the location of all trees > 20 cm dbh as they are encountered during the tree measurements (TM2 (or TM3 if available)).

SOP 7: Herbaceous Plant and Seedling/Sapling Measurements

***Note: TM1 can be responsible for this entire step, but can also get help from TM2 if there is a TM3 and TM4 available to work on SOP4-7.**

- 1) Layout first corner of subplots for module 1 at depth level 3 (1m x 1m) with meter sticks and record herbaceous species presence for this level. Next tally seedling in the 5-50 cm and 50-137 cm height classes and then tally saplings > 137 cm tall in their appropriate size classes (TM1. TM2 can record data for TM1 if TM3 and 4 are available and working on previous SOPs).
- 2) Layout the next subplot at depth level 2 (3.16 m x 3.16 m) and record any new herbaceous species and tally any new saplings and their size classes for this quadrat(TM1).
- 3) Repeat for the next corner within this module (TM1).
- 4) Examine remaining area of the module and record the presence of any additional herbaceous species and indicate a depth level of “1” (10 m x 10 m) (TM1).
- 5) Repeat these steps for remaining three modules of plot (TM1).

SOP 8: Coarse Woody Debris

- 1) Use the entire length of the two 40 m perpendicular tapes that establish the plot centroid to tally, measure and record the characteristics of coarse woody debris (pieces of decaying wood) that are ≥ 7.5 cm diameter, and ≥ 1.0 m in length (TM2)

SOP 9: U. S. National Vegetation Classification Measure

- 1) Using the U. S. National Vegetation Classification plant community (association) key for the park being sampled, and standing at plot center, carefully decide upon appropriate plant association that best represents the vegetation of the plot being sampled (TM1).
- 2) Record plant classification data and metadata (TM1)

SOP 10: Soil Measurements

- 1) The soil measurements SOP is repeated every 8 years, not at every plot revisit.
- 2) Measure out and mark with chaining pins, the location of the three soil sampling frames as per instructions and diagram in SOP 10 (Fig. 20, pg 132) and select sample areas within the three frames. Mark location of sample areas with an “X” on the datasheets and indicate sample year (TM2).
- 3) For each sample area measure litter depth and then follow remaining instructions and record data on soil characteristics and make collections of specified soil horizons (TM2).

- 4) Carefully review data sheet and make sure all soil data is carefully recorded (TM1).

SOP 11: Data Quality Assurance and Quality Control

- 1) For every plot completed, before the crew leaves the site, crew members must review all sections of the paper datasheets to ensure all fields are complete and no obvious errors exist. Each data sheet must be reviewed by someone other than the person who originally recorded the data on that sheet. Once it has been determined that the data sheet is complete, a crew member will sign his or her initials in the “DATA QC” box in the lower portion of each page. (TM1)

Standard Operating Procedure (SOP) # 1

SOP 1: Field Season Preparation

Version 0.0 (March 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
					1

Overview

This SOP describes preparations for the field season and includes a list of necessary equipment. Preparations should be completed by the start of training in late April/early May. Staff should review by March of each year and revise any sections based on lessons learned from the previous year.

Staffing

The vegetation monitoring protocol will be implemented by two teams (typically one field crew leader and one-two crew members per team, although teams can include up to 4 people) covering a total of 14 weeks during May-September each year. At least two team members should possess good identification skills for woody plants and have experience in forest sampling methods. At least one team member should be able to identify herbaceous and graminoid plants of the southeastern United States. Other desirable expertise includes knowledge of exotic plants, forest pests, ozone injury, pathogens, and soils. Implementation of the protocol will also require use of cameras, GPS units, compasses, and other field tools (see equipment list).

It is the Network Program Manager's responsibility to ensure qualified field staff are assigned/hired prior to May of each year. Student Conservation Associates (SCAs), university interns, and other cooperators will assist through various cooperative agreements available to the CUPN.

Communication & Coordination with Parks

A current NPS research permit is required for each park scheduled for vegetation monitoring. The permits should be completed in January of each year (if possible, permits should be requested for 2 years to cut down on the amount of paperwork from year to year). Some parks allow multi-year permits to cover long-term monitoring projects, while others require annual renewal. The status of vegetation monitoring research permits and applications for new permits is available at the NPS Research Permit and Reporting System website (<http://science.nature.nps.gov/research>). The Network Manager will ensure that each park has the current Vegetation Monitoring Protocol and a map of sampling locations so that any compliance issues can be addressed. All plot and tree marking procedures and any soil disturbance activities must be cleared with park managers prior to plot establishment. The network manager will also be responsible for year-end reporting to NPS for each active permit as required by the National Park Service.

In addition to permits, the key park contact at each park should be emailed two weeks prior to each trip as a reminder that vegetation crews will be out sampling. When possible, crews should stop by the Visitor Center or other park office for brief introductions and to meet any logistical needs such as picking up keys, hang tags etc. Park staff or interns may be interested and are encouraged to join crews for at least one plot to learn more about monitoring. Follow-up trip reports should be completed within two weeks of each return trip.

Schedule

Begin field crew training in the first full week of May as soon as all crew members are available. Training will last one week and will consist of formal training for the first day followed by work on real plots for the rest of the week (table 10). In future revisits of plots, revisits should be timed to be within 2 weeks of the original month and day so that resamples are taken at the same point in the growing season.

Table 10. First year's schedule for fieldwork (2011).

	Task/Location
Spring	
May (1st full week)	Training week and fieldwork at CHCH
May (2 nd week)	---
May (3 rd week)	LIRI
May (4 th week)	RUCA
May (5 th week / Memorial Day)	---
June (1 st full week)	GUCO
June (2 nd week)	SHIL
June (3 rd wk)	COWP
June (4 th wk)	KIMO
July (1st full wk / July 4 th)	---

	Task/Location
July (2nd wk)	STRI
July (3rd wk)	NISI
July (4th wk)	---
August (1st full wk)	CARL
August (2nd wk)	FODO
August (3rd wk)	---
August (4th wk)	CUGA
August (5 th wk)	---
September (1 st full wk/Labor Day)	---
September (2 nd wk)	MACA
September (3 rd wk)	ABLI

*LIRI/RUCA, COWP/KIMO, and MACA/ABLI may be combined for one 10 day work week rather than 2 separate weeks for more efficient work if that is preferable to those involved in the fieldwork.

Logistics

Once the year's schedule has been set, the team leads should reserve a CUPN vehicle or rental car for transport to and within parks. For most parks, plots can be accessed via a standard car and reasonable hiking, though in some cases transportation assistance may be needed. For example, at CUGA a few plots may require a four wheel drive vehicle, ATV, and/or an overnight camping trip. At MACA, boats along the Green River may be important to ensure efficient access to all plots. Resource managers at CUGA need to be notified well in advance to allow for assistance with these needs.

The network manager will attempt to reserve park lodging where available as soon as the field season is set each year. If no park lodging is available, nearby commercial lodging within government rates will be pursued by either the network manager or the team lead. Wherever possible, lodging should include kitchen facilities and high speed internet access.

Training

Training sessions will be provided at the beginning of each season and will involve a one-day class followed by field sessions using real plots and ending with actual field data collection for that park. Team members must read the entire protocol and all SOPs prior to training week, paying particular attention to their assigned activities. It may be useful to divide the training into discrete phases, so that a particular SOP or set of SOPs can be read, learned, and practiced.

Training will cover:

- Overview of protocol contents
- Review of vegetation communities and species of the CUPN region with special emphasis on understanding 7-8 letter species codes and nomenclatural standards;
- Review of "early detection" lists and identification of high priority forest pests and exotic plants;
- Field data entry etiquette
- Plot layout/installation and rules for rejecting/shifting pre-selected plot locations;

- Identification of specific tree conditions/diseases/foliage problems;
- Proper use of equipment for taking measurements, including GPS, compass/clinometer, measuring tape, dbh tape, spherical densiometer, digital camera, and NPS radio;
- Procedures for careful data collection and quality control;
- Procedures for yearly revisit of 5% of plots to be resampled for QAQC data quality
- Minimizing plot trampling;
- Field conduct (driving, parking, visitor/park contacts)
- Use of NPS vehicles;
- Labeling unknown plant specimens and sending away for identification;
- Job hazards and safety procedures

Training should include demonstration and practice of all measurement procedures. The critical importance of careful, accurate, and steady data collection to this long-term monitoring program must be emphasized. Trainers must stress the importance of exact adherence to SOP instructions to prevent bias in measurements among years. Lack of strict adherence to protocols will inhibit our ability to detect long-term trends. The field team leader should encourage trainees to discuss with their supervisors any concerns that arise over field procedures, the datasheets, or the database during training or later during the field season. The crew should never deviate from established protocols or alter the datasheet or database without first consulting with their supervisor. Any changes in procedures must be clearly documented in the SOP revision history, and the project database.

Training must emphasize the critical importance of careful plot behavior to minimize plot trampling. On steep slopes, in wetlands, or on plots with thick herbaceous or moss cover, all workers should place and unload packs outside the plot boundary, not within. Crew members should plan ahead and retrieve all gear for a particular set of measurements at one time, rather than taking extra trips across the plot. Crew members should minimize steps on the transects, especially in or near the eight nested subplots. Appendix C (SOPs) is organized chronologically to assist field crews in making sure that each step in the field methods is the most efficient and least likely to trample by bundling all data collection to be done in a particular part of the plot together.

Maps

Prior to each field season, prepare maps showing the year's sampling locations at each park. One map should show all plot locations and some alternate locations (in case some of the plot locations need to be thrown out). These plot locations should be overlaid on the USGS topographical maps, with roads, trails, and park boundaries included. A second map should show all plot locations overlaid on the most current aerial photography, with roads, trails, and park boundaries included. Line and point symbols for roads, streams, plots, and other features should be clearly visible but not large enough to obscure other features. Include a scale on all maps showing distances in meters or kilometers. We've found that overlaying a grid on the map with UTM coordinates in the outer margins helps a great deal in navigation. If the park is large enough, prepare a smaller park-wide location map inset to show where in the park the plot is located. Print all field maps on waterproof marine paper / Rite-In-Rain paper using a color LaserJet printer (inkjet printing does not adhere well to Rite-in-Rain paper). Finally, supply a

printed out spreadsheet with each point and X and Y coordinates in UTM NAD83, with UTM zone for each park, just in case those X/Y coordinates are needed.

Supply the crews with Gazetteer maps for North Carolina, South Carolina, Georgia, Tennessee, Alabama, and Kentucky. For Mammoth Cave, Cumberland Gap, and Little River, supply teams with the National Geographic foldable, water-resistant maps or other similar fine scale maps with trail information to help facilitate navigation.

In the first two years when we are establishing the plots for the first time, maps should be sent at least one month in advance of field work to key park staff and these staff should be asked if they see any problems with the location of any new plots that the team plans on establishing for that field season. If any plots are clearly centered directly on a large road, managed old field, building, pond, etc. they should immediately be thrown out and replaced by the next point not already assigned for sampling on the list of points (see discussion about this in main report for specifics on criteria for throwing out plots). However, if there is doubt as to whether the point is centered directly in one of these areas or not, then the point will be kept and field crews will decide whether to keep it or throw it out upon their first visit to the site.

Other Key Materials

- List of all vascular plant species in the park with their corresponding 7-8 letter code.
- List of all tree species in park.
- “Cheatsheet” with list of all plant species that have the same first 4 letters of genus and first three letters of species.
- Ecological community key for the park.
- Laminated sheets with tree status definitions, tree vigor definitions, tree dieback notes/pictures, decay class codes sheet, and sample diagram of a typical plot with information on which of the nested subplots get sampled.
- Information on forest pests and exotic plants.

GPS Setup

Using DNR Garmin or other similar software, upload plot coordinates into the CUPN GPS unit and/or handheld device (see the [Using the Global Positioning System SOP](#) and the link to the DNR Garmin website:

<http://www.dnr.state.mn.us/mis/gis/tools/arcview/extensions/DNRCGarmin/DNRCGarmin.html>).

Immediately after uploading the plot coordinates, it is critical to check the GPS map page to ensure that the plot locations are shown correctly and are in the correct projection. One easy way to check that the points loaded properly is to navigate manually to the park in the GPS’s map function and see if the points line up approximately with where they should be based on landmarks such as highways and towns. Although not perfect, this method will help field crews avoid gross projection errors that may place the plot locations in a different state or hemisphere.

Quality Control Points Preparation

Each year, 5% of the 112 plots, i.e., six plots, will be selected for repeat visits to ensure consistency in plot data collection across the network. Prior to the field season beginning, the GIS Specialist will choose 3 of the 14 parks and will then randomly choose two points in each of those three parks for a revisit. Some points that are particularly difficult to access may be

excluded from the points chosen, but otherwise this will be done randomly. Field crews measuring the plots will not be informed as to which parks or plots were chosen. Instead, a separate field crew will be asked to go back and resample some of the key measures within the plot within 2 weeks of the first team's sample. The list of resampled plots will be given to the Network Program Manager, so logistics can be arranged separately from the regular plot work and so that the field crew that measured the plot originally does not know that it is one of the quality control points. Once completed the duplicate plot results will be compared to initial results to identify any differences that are deemed significant. If any large differences occur, then actions may range from better training the following field season for the measure that showed the largest differences to "disqualification" of the data for those measurements in that year so that the data is not used in trend analyses.

Communication and Crew Oversight

The crew should carry a NPS radio when traveling in remote areas of parks at CUGA, LIRI, and MACA. In all other situations, carrying park radios will be optional. Radios should be programmed to the appropriate frequencies for each park. Crew members should know which frequencies to use, how to contact park radio dispatch, and be familiar with proper radio etiquette. In parks with cell phone coverage, crew members will be encouraged to carry a cell phone in the field for safety and to call their supervisor concerning protocol questions, although this is by no means required. It is essential for the crew to maintain regular contact with CUPN staff throughout the field season. Establish a regular weekly telephone call time between each team leader and supervisors to review the week's work. The update should cover questions or problems related to plots, protocol, logistics, and scheduling. The CUPN Program Manager and any other supervisors should try to join field teams at least twice during the field season to directly observe data collection procedures.

Contracts

If soil samples are taken in a particular year, CUPN will select an experienced forest soils chemistry laboratory, and have a purchase order or other contract in place for soil sample analysis. Several soil laboratories have sufficient capabilities and have capacity to quickly analyze samples, including the labs used by the Carolina Vegetation Survey (Brookside Labs in New Knoxville, Ohio). The Network Manager will make a final decision about the lab to be used to analyze samples during the summer of each year.

Review of Yearly Staff Roles

All timing and staff roles are presented in table 11.

Table 11: List of Tasks and Responsible Staff

Task	Staff	Timing
Finalize field schedule for crews	Project Leader	January
Reserve in-park housing for field crews for parks (where that opportunity exists)	Field Crew Leader	January
Establish and refine annual and seasonal budgets	Project Leader/ Program Manager	January
Acquire the appropriate permits	Field Crew Leader	February
Hire seasonal field crew if any are needed	Program Manager/ Project Leader	February
Prepare, repair, and/or purchase equipment	Field Crew Leader	March
Confirm with park managers the correct method for permanently marking plots (some parks may want to opt out of conduit)	Project Leader	March
Randomly select 3 parks and 2 plots in each of the 3 parks for QAQC	GIS Specialist	April
Identify who will be taking QAQC data for the year	Program Manager	April
Prepare database and datasheets for the field season (review species lists, add crew members names, etc.)	Project Leader / Data Manager	April
Compile training and field packet that includes maps of all points, coordinates of points, species lists, and datasheets.	Project Leader, Network Manager, Early Detection Leads, GIS Specialist	April
Arrange and conduct field crew training	Field Crew Leader	May
Coordinate directly with park resource managers when conducting field work in each park (call at least two weeks in advance to confirm field work dates).	Field Crew Leader	May – Sept
Identify plants accurately and/or process unknown plants for later identification	Field Crew Leader	Ongoing
Participate in field season and oversee field crew during field season, providing logistic and administrative support	Field Crew Leader	Ongoing
Ensure plot work meets quality standards	Field Crew Leader	Ongoing

Task	Staff	Timing
Ensure adequate numbers of plots are established and/or measured each season at each park	Field Crew Leader	Ongoing
Ensure effective communication between park staff, field crew, and other CUPN staff	Field Crew Leader	Ongoing
Enter all data into master database quickly after data is taken.	Data Manager/Intern	Ongoing
Review and revise monitoring protocol and standard operating procedures on a yearly basis	Project Leader	October-December
Conduct data verification on 10% of forms once data from hardcopy forms are entered into database (exact methods to be determined as part of database development)	Data Manager/Intern	November
Conduct data validation after records are entered into database	Project Leader	November
Assure datasets and specimens are processed according to NPS guidelines	Curatorial Specialist	November
Compare QAQC data to original data for the 5% of plots that were resampled this summer.	Project Leader	November
Data analysis and report writing	Project Leader	November-December
Submit summary reports to permit reporting system for each active permit	Field Crew Leader	December

Supplies & Equipment

Required equipment and supplies for vegetation monitoring are listed below. Equipment should be organized and maintained in good working condition. At the end of each season the crew leader will inventory the condition of all equipment and prepare a list of required repairs or replacements. Mark each piece of equipment with a piece of brightly colored flagging to assist with locating it on the forest floor during data collection. Order any new supplies required for work by February. Especially, plan for having enough 12” long pieces of aluminum conduit and other hard-to-get items.

CUPN Seasonal Vegetation Monitoring Supplies & Equipment Check List:

General:	Check
Map showing all primary plot locations, alternate locations, and any “target community” plot locations overlaid on the USGS topographical maps, with roads, trails, and park boundaries included	
A second map should show all plot locations overlaid on the most current aerial photography with roads	
Paper list of all plots to be visited with UTM coordinates.	
Park maps with roads and trails if available	
Road maps or state Gazetteers for park region	
Master binder containing Appendix C (SOPs), ecosystem keys, and maps listed above as well as any other important documents. This binder will be used both during training and during the field season.	
Park permits	
Rolls of brightly colored flagging	
Pencils (sharpened or with extra lead)	
Black industrial “Sharpie” markers	
Small dry-erase board or other system to be used in photographs (perhaps even just the back of a datasheet)	
Dry-erase markers (if using dry erase board)	
Daypacks (1 for each team member)	
First aid kit	
Insect repellant	
Poison ivy soap (Tech-nu brand is best)	
Water and food for each day in field	
Brightly colored field vests – optional	
Rain gear including rain coat and rain pants	
Metal detector (if any of the plots in the park were marked using “yard staples” instead of conduit)	
Plot Establishment:	
GPS unit and spare batteries for each unit	
Backup GPS unit in case primary GPS unit fails	
Compass with ability to also measure slope (clinometer) and aspect (2) and ability to set declination.	
100-m tape (1)	
50-m tape (3)	
Chaining pins (at least 7) – also called surveyor’s steel arrows	
“Yard staples” for use in areas where we can’t use conduit	
18” long aluminum conduit (7 per plot)	
Blue anodized numbered tree tags (2 per plot)	
Nails (2 per plot)	
Hammer	

Plot Measurement:	
Datasheets (on regular and Rite-in-Rain paper) – print out regardless of whether there is handheld data collection since you need these as backup	
Enclosed clipboard (1 per team member)	
Canopy “spherical densiometer” (concave model)	
DBH tape	
Meter sticks – at least 2	
Peterson’s Eastern Trees field guide or other woody species guide	
Preferred field guide to herbaceous species (optional)	
Park species list that includes a master list of 7-8 letter codes for each species	
List of all woody plant species in park.	
Early Detection List for Exotic Plants and Insects	
Compact, waterproof binoculars (8x)	
PVC Quadrat frame - 1 x 1 m	
10x hand lens (2) (OPTIONAL)	
Plastic bags for plant samples	
Wildflower identification guides (to be decided upon later)	
Sturdy trowel	
Sampling square for soil measurements	
Bunny soil knife or keyhole saw for soil measurements	
Clippers	
Sealable gallon-sized plastic bags for soil samples (3 per plot)	
Digital camera, extra batteries	
Charged AA rechargeable batteries (8)	
Spare 9V batteries	
In Field Office:	
Flora of the Northeast - Gleason & Cronquist	
Illustrated Guide to the Flora of the Northeast - Gleason & Cronquist	
Up-to-date Weakley 2010 (in binder or hardbound)	
Flora of Kentucky (for KY parks), and others.	
Full-size plant press	
Newspaper for pressing plant samples	
AA Battery recharger and rechargeable batteries	
Replacement reels for tapes (optional)	
Connector cables for GPS unit and digital camera	

References

Perles, S., J. Finley, and M. Marshall. 2010. Vegetation and soil monitoring protocol for the Eastern Rivers and Mountains Network, Version 2. Natural Resource Report NPS/ERMN/NRR-2010/183. National Park Service. Fort Collins, Colorado.

Standard Operating Procedure (SOP) # 2

SOP 2: Using the Global Positioning System (Current instructions tailored to use of Garmin Map 76)

Version (January 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

Overview

This SOP describes the proper use of the CUPN Garmin GPS units. This methodology will continue to evolve as new GPS units are introduced for use by NPS personnel. Note: This SOP is meant as a tutorial for using whatever GPS unit is used by the teams in that particular field season. Specific GPS unit tasks are also outlined in SOP 3: Site Selection and Plot Establishment. The main functions provided by the GPS receiver are to provide a navigation tool whereby predetermined sample points can be uploaded, then used to navigate to the selected plot locations and finally collect field waypoints to document the actual point where the plot was established.

Step by Step Instructions

Install two fully charged rechargeable AA batteries in the back of the unit. Always carry two additional fully charged batteries as back up. Recharge batteries as necessary. Turn on the GPS by depressing the power button (red on Map 76) for 2 seconds. Check SETUP options by pressing the menu button twice, then scroll down to the SETUP selection and press ENTER. Scroll through the sub-menus (using the Rocker keypad or touch screen for newer units) to following menus and ensure that the following settings are in place:

System: GPS = Battery Saver
 WAAS / EGNOS = Enabled

Units: Position Format = UTM UPS
 Map Datum = NAD 83
 Distance / Speed = Metric
 Elevation = Metric

Heading: Display = Degrees
 North Reference = True

Set other settings as desired by user. These settings will be saved on the GPS unit. It should not be necessary to re-enter them each time the unit is turned on.

To turn off the Garmin GPS unit, press and hold the small red power button near the antenna for 2 seconds.

Uploading Plot Locations

GPS coordinates for pre-selected plot centers should be loaded into the unit before field sampling. The datum for all coordinate values is NAD 83. The coordinate system is Universal Transverse Mercator (UTM). The zone is 17 for CARL, COWP, CUGA, GUCO, KIMO, and NISI. The zone is 16 for ABLI, CHCH, FODO, LIRI, MACA, RUCA, SHIL, and STRI.

Use the Minnesota DNR Garmin extension in Arcview 3.x or ArcGIS 9.x to upload plot locations from the shapefile to the GPS unit. Immediately after uploading the plot coordinates, it is critical to check the GPS map page to ensure that the plot locations are shown correctly on the GPS, thus ensuring that the coordinates were uploaded in the correct projection.

Navigating using the Garmin GPS Map 76

With the receiver on and locked into enough satellites to have 3D navigation, push the “Find” button. Select “Waypoints”

Choose “Nearest” if you are in the vicinity of the waypoint or “Find by Name” if you need to locate a particular point.

Select your waypoint, then “Enter”

Choose “Goto” (highlighted), then “Enter”

Use the screen with the compass arrow to read and manually set your compass bearing (the Garmin 76 does not have a built in compass, so do not think that the compass arrow is pointing the actual direction you need to go. Use it to set your compass bearing)

Page – use the map page to be sure you are going the right way to get to your waypoint

Page – when you get close to your point, use screen with compass arrow to get closer to your point. Navigate as close to your point as time will allow, it is generally not necessary to try to navigate closer than 2-3 m from the selected point, be primarily concerned with getting consistent location information.

NOTE: Unlike a compass, if you stop and turn to face a different direction, the GPS will not reposition until you move again. Also, the arrow that represents your position on the Map page is not necessarily pointing in the direction that you are moving. A compass should be used to determine the correct direction, and care must be taken to hold the compass sufficiently far from the GPS unit to avoid influencing the compass needle.

Recording a New Location

When you are satisfied with your location, depress the “Enter” button for more than two seconds. You will see the Mark Waypoint screen. A default three-digit name and symbol for the waypoint will appear at the top of the screen.

Toggle up to the Waypoint Name, when highlighted press “Enter”

Use the onscreen keypad to enter name of new waypoint, (i.e. CUGA###)², then hit “OK”, Back at the Mark Waypoint screen, toggle to the bottom left and highlight “Avg” then hit “Enter”. You will then see an screen that shows the averaging of the waypoints data including a measurement count (bottom of screen).

When you reach >100, Hit “Enter”, then record the x and y UTM values, the UTM zone and estimated accuracy (ideally less than 10 m if possible) on field form.

Ensure that the plot is named correctly, then scroll down to “OK”, and press “Enter”

Also press “Page” to get to the Satellite page that shows the bar graph for your satellites. There is a bar shown for each satellite you are getting a signal from. Record the number of satellites (if you are receiving a WAAS signal, there will be a “D” on the bottom of one or more bars)

Delete a nearby Waypoint

With the unit on, depress the “Find” button, then select “Waypoints” Scroll to desired waypoint, highlight it and hit “Enter”

At the bottom of the page, toggle to “Delete”, press “Enter” and then select “Yes”

Delete all Waypoints

Only do this if all the new Waypoints have been downloaded and saved, and you need to upload new data. Preferably this task will be performed by the data manager or GIS Specialist.

With receiver on depress “Find”, then select “Waypoints”, then, press “Menu”, select “Delete” then choose “All”, Press “Enter”, select “Yes”, press “Enter”

Downloading Recorded Location to ArcGIS

Each week, use the Minnesota DNR Garmin extension in Arcview 3.x or ArcGIS 9.x to download the recorded field plot locations from the GPS unit to a shapefile. Save this shapefile

² Note that the naming convention when recording new waypoints is the first 2 letters of the park acronym plus the plot number (for instance CU0005 for plot #5 at Cumberland Gap NHS).

using the following nomenclature: <four letter park code>+<plots>+<YYYY-MM-DD>.shp.
One example would be “CUPNplots-2011-06-11.shp”)

Suggested Reading

Garmin GPSMAP 76 Owner’s Manual

Garmin GPSMAP 76 Quick Start Guide

Equipment List

GPS (Garmin Map 76 or Juno Trimble preferred)

References

Garmin GPSMAP 76 Owner’s Manual

Garmin GPSMAP 76 Quick Start Guide

Perles, S., J. Finley, and M. Marshall. 2010. Vegetation and soil monitoring protocol for the Eastern Rivers and Mountains Network, Version 2. Natural Resource Report NPS/ERMN/NRR-2010/183. National Park Service. Fort Collins, Colorado.

Standard Operating Procedure (SOP) # 3

SOP 3: Site Selection and Plot Establishment

Version 0.0 (March 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

Time allotted: about 60 minutes

Overview

This SOP provides instruction for establishing plots and collecting site information. Prior to the field season, the team leader should use the list of all generalized random tessellation stratified (GRTS) selected plot locations and numbers to determine which plots will be visited in this field season in each park. For parks with extra resources to sample additional plots, this is the time to also identify those plots and determine the order in which they will be visited and by whom.

Since plot marking procedures may vary by park, the field crew members should have specific instructions on how to permanently mark each plot for each park. These plot marking procedures will have been approved by the natural resource and cultural resource manager at each park prior to plot establishment. These procedures may vary by park in response to individual park requirements.

Definitions

Horizontal distance is the level, straight line distance between two points. This contrasts with slope distance which is measured parallel to the ground surface. Slope distance and horizontal distance are equivalent on flat land. On sloped land, the horizontal distance between two objects is less than the slope distance.

True north is the direction of the North Pole, from your position. This contrasts with magnetic north—the direction a compass needle points when in the northern hemisphere.

Magnetic north varies across North America with location and over time. To locate true north, it is necessary to adjust a compass to account for the declination, which is the difference between true north and magnetic north using a magnetic declination chart or table (e.g., <http://www.ngdc.noaa.gov/geomagmodels/Declination.jsp>). Adjust your compass by dialing the declination into the faceplate to the nearest degree. Set the compasses of all field crew members for the same declination. For 2010, the declination for CUPN parks are found in table 12.

Table 12. Declinations for 2011 for each park.

Park	Declination as of July 1, 2010	Compass Adjustment for Summer 2010
ABLI	4° 11' West	4° West
CARL	6° 17' West	6° West
CHCH	4° 8' West	4° West
COWP	6° 40' West	7° West
CUGA	5° 37' West	6° West
FODO	2° 28' West	2° West
GUCO	8° 17' West	8° West
KIMO	6° 57' West	7° West
LIRI	3° 46' West	4° West
MACA	3° 51' West	4° West
NISI	6° 24' West	6° West
RUCA	3° 50' West	4° West
SHIL	1° 55' West	2° West
STRI	3° 27' West	3° West

NOTE: As an example, in 2011 when we visit GUCO to collect plot data, we will want to adjust the declination on the compass to correct for the 8 degree difference. Most compasses have a setting ring on the bottom of the compass that allows for this correction. Simply turn the main compass ring so that the index pin is over 352 degrees (8 degrees to the west of north is 352 degrees). Once this setting has been changed, it will not need to be changed until moving to a new park with a different declination. Particular care needs to be taken to adjust the declination in the correct direction, as 4 degrees West could be thought of as magnetic north is west of true, or true is west of magnetic by this amount.

Step by Step Instructions

Step 1: At beginning of the field day, determine which two points the team will visit that day based on the relative accessibility of the first point to the second so that at least two points can be completed by day's end.

Step 2: Turn on GPS enabled device (either GPS unit or handheld unit with GPS capabilities) and navigate to the point (see "Using the Global Positioning System" SOP above). Once the field teams have navigated to the location of the plot using GPS, they will be at the center of the plot as well as at the "centroid" of the grid cell that was chosen using GRTS.

Step 3a. If this is a new plot that has not yet been established, then follow these directions.

Sampling points have been selected using GRTS so that each of the points visited is the “centroid” of one of the park’s 40 m x 40 m grid cells. Once confident that the team is within 10 meters of the actual mapped GPS point that was generated for this project (GPS reading should be within ten meters of target point location). If the location cannot be located within 10 meters due to poor GPS coverage, then move around to see if GPS coverage changes. If this still does not work, then note that this is an issue and continue setting up the plot in the approximate location. The field team should next establish the “centroid point” of the 40 m x 40 m grid cell. Then the team should start filling out the data sheet as they continue to set out the point, including filling in driving and walking directions to the plot centroid point. Record GPS data in your GPS unit or handheld by taking a waypoint:

Note: If the area around the plot or access to the plot represents a safety hazard (slope more than 30 degrees (58% of slope), slippery waterfall, etc.), discard the plot and record the reason. Refer to the next “alternate” plot number on the list of plots and proceed to that plot instead. Repeat Step 1 when you arrive at that new plot.

Note: If the plot to be laid out will fall **partially into a “restricted” category as outlined on page 11 of the main report**, then the teams may try to either move the plot or reduce the size of the plot to ensure that it is primarily in forest. Restricted categories include paved roads, ungated public dirt roads, rights of way/shoulders/fields obviously mowed more than twice a year, buildings and rooftops, parking lots (paved or unpaved), steep ravines or cliffs, ponds, lakes, and large creeks or rivers. If more than $\frac{1}{4}$ of the plot’s total area is considered a restricted category or if ANY of the plot occurs outside of the park boundary, then there is an option to shift the plot by 10 meters. Choose the most obvious direction that will allow for plot placement. If the new center now allows you to place the plot with less than $\frac{1}{4}$ of the area in a restricted category, then do so. If a corner of the plot hits a restricted category, then you may still include that corner as long as the restricted category does not take up more than $\frac{1}{4}$ of the total plot. Do NOT, however, place conduit or other types of permanent markers in any of these restricted areas. If the plot center and adjacent area are safely accessed and do not fall into a “restricted” category, then go to step 2.

If the plot cannot be moved successfully, but the plot can be reduced to either a 20x10 m plot or a 10 x 10m plot and sampled successfully, then reduce the plot size (see figure 5). If not, then throw out the plot and replace it with a plot from the list of “extra” plots on the alternate plots list that were generated for this purpose.

If plot was thrown out because there was no suitable area to sample, then still fill out the appropriate blanks on the first page of the plot sheet so we can document why the plot was not sampled.

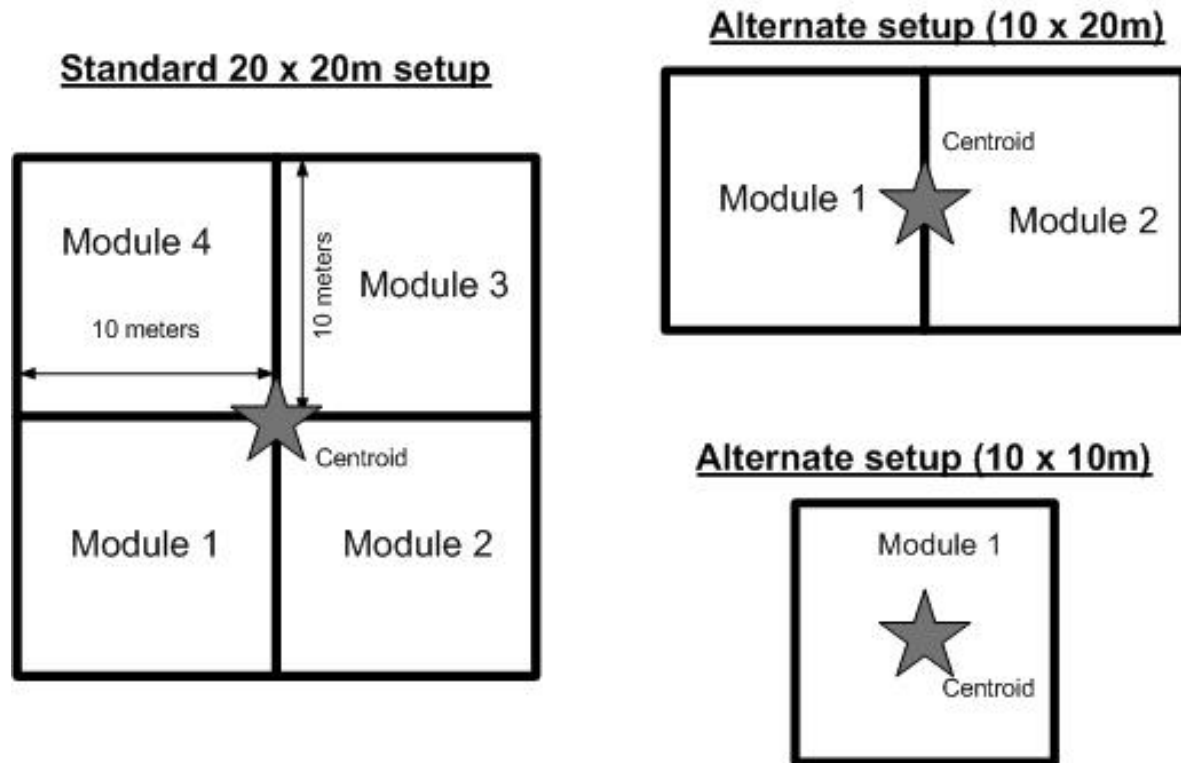


Figure 5. Different plot options for setup of plot in difficult circumstances.

-If the plot conduit cannot be placed anywhere in the plot because the site is heavily managed or mowed, it is a sensitive archaeological site, or there isn't substrate to allow the conduit to stay in place, then consider using the "yard staples" (Figure 7, 8). Yard staples are much thinner than conduit and therefore will not damage lawn equipment if they work their way out of the soil. They are also less likely to alter an archaeological site under the soil. We suggest that fieldworkers tie a piece of brightly colored flagging to the top of each yard staple to make it easier to find upon revisit. These yard staples can be refound using small metal detectors in future years, pending approval from the park to allow use of a metal detector to find these materials. If yard staples are not helpful in this situation, then take very careful measurements from tag trees to centroid point so that refinding the plot will be as easy as possible. If neither yard staples nor conduit can be used (such as on scour bars or other high energy environments near streams), then find an area outside of the plot that is suitable for conduit placement and tag tree placement and give detailed directions from the conduit outside of the plot to the actual centroid of the plot.

If using a Garmin Map 76, Hit **Menu**, then **Menu**, then select **Mark**

You will see the **Mark Waypoint** screen

Toggle up to the **Waypoint Name**, when highlighted press **Enter**

Use toggle to enter name of new waypoint, (i.e. **CUGA###**)³, then hit **OK**, then **Enter**

Back at the **Mark Waypoint** screen, hit **Menu**, then **Enter** (Average Location)

Points will be averaged (measurement count)

³ Note that the naming convention when recording new waypoints is the first 4 letters of the park acronym plus the plot number (for instance CUGA0005 for plot #5 at Cumberland Gap NHS).

When you reach >100, record the 2 UTM values and accuracy on field form and SAVE. Ensure that the plot is named correctly, then scroll down to OK, and press Enter. Also press **Page** to get to the screen that shows the graphics for your satellites. There is a bar shown for each satellite you are receiving. Record the number of satellites that provided the position (if you are receiving a WAAS signal, there will be a “D” on the bottom of one or more bars). WAAS is a system of satellites and ground stations that provide GPS signal corrections, giving you a much better position accuracy.

Next, complete the plot establishment portion of the datasheet. Mark the location with a piece of conduit hammered into the ground so that only approximately 4 inches of the conduit shows above the ground layer (see alternate plot marking step above if your plot is in an area that is mowed or managed or if the conduit is not appropriate for the site (archaeological site, stream bed, etc.). Then find two “tag” trees that are fairly large and distinctive and ideally within 5 meters of the centroid point. Mark each tag tree at 1.37 m from the ground (DBH) with an anodized, numbered tag so that it will be easy to find in future years. Record the compass direction from the tree tag to the conduit, the number of the tag, and distance from tag tree to conduit on the datasheet, in addition to the color of the tag, the tag number, and tree species for all tag trees. This process will make the centroid point much easier to find in future years. Tags should be affixed using a hammer and nail with the angle of the nail head lower than the point at which it goes into the tree so that the tag slides down the nail as the tree grows. The tags should generally either face the direction in which the field teams are most likely to come back to the plot in the future or upslope. One exception to this rule is when the trees are very close to a trail. In this case, tags should be on the opposite side of the tree from the trail, especially if the tree is within 5 meters of the trail, to avoid drawing the casual visitor’s eye to it. Also, avoid placing conduit less than 5 meters from any well traveled trail if the conduit would be visible easily from the trail.

Once you have established the centroid point and tag tree, take a few minutes to look around the vicinity of the plot.

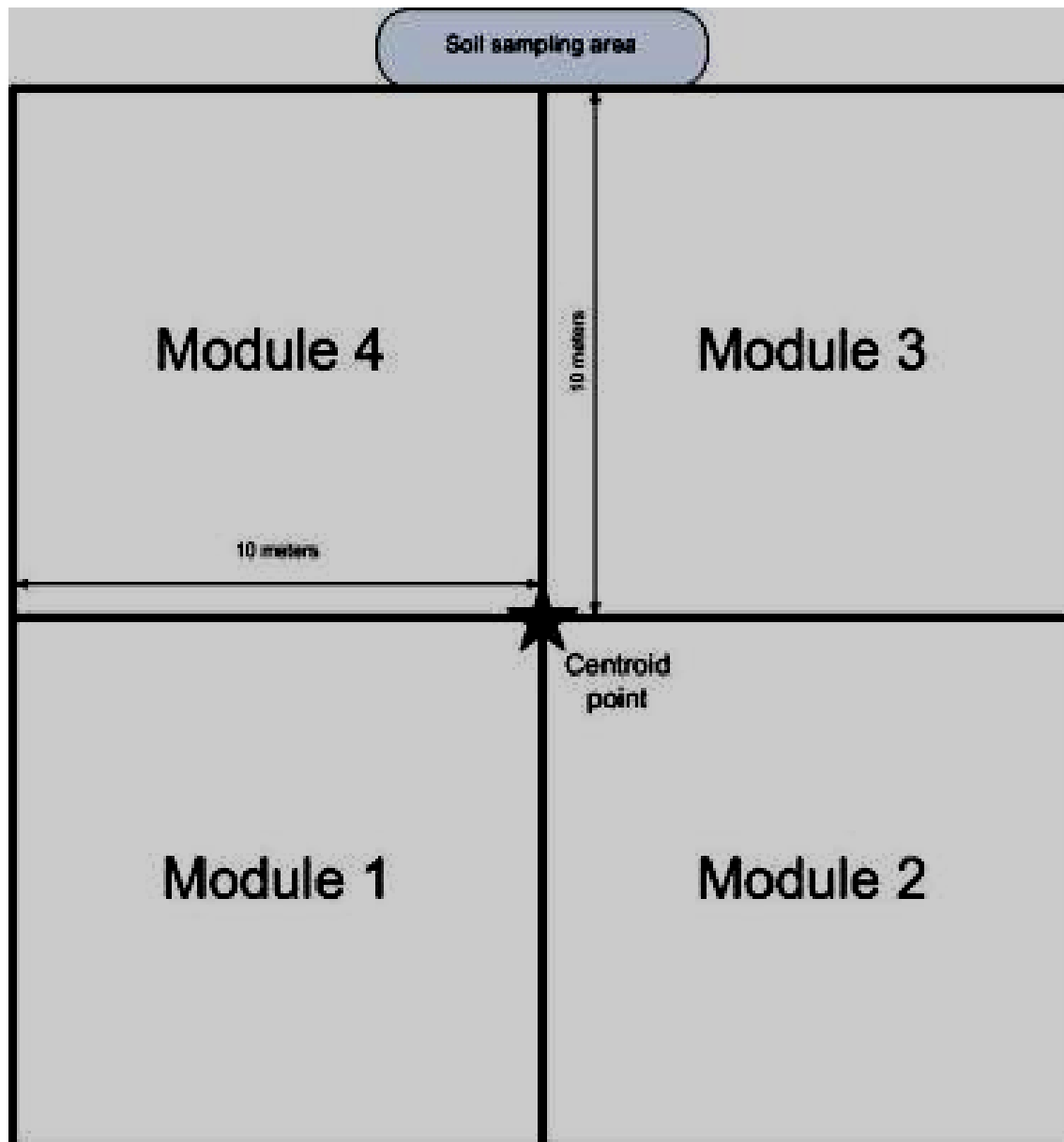


Figure 6. Diagram of 20 x 20 m plot

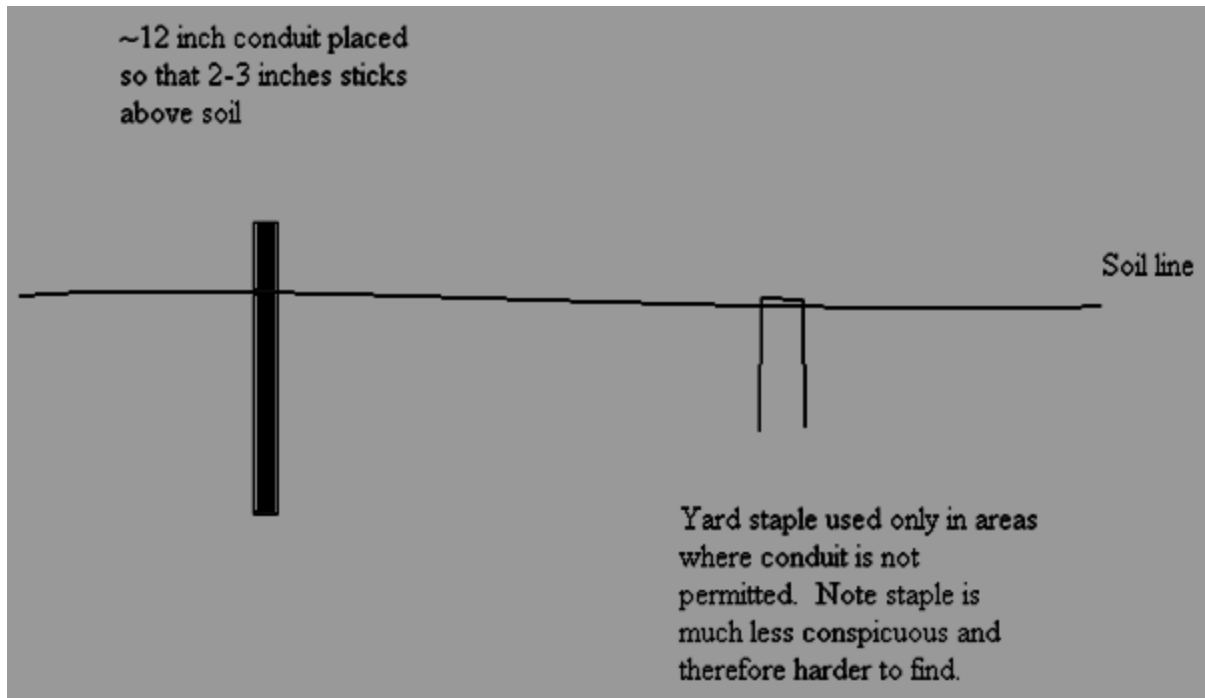


Figure 5. Comparison of profile for conduit vs. yard staple



Figure 6. Yard staples can be used as alternatives to conduit.

Step 3b. If this is a revisit of an already established plot, then follow these directions. Using GPS, navigate back to the plot. Refer to original data sheet to determine the tag tree's size, species, and which direction the tag is facing and look for the tag tree. Once located, find the conduit and go to step 4c. If any conduit or tags are missing, use spare conduit or tags to replace them and mark any replacement information on the data sheet.

Table 13. Example of GRTS generated points for MACA.

*Data projected in NAD 1983 UTM Zone 16N.

Park ID	Original X Coordinates*	Original Y Coordinates*	GRTS Assigned Weights
MACA-00001	583560.9945	4123708.8203	2028.7813
MACA-00002	580240.9945	4117028.8203	2028.7813
MACA-00003	576040.9945	4112748.8203	2028.7813
MACA-00004	568440.9945	4116828.8203	2028.7813
MACA-00005	584480.9945	4119428.8203	2028.7813
MACA-00006	583240.9945	4117788.8203	2028.7813
MACA-00007	575680.9945	4116708.8203	2028.7813
MACA-00008	576120.9945	4120748.8203	2028.7813
MACA-00009	581960.9945	4112748.8203	2028.7813
MACA-00010	580960.9945	4119508.8203	2028.7813
MACA-00011	571320.9945	4120668.8203	2028.7813
MACA-00012	573440.9945	4122148.8203	2028.7813
MACA-00013	579840.9945	4114068.8203	2028.7813
MACA-00014	575120.9945	4112228.8203	2028.7813
MACA-00015	567600.9945	4120948.8203	2028.7813
MACA-00016	580760.9945	4109708.8203	2028.7813
MACA-00017	585360.9945	4124548.8203	2028.7813
MACA-00018	578880.9945	4120788.8203	2028.7813
MACA-00019	575600.9945	4113588.8203	2028.7813
MACA-00020	572520.9945	4119228.8203	2028.7813
MACA-00021	584520.9945	4122268.8203	2028.7813
MACA-00022	581240.9945	4117868.8203	2028.7813
MACA-00023	577680.9945	4114788.8203	2028.7813
MACA-00024	576720.9945	4120148.8203	2028.7813
MACA-00025	581600.9945	4115668.8203	2028.7813
MACA-00026	576760.9945	4111708.8203	2028.7813
MACA-00027	569720.9945	4121068.8203	2028.7813
MACA-00028	575200.9945	4121748.8203	2028.7813
MACA-00029	579880.9945	4112108.8203	2028.7813
MACA-00030	574040.9945	4113948.8203	2028.7813
MACA-00031	569040.9945	4121188.8203	2028.7813
MACA-00032	580240.9945	4111748.8203	2028.7813

Step 4a. If this is a new plot and it is of standard 20 m x 20 m size, then begin laying out the plot. Starting at the centroid point, attach center tape (ideally the 50 m tape) to a chaining pin and roll out center tape in to the east and west (20 meters in each direction for a standard plot, less if the plot size was reduced). If any large trees are directly in the way of your centerline, then simply continue around the tree as best as possible and pick up with your direction as best

as possible on the other side of the tree. Tape layout is best done with two people, one standing at the centroid point and holding the tape end while the other team member rolls out the tape in the direction of the compass bearing (azimuth) of the plot. The team member standing at the centroid can help ensure the tape is laid out in as straight a line as possible. Once the team member has rolled the tape out 20 meters, s/he can signal to the person at the centroid point to start pulling the tape out in the opposite direction. The second team member then helps the first person (at the centroid point) to lay out the other 20 meters of tape in as straight a line as possible so that the 40 m long baseline tape is arranged with the 20 m mark at the center of the conduit. This centerline will serve as the central axis for the 20 m by 20 m plot but will also serve as a sampling transect for snags and coarse woody debris (CWD). Once finished with this layout, a second tape is run so that it passes directly through the centroid point perpendicular to the centerline tape already measured out (north to south). This tape should also be laid out 20 meters to each side of the centerline for a total of 30 meters and this will serve as the second coarse woody debris (CWD) transect (Figure 9).

*Note: If the plot was reduced below the original 20m x 20m size to either a 10m x 10m or a 10m x 20 m, then you may reduce the CWD transects in any direction in which the transect would cross over a land use category that we do not wish to sample (road, building, mowed lawn, etc.).

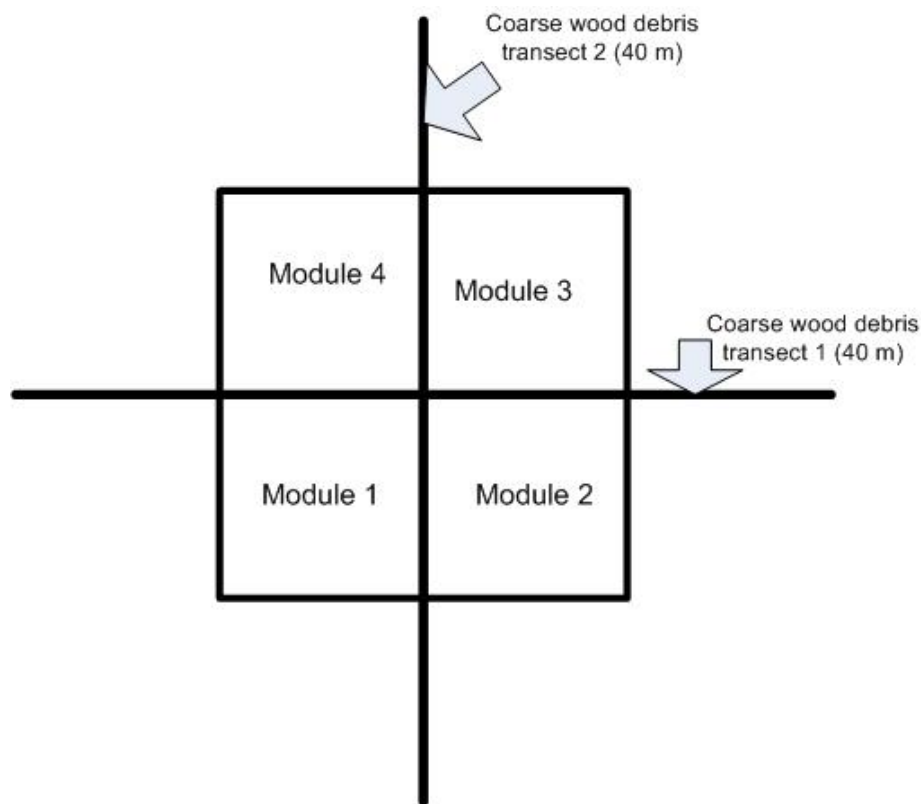


Figure 7. Location of coarse woody debris sampling transects in relation to 20 m x 20 m plot.

Now we are ready to layout the rest of the intensive 20 m x 20 m vegetation plot. The center of this plot is where the two CWD transects cross one another (which you just laid out at the beginning of this step). Now, establish the edges and outer corners of the block of four intensive

modules with perpendicular tapes. Refer to figure 10 below and begin on step 5 to finish laying out the plot.

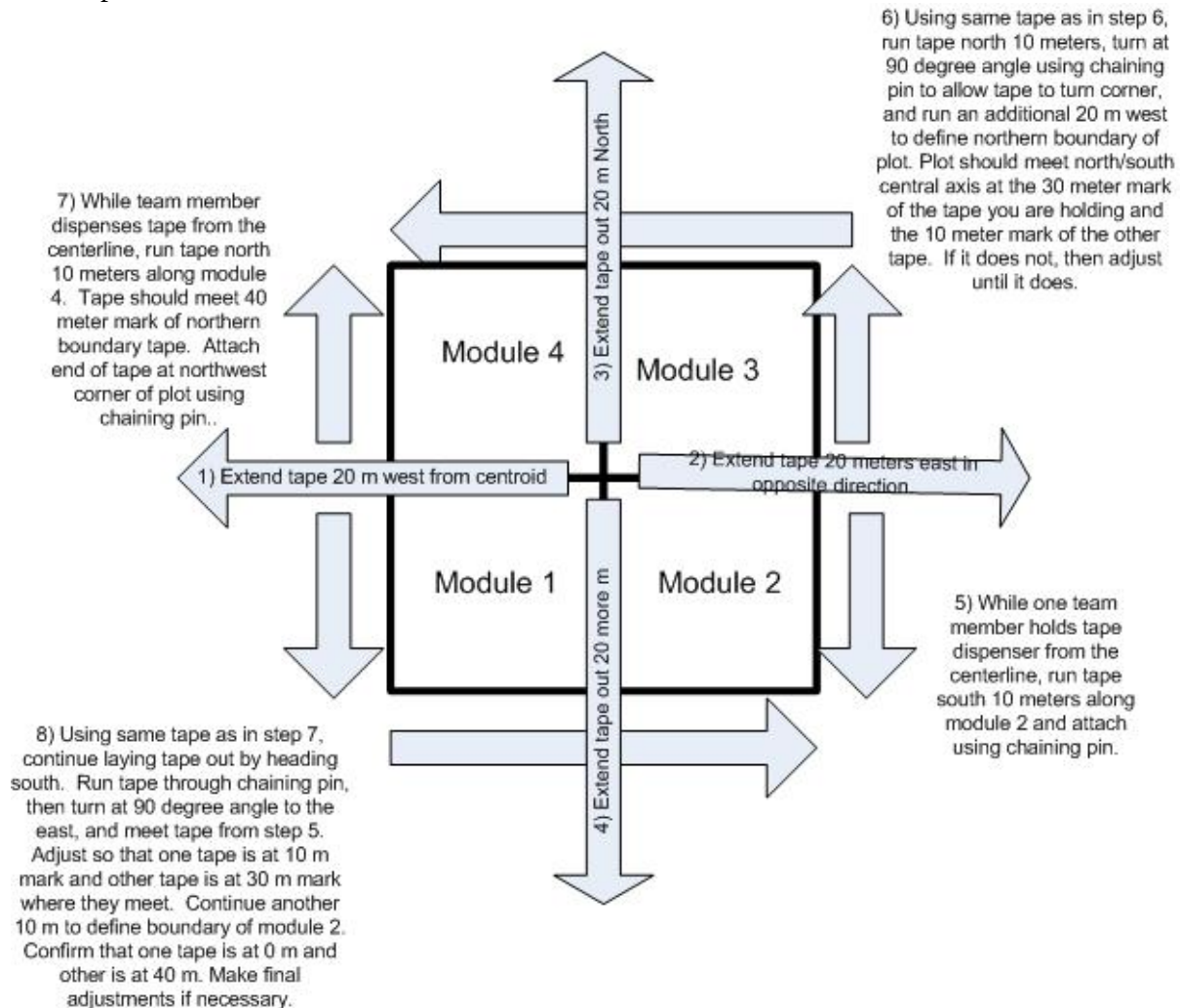


Figure 8. Detailed instructions for laying out 20 m x 20 m plot and CWD transects at same time.

Axes always run north-south and east-west. To be most efficient, use two of the 50 m tapes. Start at the 30 meter mark of the centerline (the eastern edge of the plot) and have one person grab the end of the tape and run it out 10 meters perpendicular and south of the centerline tape. Secure that end of the tape with a chaining pin. Then walk the tape out in the opposite direction 10 more meters (towards the north) and put down another chaining pin. At this point, you've just defined one side of modules 2 and 3 (Figure 10). Turn 90 degrees (to the west) and, while wrapping the tape around the chaining pin, continue walking parallel to the north/south centerline tape. Your tape should have met the north/south centerline tape at its 20 meter mark. Continue past this tape another 10 meters to define the entire northern boundary of the plot and put the end of the tape down, securing it so it doesn't move during plotwork. Congratulations, you just laid out the eastern and northern boundaries of the plot! Then walk down to the 10 m mark of the east/west centerline and repeat the last paragraph of steps to define the southern and western boundaries of the plot, except in the opposite direction. At this point you should have the 20 m x 20 m plot completely laid out. If the tapes you have laid out don't match each other

(one tape meets the other at 43 m instead of 40 m for instance) this indicates that the plot was not established correctly. Adjust the tapes so that each module is exactly 10 m x 10 m.

Once the full plot has been established using tapes, field team members will then use the supplied set of 7 pieces of 30 cm long metal conduit tubing posts to mark the 10 m, 20 m, and 30 m mark along the centerline as well as the 4 corners of the 20 m x 20 m plot (Figure 11). In some cases (such as large rock outcrops within the plot), it will be impossible to use conduit to mark some locations. In these cases, please note on the plot sheet which pieces of conduit were not able to be placed. Also hang brightly colored flagging on the conduit or directly above the conduit if there is an overhanging branch to which it can be tied. This flagging will be taken out as the plot is being dismantled, but the pieces of conduit will stay so that the plot can be found next time it is visited.

If the plot is in an area designated as a “no conduit” area (such as a mowed area or an archaeological site), please use “yard staples” with flagging attached instead of conduit to mark the plot so that mowers will not hit the markers. As with the centroid point, consider using yard staples marked with bright flagging if the conduit cannot be used for the plot.

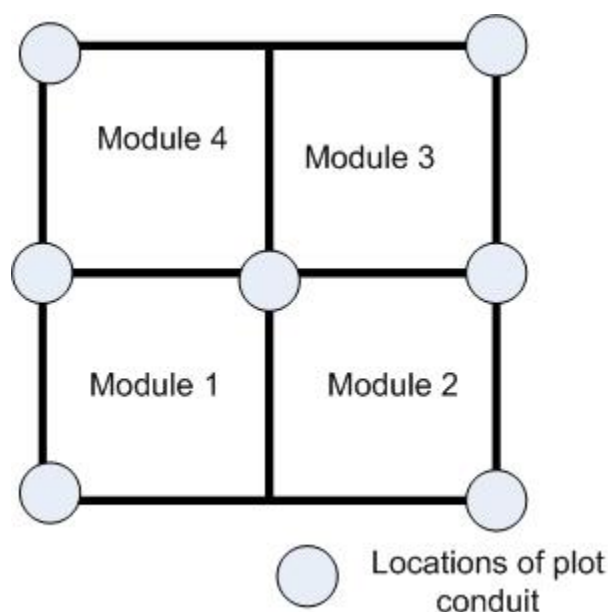


Figure 9. Locations of plot conduit.

Modules are numbered in counter-clockwise order starting with module one (module 1 is always the southwest module for the plot). There is a place on the datasheet to draw in the configuration and module numbering scheme. In contrast, corners of the modules are numbered in a clockwise fashion: for an observer standing in a module and facing the center tape, corner 1 would be in front of the observer to the left, corner 2 in front of the observer to the right, and so forth (Figure 12).

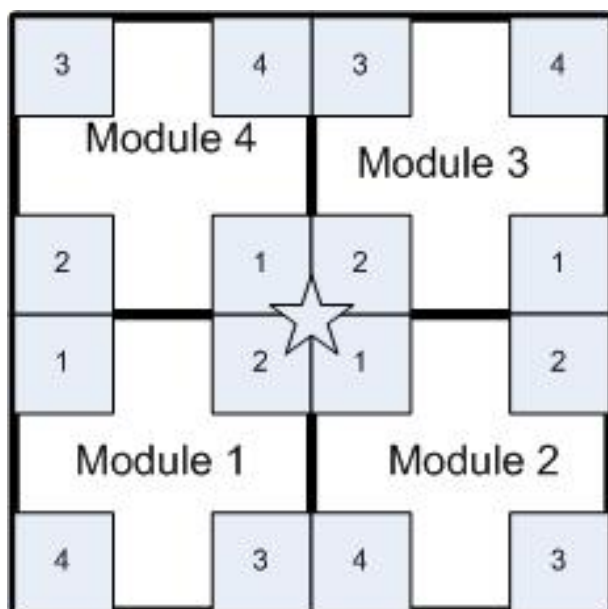


Figure 10. Location and numbering of nested subplots

There will be cases where parks will not allow conduit to be put into the ground or where there are other considerations that prevent conduit or tags. In these cases, clear notes will be provided on the cover sheet of the plot sheet to explain alternative permanent markings. Where there is no ability to permanently mark any points (such as in glades), field teams are required to collect the most precise GPS measurements possible and document the exact location of tag trees, etc. in relation to the centroid point. If there is no way to mark the plots and survey grade GPS with submeter accuracy is available and travel distances are not far, teams should use those units instead, taking GPS points at each of the locations on the plot where posts would normally be placed. If teams cannot place the conduit in the exact location where it is supposed to go, try to place it one meter to the north. If this does not work, pick another location and give specific directions in the data sheet detailing the actual location of the centroid point relative to the conduit. Yard staples may be used in cases where full conduit is not feasible.

Data fields:

Plot Establishment		
Field Name	Field Description	Data Type
Plot #	Four letter park acronym + three digit GRTS order # (e.g., CUGA179)	Text
QA/QC	Is this a "repeat" data collection effort, as designated by the GIS specialist for quality control purposes? Circle Yes or No.	Yes/No

Date	The date that data collection occurs in mm/dd/yyyy format (e.g., 5/17/2011).	Date/Time
Park	The four letter park acronym where the plot is located (e.g., ABLI, CARL, CHCH....).	Text
GRTS Order	Three digit plot number or id assigned to plot via the generalized random-tessellation stratified (GRTS) sampling methodology (e.g., 123, 978, 022,...)	Number
Start Date	The date that data collection starts in mm/dd/yyyy format (e.g., 5/17/2011).	Date/Time
Start Time and Total Time	The time of arrival to the plot using local time (with Am or PM) and total hours it takes to fill out data sheet.	Date/Time
Crew	Full name of all involved in the field data collection. Circle the name of the field crew leader.	Text
GPS file name	File name created by field observer in the GPS (i.e., what did you name the point in the GPS device when you saved it?). Naming convention should be park acronym><3 digit plot number>. (e.g., STRI079).	Text
GPS model	The model of the GPS unit used in the field to acquire coordinates for the plot (e.g., Map 76cs)	Text
GPS Unit ID	Unique identifier assigned to the GPS unit used in the field (e.g., CUPN1, Lillian,...). May also use the last 3 digits of the serial number.	Text
Field UTM X	The 6-digit latitude of the plot center, also known as easting, as recorded (and saved) in the field with the GPS. (e.g., 579129)	Number
Field UTM Y	The 7-digit longitude of the plot center, also known as northing, as recorded (and saved) in the field with the GPS. (e.g., 4116209)	Number
Zone	The UTM zone is 17 for CARL, COWP, CUGA, GUCO, KIMO, and NISI. The zone is 16 for ABLI, CHCH, FODO, LIRI, MACA, RUCA, SHIL, and STRI.	Number
No. times waypoint averaged	Utilizing the averaging function on the GPS unit, the number of iterations or times the point is averaged. Although not always possible it is recommended to allow unit to complete 100 iterations.	Number

GPS Error	Record the horizontal error estimate from the GPS (in meters).	Number
WAAS enabled	Are you picking up WAAS when recording GPS coordinates?	Number
Directions to Plot	Starting from a road, known trail head, etc. provide detailed directions to aid another crew in returning to the plot. Ideally include GPS coordinates for where your vehicle was parked or where you accessed the area.	Memo
Travel Time from Vehicle	Length of time taken to travel from vehicle to plot, recorded in minutes.	Number
Permanent Plot Established	Circle Yes or No; If no, provide criteria/justification for not establishing plot (e.g., on pvt. land, within mowed field, etc.)	Yes/No
Compass Adjusted for declination	Confirm that the compass you are using has been adjusted	Yes/No
Plot Marking		
Tag #	Number on tag attached to "tag tree" for plot. Ideally these trees (two per plot) should be fairly large and distinctive and within 5m of centroid of plot.	Number
Tag Color	Color of tag attached to tag tree.	Text
Tag Tree Species	Species of tag tree.	Text
DBH of Tag Tree	DBH of tag tree.	Number
Direction Tag is Facing	Compass bearing (1-360°) the tag is actually facing. This is determined by standing with tag at your back and compass held out directly in front of you.	Number
Direction to Conduit	Compass bearing (1-360°) from tag tree to plot center. Typically plot center marked by rebar stake.	Number
Distance from Tag Tree to plot center	Measured distance from tag tree to plot center. Typically plot center marked by rebar stake. Measure to nearest tenth meter.	Number
Plot Layout		
Plot Shape/Size	Is the established plot 20 x 20m (standard) or 10 x 20m (alternate 1) or 10 x 10m (alternate 2).	Text

Taxonomic Standard and Authority Used for plants	Both standard and authority for taxonomy need to be documented here. Defaults may differ by park.	Text
Plot Layout Notes	Record any unusual plot features or problems encountered during plot setup. Note any problem or irregularities inserting plot markers; features which indicate plot history, including evidence of past agricultural, silvicultural, or recreational use regardless of how long ago.	Memo
Plot Diagram	Diagram which is used to add any notes about particularly important plot features	Attachment
Field Quality Check	At conclusion of field data collection and before leaving plot, the field crew leader should review the field datasheet for completeness and accuracy. A place on at bottom of each data form is available for initials and date, to indicate this check took place.	Text
Elevation (m)	Elevation recorded from GPS unit in meters	Number
Slope (degrees)	Average slope recorded from center of plot	Number
Aspect (degrees)	Average aspect recorded from center of plot	Number
Landform	Circle landform that best characterizes the location of the plot	Checkbox
McNab indices (landform index and terrain shape index)	Refer to Carolina Veg Survey protocols for details on collecting this data	Numbers
Topographic position	Best estimate of topographic position	Checkbox

Indicators of Disturbance	Check all that apply in terms of disturbance indicators	Checkbox

Step 4b. **If this is a new plot but it falls partially in a restricted category the first try to move it 10 meters in a random direction (as detailed in steps above). However, if moving it still does not allow for placement, then you can consider making the plot smaller if that smaller size would allow it to avoid restricted categories.** This should be a fairly rare circumstance, but it will happen. In cases such as this, the centroid point will always be the true center of the plot. The plot will be laid out around the centroid point and all corners of the plot will be marked by pieces of conduit placed into the ground. Follow the same directions as above for sampling the plot, and fill out the same data. Options include a 10m x 20m plot or a 10m x 10m plot.

Step 4c. **If this is a revisit of an already established plot,** then you may navigate to the centroid point and look for the previously established tag tree. Tags will be small (8 cm diameter) colored metal tags with numbers. The plot sheets will tell you which direction the tags are facing, what species you are looking for, and the diameter of that individual. Once found, confirm that the tag tree is indeed the one you thought it was by checking the tag number against the plot sheet. If it is clear that a tag tree has fallen or otherwise become useless or has died, please establish a new tag tree and take new notes regarding that tag tree AND indicate on the old plot sheet that the old tag is gone and shouldn't be used for future visits. This means that field workers should confirm all tags on all tag trees as part of their revisit.

If at least one tag tree is still relevant, the plot sheet will then give you specific directions from the tag tree to the conduit. Once the conduit is found, you can begin to lay out the centerline tape. If there are two members of the team, it may be helpful to have one member walk ahead to "flag" the other pieces of conduit that define the plot boundaries as they are found and then have the other member lay out the tape in as straight a line as possible. If any posts/conduit are missing, they should be replaced as part of the revisit.

Equipment List

bundle of conduit (up to seven pieces per plot)
hammer or mallet for getting conduit into the ground
4 nails
2 anodized aluminum tags
GPS unit
Bright colored flagging (at least one roll)
Yard staples (at least 8)
6 pin flags
3 50 m or longer tapes
6 chaining pins

References

- Bate, L. J., M. J. Wisdom, E. O. Garton, and S. C. Clabough. 2008. SnagPRO: snag and tree sampling and analysis methods for wildlife. Gen. Tech. Rep. PNW-GTR-780. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 80 p. <http://www.arlis.org/docs/vol1/A/309145529.pdf>
- Jenkins, M. A. 2008. Great Smoky Mountains National Park: Vegetation Monitoring Protocol. National Park Service, Great Smoky Mountains National Park.
- Lee, M. T., R. K. Peet, S. D. Roberts, and T. R. Wentworth. 2008. CVS-EEP Protocol for Recording Vegetation, All Levels of Plot Sampling. Version 4.2. Carolina Vegetation Survey. <http://cvs.bio.unc.edu/protocol/cvs-EEP-protocol-v4.2-lev1-5.pdf>
- National Park Service. 2002. Field Data Collection with Global Positioning Systems Standard Operating Procedures and Guidelines. 06/05/02. Accessed 4/8/2010. http://www.nps.gov/gis/data_standards/field_data_collection_GPS.html
- Perles, S., J. Finley, and M. Marshall. 2010. Vegetation and soil monitoring protocol for the Eastern Rivers and Mountains Network, Version 2. Natural Resource Report NPS/ERMN/NRR-2010/183. National Park Service. Fort Collins, Colorado.

Standard Operating Procedure (SOP) # 4

SOP 4: Plot Photopoints

Version 0.0 (January 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

Time allotted: 10 minutes

Overview

This SOP documents the procedure for photographing plots. Photographs will be archived and used as a visual reference for documenting changes in appearance of plots over time. It is best to take photographs shortly after plot setup to record plot conditions before trampling occurs.

Step by Step Instructions

Photograph the plot from both ends of the 20 meter east/west centerline pointing in towards the center of the plot and mark the photos on the plot map as in the example below (Figure 14).

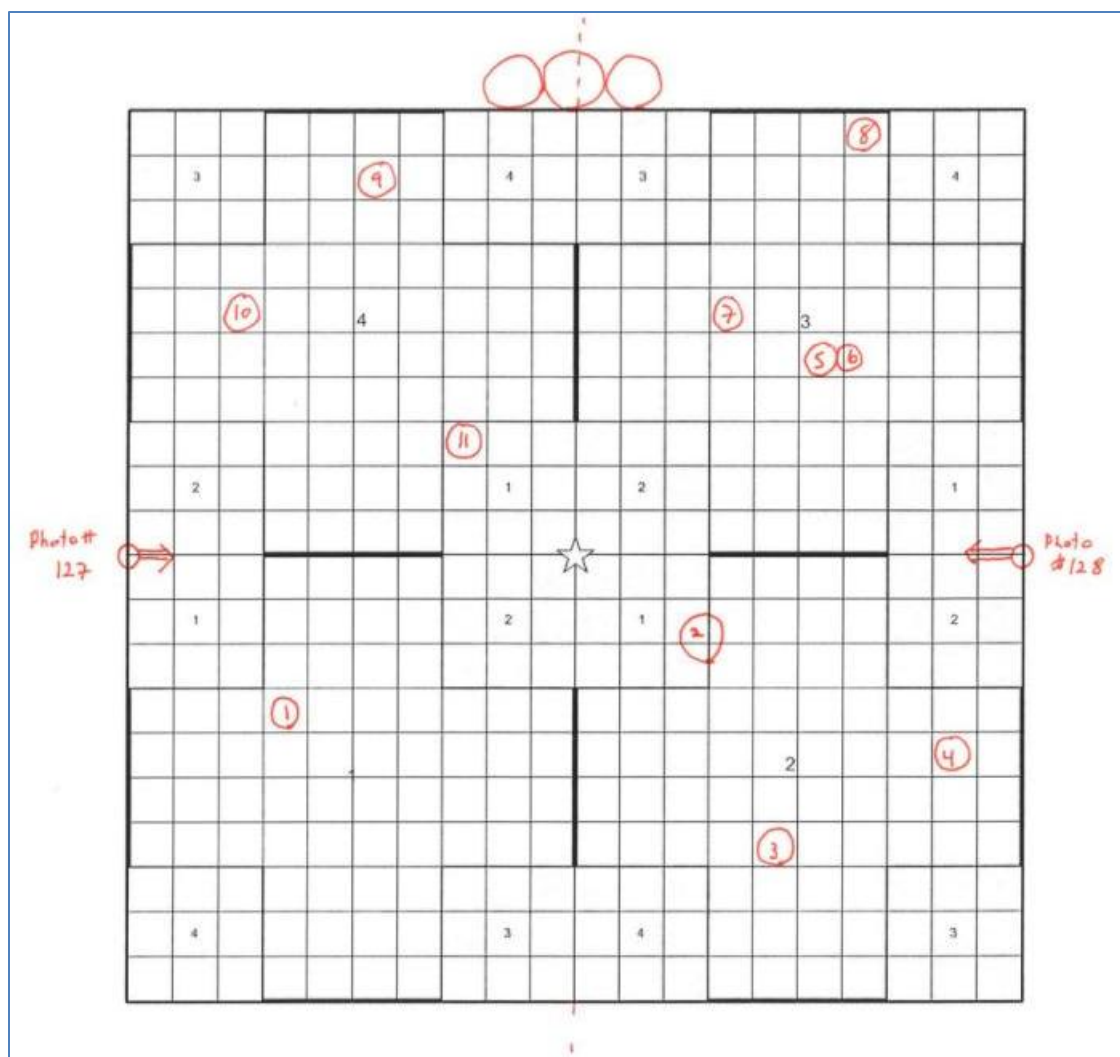


Figure 11. Example of gridded plot data sheet filled out with information about photo direction and tree location.

If the scene at this location is blocked by a large tree or obstruction, move one pace to the right of where you are standing and indicate this on the gridded plot diagram. The photo should be taken from this point facing towards plot center and the photo should be shot as if one were aiming to center the photo on the head of an averaged size person 20 meters away (photo will follow the slope in which it is pointed at eye level).

If a photo cannot be taken from one pace away from each end of the transect, move the photo location to one corner of the plot on the same end and point camera toward center of plot to take photo. Note the alternate location of the photo on the data sheet. If necessary (in very thick vegetation), the plot photos can also be taken from plot center facing outward in the direction of the centerline. In this case, clearly explain on the gridded data sheet where the photo was taken and which direction the camera was facing.

An identification sign must be used to make it easier to keep track of which photos are with which plots. Insert a sheet of paper or other flat marked up object printed with the park name,

plot number, and date in large black letters into the portable sign. There are multiple solutions. You can use a spare blank piece of paper to write the plot information and take a picture of the sheet with plot data, then snap the photo of the plot. Some crews bring along a small dry erase board to waste less paper. Team members can also hold up the sign while the photo is being snapped or place the portable sign 2–5 m on the ground and take a picture of the sign while taking a photo of the plot itself. But beware that this can sometimes cause focus issues on automatic cameras so that either the landscape is blurry or the sign is blurry. If time allows, also take a photo of the filled in plot data sheet, which has the location information for the plot written on it.

Use the “landscape mode” or equivalent on your camera to get maximum coverage of all vegetation layers. Do not zoom-in on the scene. Allow the camera to automatically select the appropriate aperture for the given light conditions. Check photo quality on the camera’s LCD screen. Take additional photographs if the quality is questionable. If lighting is questionable, take one photograph with flash and one photograph without flash. Be aware that sometimes the flash causes the vegetation close to bleach out, and the vegetation further away to be quite dark in the image. If the camera has a date stamp function, make sure the date and time are set correctly and turn this function on, so the date and time will be displayed in the photograph. Mark direction of photo with label on plot data sheet map (figure 14).

In remeasured plots, field crews should examine photographs from previous visits and attempt to recreate the position and angle used.

At end of each field week, field crew member will download all photos from camera, make sure to rename photo files using the standard naming convention, and annotate plot data sheets with the correct name of each photograph. Photographs should follow the naming convention of <park code>+<plot number>+<date>+<direction>.jpg where the date is YYYYMMDD and the direction is either E or W (or NE, NW, SE, or SW if the photo placement was changed due to some obstruction).

Data Fields:

Photopoint 1	
Photographer initials	
Mark photopoint location and direction on plot diagram	Yes/No
Camera: text name of camera or make/model of camera	
Did you take photo of sign before taking plot photo (with park acronym, direction of photo, plot #, and date on it?)	Yes/No
Photo notes (includes photo file name if you can find this on your camera): <i>text</i>	
Other photo notes (to be used if you took additional photos or if you need to document something related to one of the photos taken)	

Equipment List

Relatively high quality camera

Dry erase board and marker or other way of creating a sign for each photo.

Gridded plot datasheets (# needed)

References

Perles, S., J. Finley, and M. Marshall. 2010. Vegetation and soil monitoring protocol for the Eastern Rivers and Mountains Network, Version 2. Natural Resource Report NPS/ERMN/NRR-2010/183. National Park Service. Fort Collins, Colorado.

Standard Operating Procedure (SOP) # 5

SOP 5: Canopy Closure Measures

Version 0.0 (January 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

Time allotted: 15 minutes

Overview

Canopy closure provides a measure of the density of the leafy photosynthetic forest cover, at the time of year it is measured. Generally a high amount of canopy closure indicates a low light environment on the forest floor, or field stratum. Conversely, a low amount of canopy closure can indicate changes in the canopy due to natural or human caused disturbance such as wind throw, forest pest damage, etc. The spherical densiometer is an economical and durable device for measuring canopy cover which is also quick and easy to use. The instructions for use of the spherical densiometer are found on the inside cover of the device. It is very important that the instructions be understood and followed, to ensure that the data is collected correctly. If the instructions for the densiometer are not followed consistently, the reliability of the data collected is compromised.

Step by Step Instructions

Crew members use the spherical densiometer to measure canopy cover at the center of each of the four intensive 10 m x 10 m modules (1, 2, 3, and 4). Crew members must be familiar with the instructions for using the spherical densiometer, found on the inside cover of the device. A crew member holds the spherical densiometer out in front of her/him, at elbow height (~ 1.0 m) to get a reading. This reading will be a number from 1-96 and is based on the number of closed canopy grid cells on the device. In each grid cell, one must imagine four dots, as described in the instructions. In forested environments, crew members should count up and record all the shaded



dots representing the canopy cover. There will be 1 to 4 shaded dots per grid cell. The total number of shaded dots will be a number 1 - 96. Crew members repeat this measurement in each of the four cardinal directions (N, E, S, and W), and do this in each of the 4 modules. Before data analysis occurs, the four values collected from each module are multiplied by 1.04 to get a percent canopy cover (1% - 100%) and then averaged for the plot (Ganey & Block 1994).



Spherical densiometer grid (above and right)

Note: Walk directly to the center of each of the modules to be measured and take the measurements. When working in the plot walk carefully to minimize trampling effects.

Optional Data Collection Method:

We discourage teams from using the optional data collection method. However, if the spherical densiometer has been lost or broken, then canopy closure should be visually estimated. Although visual estimation is a much less repeatable method than spherical densiometer, a measure of canopy closure is important to understand large scale changes over time. Ideally, team members will have calibrated their visual canopy closure measuring ability with each other during training and should come up with consistent numbers as a consequence. Look up at the canopy and estimate the relative space of occupied canopy (all leaves and stems included) from 0-100%. Repeat this measure at each module.

Data Fields:

Module	Direction	Spherical Densiometer tally of shaded canopy dots (0-96)	Visual estimate of relative occupied canopy (1-100%) (OPTIONAL)
1	N		
1	E		
1	S		
1	W		
2	N		
2	E		
2	S		
2	W		
3	N		
3	E		
3	S		
3	W		
4	N		
4	E		
4	S		
4	W		

Equipment List

Spherical densiometer

Canopy closure datasheets (# needed)

References

Ganey, J. L., and W. M. Block. 1994. A comparison of two techniques for measuring canopy closure. West. J. Appl. For. 9:21-23.

Standard Operating Procedure (SOP) # 6

SOP 6: Tree Measurements

Version 0.0 (January 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

Allotted time: 50 Minutes

Overview

This SOP records species, diameter, and various measures of condition of all live and standing dead trees ≥ 10 cm diameter at breast height in the entire 20 x 20 meter plot. The data are collected separately for each of the four 10 m x 10 m modules. These data will provide information on tree growth through time, mortality, condition, stand structure and stand composition. **If this is a resample, make sure that the list of trees and the map of trees found during the last sampling are taken out into the field to make it easier to match up present day trees with ones measured previously.

Definitions

Diameter at breast height (DBH) is the diameter of the tree trunk (also called bole) at 1.37 m (4.5 feet) above the ground line on the uphill side of the tree. It is very important that the dbh is measured at 1.37 m height. The dbh is measured to the nearest 1 cm for trees ≥ 10 cm diameter at breast height.

Horizontal distance is the level, straight line distance between two points. This contrasts with slope distance which is measured parallel to the ground surface. Slope distance and horizontal distance are equivalent on flat land. On sloped land, the horizontal distance between two objects is less than the slope distance.

Standing dead trees (also called **standing snags**) lack any living parts (i.e., leaves, buds, or cambium) at or above breast height (1.37 m), and lean <45 degrees from vertical, as measured along the trunk (bole). Standing dead trees need not be self-supported. Once included, standing dead trees are tracked until they no longer qualify as standing dead. Dead trees leaning >45 degrees from vertical are considered coarse woody debris and are measured according to the Coarse Woody Debris SOP.

Live trees have living parts (i.e., leaves, buds, or cambium) at or above breast height (1.37 m). Live trees that have been temporarily defoliated or are leaning or fallen are considered live trees. Live trees do not have to be self-supported, they may be supported by other trees, branches, or their crown.

Trees are woody species with a diameter greater than or equal to 10 cm at breast height (1.37 m) and capable of attaining heights >7 m. Refer to the CUPN Master Plant List to determine which woody species are considered trees. A one page example sheet from the Master Plant List will be provided to field crews. This sheet will list examples of those woody plants for which the life form is not obvious (i.e. *Cornus florida*, *Carpinus caroliniana*). This will make it easier to quickly determine whether a species being recorded is considered to be a tree, shrub, or vine. When in doubt, go ahead and record the DBH since we can always throw data on non-trees out later.

Step by Step Instructions

Step 1. According to the Site Selection and Plot Establishment SOP, four modules (10 m x 10 m modules) are established within the plot. Start with module 1, visually determining your strategy for measuring trees so that each tree is counted once and only once. This can be done by measuring the trees starting in one corner of the module and working through the whole module. You can work in a circular or linear pattern depending on the arrangement of trees in a module. In particularly dense foliage, flagging may be helpful to mark the starting tree and the boundary between trees that have been recorded and those that have not. This may be less of an issue since you are only measuring 10 cm + DBH trees.

Step 2. Look for your first tree of more than 10 cm DBH. On the plot sheet, write down the module # in which this tree occurs. Also record the species and DBH. Trees >20 cm DBH are numbered and mapped. Tree number is chronological for the plot beginning with tree #1. For each species, record the 7-8 letter code that corresponds to the scientific name (see species list for CUPN with 7 letter codes. If the codes are inaccessible, spell out the ENTIRE species name, no abbreviations. Unique codes generally consist of the first 4 letters of genus and first 3 letters of species of that tree with an extra 8th digit where species names are similar. In assigning species names and uncertainty values, **follow SOP 14: Recording Species and Reference.**

Step 3. Determine the **tree status** of each recorded tree (see below). If live tree, proceed to step **4a**. If standing dead, proceed to step **4b**. If “no status”, “fallen dead”, or “removed” then mark it as such and proceed to the next tree.

TREE STATUS. Record a status code for each tree.

0 No status. Previously tallied tree is no longer in sample because the tree: a) shrunk below 10 cm DBH (i.e. tree damage), b) center of tree trunk is now outside the plot boundaries, c) was incorrectly tallied last time, or d) a change in procedure now excludes this tree. Record the reason in Tree Notes.

1 Live tree. New live trees in remeasured plots are assumed to be in-growth. If a tallied new tree was obviously missed during a previous inventory, note this in Tree Notes. New trees will be given the next tree number available (if there are already 25 trees documented in the plot, then a new tree would be assigned tree number 26). Live trees have living parts (i.e., leaves, buds, or cambium) at or above breast height (1.37 m).

2 Standing dead tree. Tree lacks any living parts (i.e., leaves, buds, or cambium) at or above breast height (1.37 m), and leans <45 degrees away from vertical, or straight up and down.

3 Removed. Previously tallied tree has been cut and removed by humans during harvest, forestry treatment, hazard tree removal, or land clearing.

4 Fallen dead tree. Previously tallied tree has fallen and will no longer be tracked as a live tree. This includes dead trees leaning over >45 degrees from vertical.

Step 4a. Determine whether your tree is alive or dead (see definitions above). If alive, pick the appropriate codes for three factors: **crown class**, **tree vigor**, and **tree dieback**. Also include any specific **tree damage types** by placing the appropriate four letter code in the “tree condition/damage codes” column. You can add as many codes as you need in this column. Also, pick any **foliage condition codes** that apply and estimate the percentage of foliar cover affected by the foliage condition. See below for all the codes that will be used:

CROWN CLASS. Assign crown class code describing tree crown position in canopy and amount of sunlight received (see illustration below).

1 Open-grown – crown has received full sunlight from above and all sides through much of its life, particularly during early development, as seen by well-developed lower branches.

2 Dominant – crown extends above canopy, receiving full light from above and some light from sides. Taller than the average tree in stand and has well-developed crown.

3 Co-dominant – crown at the general level of the canopy, receiving full light from above but little direct light from sides. Typically, co-dominant trees have medium-sized crowns and are crowded on the sides; in dense stands, co-dominant trees have small crowns.

4 Intermediate – tree is shorter than co-dominant trees but with a crown that extends into the general canopy. Tree has small crown and is very crowded from the sides.

5 Overtopped – crown is entirely below the general level of the canopy.

TREE VIGOR. Vigor is a measure of overall tree health and vitality. This measure compares the subject tree to an “ideal” healthy specimen of that species. Record the general overall health of the tree using the codes below. Estimate vigor before estimating dieback or recording tree or foliage conditions. Several factors should be considered when assessing vigor:

- How much of the crown is missing or damaged from recent or long past disturbances? Old injuries should be considered in the vigor assessment until the tree builds a new crown that makes the old injury largely invisible.
 - How much of the crown is composed of dead snag branches? Snag branches are large branches without small twigs <2.5 cm (1.0 inch) in diameter, usually with the bark absent or with dead bark peeling away.
 - How much of the crown contains foliar discoloration or dwarfed or misshapen leaves?
1. Healthy. Tree appears to be in reasonably good health with <10% missing/damaged crown, branch or twig mortality, discoloration, or dwarfed leaves present.
 2. Light Decline. Less than 25% of the crown is missing or damaged. Branch mortality, twig dieback, foliage discoloration, or dwarfed leaves are present on 10 – 25% of the crown.
 3. Moderate Decline. Branch mortality, twig dieback, foliage discoloration or dwarfed leaves on 26 – 50% of the crown. Between 26 and 50% of the crown is missing or damaged.
 4. Severe Decline. More than half of the crown is missing, damaged, or contains branch mortality, dieback, discoloration or leaf dwarfing, but foliage still present to indicate that the tree is alive.
 5. Functionally Dead. There may be a few epicormic shoots on the bole, but the vast majority of the crown branches are missing or dead and leaf-less. Phloem under bark has brown streaks.

Current defoliation should NOT be considered in the vigor assessment. A defoliated tree does not necessarily have low vigor. Vigor is difficult to assess for trees that are currently undergoing partial or severe defoliation. For those trees, make the best assessment possible by considering crown structure, snag branches, and any intact foliage that may remain.

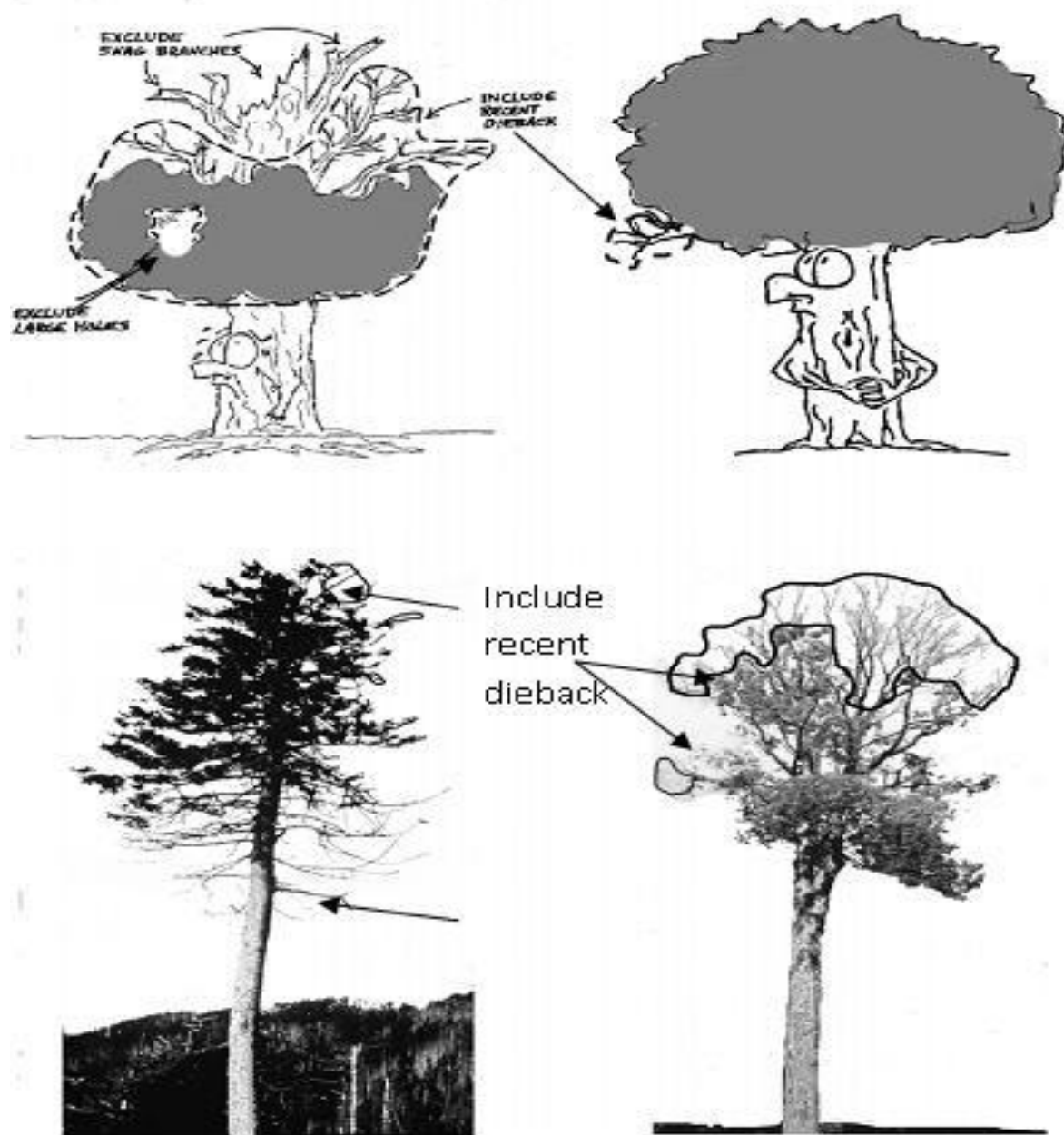


Figure 12. Examples of tree dieback.

TREE DIEBACK. Branch and fine twig dieback is defined as branch mortality that begins at the terminal portion of a limb and progresses downward (figure 15). This measurement is an estimate of the proportion of the crown silhouette involved in dieback. Assume the perimeter of the crown is a two-dimensional outline from branch-tip to branch-tip. Then estimate the amount of the outline that includes dieback. Record the proportion of the crown with crown dieback using the following categories: 1) 1–10%, 2) 10–25%, 3) 25–50%, 4) 50–75%, 5) 75–100%.

The following should be **excluded** from the dieback percentage:

- **Snag branches** (large branches without small twigs <2.5 cm in diameter, usually with the bark absent or with dead bark peeling away). Snag branches are assumed to have died much earlier and should not be included in the dieback percentage.
- **Large holes or gaps in the crown** where branches never developed.
- **Branch mortality at the base of the crown**, assumed to be the result of shading.

Note: Dieback should ideally be estimated when leaves are mature, but before the appearance of fall color. This may mean that we can only estimate dieback for summer plots and not spring plots. One crew member is required to make the estimate of dieback from two different sides of each tree, standing at a minimum of a 90° angle apart around the tree. The diagram above illustrates what to include and exclude when assessing dieback.

TREE CONDITION CODES/TREE DAMAGE CODES. These codes cover the **Pests and Pathogens**. Field teams need to be familiar with the identification of these, see Appendix E.

AAB Asian Ambrosia Beetle
ALB Asian Longhorned Beetle
BBD Beech Bark Disease
BTC Butternut Canker
CHB Chestnut Blight
CPB Common Pine Shoot Beetle
DWA Dogwood Anthracnose
EAB Emerald Ash Borer
EHS Elongate Hemlock Scale
ETC Eastern Tent Caterpillar
GPM Gypsy Moth
HWA Hemlock Woolly Adelgid
RPBB Redhaired Pine Bark Beetle
TCD Thousand Cankers Disease
SOD Sudden Oak Death
SWW Sirex Woodwasp
RAB Redbay Ambrosia Beetle

***Note: For AAB, ALB, EAB, GPM, and RAB, please take photographic evidence of the forest pest/pathogen. These are all very serious pests that have either not been found in most parks or are very sporadic within the parks, so any identification in the field needs to be verified by a third party.**

If a forest pest or pathogen that is new to the park being monitored is detected, or suspected of occurring, a specimen of the pest, or a photo of the pest or symptoms should be made. These vouchers should be provided as quickly as possible to:

Kurt Helf, Invertebrate Ecologist
 Mammoth Cave National Park
 P.O. Box 8
 Mammoth Cave, KY 42259

kurt_helf@nps.gov

This information can then be used to help with the early detection of forest pests.

Damage Code	Description of Damage
ABGR	<u>Abnormal growth</u> pattern for the species. This category would include a range of physical deformities not included in the remainder of the damage codes.
BIRD	<u>Bird</u> damage such as woodpecker or sapsucker holes.
BLIG	<u>Blight</u> is generally defined as any plant disease or injury that results in general withering and death of the plant without rotting. Blight can result from a wide variety of needle, cone, and stem rusts, as well as canker diseases, and is often species- or genus-specific.
BROK	<u>Broken</u> top of the tree.
BROM	Witches' <u>broom</u> diseases are characterized by an abnormal cluster of small branches or twigs on a tree as a result of attack by fungi, viruses, or insects.
BURL	A hard, woody, often rounded outgrowth on a tree. This occurs naturally in some tree and shrub species, and is a sign of an infection or disease in other species.
CONK	The knobby fruiting body of a tree fungal infection visible on a tree bole, such as a shelf fungus.
CROK	<u>Crooked</u> or twisted bole for species in which this is uncharacteristic.
DECY	Advanced <u>decay</u> of bole and limbs.
DTOP	Dead top.
EPIC	<u>Epicormic</u> sprouting, adventitious shoots arising from suppressed buds on the stem; often found on trees following thinning or partial girdling.
FIRE	<u>Fire</u> scar or cambial damage due to fire.
FORK	<u>Forked</u> top of a tree or multiple primary leaders in a tree crown for species in which this is uncharacteristic. Forks assume vertical growth and should be distinguished from branches, which assume horizontal growth.
FRST	<u>Frost</u> crack or other frost damage.
GALL	<u>Galls</u> found on stems, leaves or roots. Galls are formed by infection of the plant by bacteria or fungi, or by an attack by certain mites, nematodes, or insects, most notably wasps.
HOLW	<u>Hollowed-out</u> trees. Repeated hot fires can burn through the bark and the tree's core may then rot out, especially in trees with tough bark, but soft heartwood. These hollowed-out trees are sometimes called "goose pens" because early settlers kept poultry in them.
INSE	Visible <u>insects</u> in the tree bole or the canopy, or their sign, such as frass, pitch tubes or bark beetle galleries.
LEAN	Tree is <u>leaning</u> significantly. If on a slope, tree deviates considerably from plumb.
LIGT	<u>Lightning</u> scar or other damage to the tree caused by lightning.
MAMM	Damage caused by <u>mammals</u> , such as bear claw marks, porcupine or beaver chewings, and deer or elk rubbings.
OZON	<u>Ozone</u> damage. Ozone injury is often seen in the form of stippling or speckling on the leaves or needles of trees. This discoloration varies among species and ranges in color from red or purple to yellow or brown. Susceptible species often drop their leaves prematurely.
ROOT	Large exposed <u>roots</u> .
ROTT	A <u>rot</u> of fungus other than a conk, often associated with a wound or crack in a tree.
SPAR	Unusually <u>sparse</u> foliage for that species and size of tree.
SPRT	Basal <u>sprouting</u> ; new shoots arising from the root collar or burl.
UMAN	<u>Human</u> -caused damage such as axe marks, embedded nails or fence wire, or vandalism.
VINE	<u>Vines</u> present in canopy or climbing bole of tree. List vine species or genus in the Notes section of the paper data sheet or the Vine Species section of the database.
WOND	A <u>wound</u> to a tree that cannot be identified by one of the other damage codes, including wounds or cracks of unknown cause.

FOLIAGE CONDITIONS. Visually assess canopy foliage and record up to three (3) problems; **chlorosis (C)**, **necrosis (N)**, **holes (H)**, **small leaves (S)**, **wilting (W)**, **leaf loss (L)**, or **other (O)** – describe in Tree Notes). **Chlorosis** is a condition where leaves produce insufficient chlorophyll and instead appear ghostly white. **Necrosis** is the premature death of cells and can occur in some leaves. Only record L for needle loss if fine twigs in the canopy are affected – disregard lower branches and large dead branches. If none of these conditions exist, record a horizontal line in the Foliage Condition box.

Current defoliation should be recorded here. If the defoliating pest is known and recorded under Tree Conditions, record **O** (other) for Foliage Conditions. If the defoliating pest is unknown or not listed under Tree Conditions, record **L** (leaf loss). Record the amount of defoliation in Foliage Percentage below.

FOLIAGE PERCENTAGE. Estimate amount of crown affected for each foliage condition using the following classes: **0–10, 10–25, 25–50, 50–75, 75–100%**.

Step 4b. If the tree is considered to be a dead standing tree (see definition above), then collect information on the decay class and snag height (visual estimate in meters).

SNAG DECAY CLASS. For each standing dead tree, record code indicating the tree’s stage of decay.

Snag decay class	Bark	Log shape and integrity	Color of exposed wood	Texture of rotten portions	Primary surface substrate	Branches and twigs
1	Firmly attached	Round and solid. Freshly fallen, intact logs	Fresh color, not stained by weathering	Intact, no rot or conks. Stem decay absent.	Sound, tight bark	Branches retain many small twigs
2	If present, decayed, faded and not firmly attached	Round and solid	May be bleached and relatively smooth (like driftwood)	Mostly intact, sapwood partly soft and starting to decay, but can't be pulled apart by hand	Decayed bark and hard wood - impenetrable with fingernail or pen point	Branches retain some small twigs, often with peeling bark
3	Generally absent, except in <i>Betula</i> and <i>Prunus</i>	Round and firm, piece supports its own weight	Reddish-brown, or original color	Hard, large pieces of sapwood can be pulled apart by hand.	Soft wood - will spring back if compressed, easily penetrated with fingernail or pen point	No small twigs, but branch stubs will not pull out
4	Absent	Oval or flattened, no longer a solid piece, though some hard chunks remain. Piece does not support its own weight, but maintains its shape	Reddish or light brown	Soft, small blocky pieces, a metal pin can be pushed into heartwood	Very spongy wood - responds to finger pressure and may exude moisture. Powder wood flows through fingers like coarse sawdust	No small twigs, branch stubs pull out
5	Absent	Quite flat or flat with some rounding. Piece no longer maintains its shape, but spreads out on the ground	Red-brown to dark brown	Soft, powdery when dry	Loosely aggregated powder wood	No small twigs. Branch stubs and pitch pockets have usually rotted down

Step 5. If the live tree or dead snag is greater than 20 cm dbh, use the supplied plot diagram to accurately map the snag location and write in the assigned tree # on the map (Figure 13, 14). Record any unusual tree features or notes required above, including location of diameter measurement if not measured at breast-height or the relative position of each of the stems of a clumped tree/copse. Record the species of vine present if any vines occur on tree and reach above the 1.37 m mark.

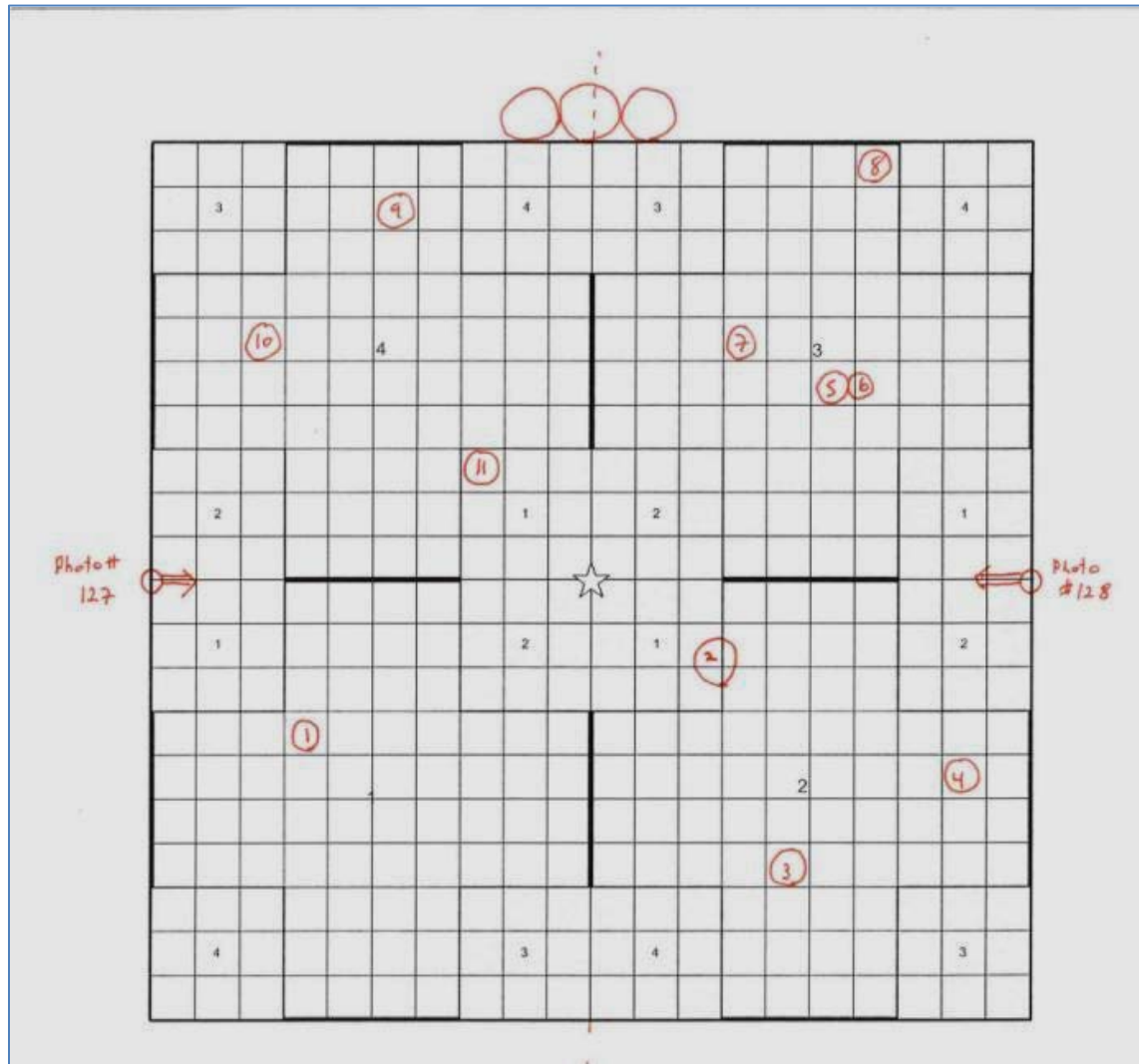


Figure 13. Sample gridded plot sheet with all trees (live or standing dead) over 20 cm dbh mapped (trees more than 10 cm dbh are recorded but only trees more than 20 cm dbh are mapped)

Other details about the protocols

A tree on the plot boundary will be included only if the center of the tree base lies directly on or within the plot boundary. To determine if the center of the tree base falls in the plot, measure the horizontal distance from the centerline tape to the front of a crew member, standing adjacent to the tree base center. If the distance from the plot centerline to the center of the tree base is

greater than 10.0 m, then the tree falls outside the plot and is not tallied. The lean of the tree bole into or out of the plot does not affect whether the tree is tallied.

Each tree greater than 20 cm diameter at 1.37 m (dbh) will be mapped. Consider the plot itself as a plotting graph. For this, 8 ½ x 11 graph paper with gridlines and a printed plot layout will be used. The large trees in each 10 m x 10 m module of the entire 20 m x 20 m plot can be mapped on one sheet of 5 mm graph paper. This will give future monitoring teams an easy way of determining whether the tree they are measuring is the same as the one you measured or a different one. Even though we are recording data on all trees more than 10 cm dbh, we are only mapping trees greater than 20 cm dbh. This allows us to streamline the data collection effort a bit and avoid taking large amounts of data on trees with relatively low importance.

Key details on measuring DBH

Measure tree diameter at breast height, 1.37 m above the ground, on the uphill side of tree. Do not measure from a pit or atop a mound or emergent rock. For a coarse measurement of DBH, just hold a Biltmore stick out at arm's length and judge whether the tree DBH clearly fits into a category. If not, use DBH tape to confirm the measurement to the nearest 1 cm.

Make certain that you are reading the correct side of the DBH tape; often one side has standard centimeters and the other side has units calibrated to give the diameter in centimeters when wrapped around the circumference of the tree. Press the hook at the end of the tape into the bark and then run the tape around the trunk, ensuring that the tape is straight, pulled tight (no kinks) and perpendicular to the axis of the trunk (see figure 16). Tapes that are not run straight will overestimate the trunk diameter. Read the number where the tape crosses the zero mark at the hook end of the tape.

For unusual situations, determine where DBH should be located on the tree, using the guidelines below (also see illustrations below). Note the location of the DBH measurement in Tree Notes, using distances and unique tree characteristics. Always note deviations from previous measurements in the Tree Notes section.

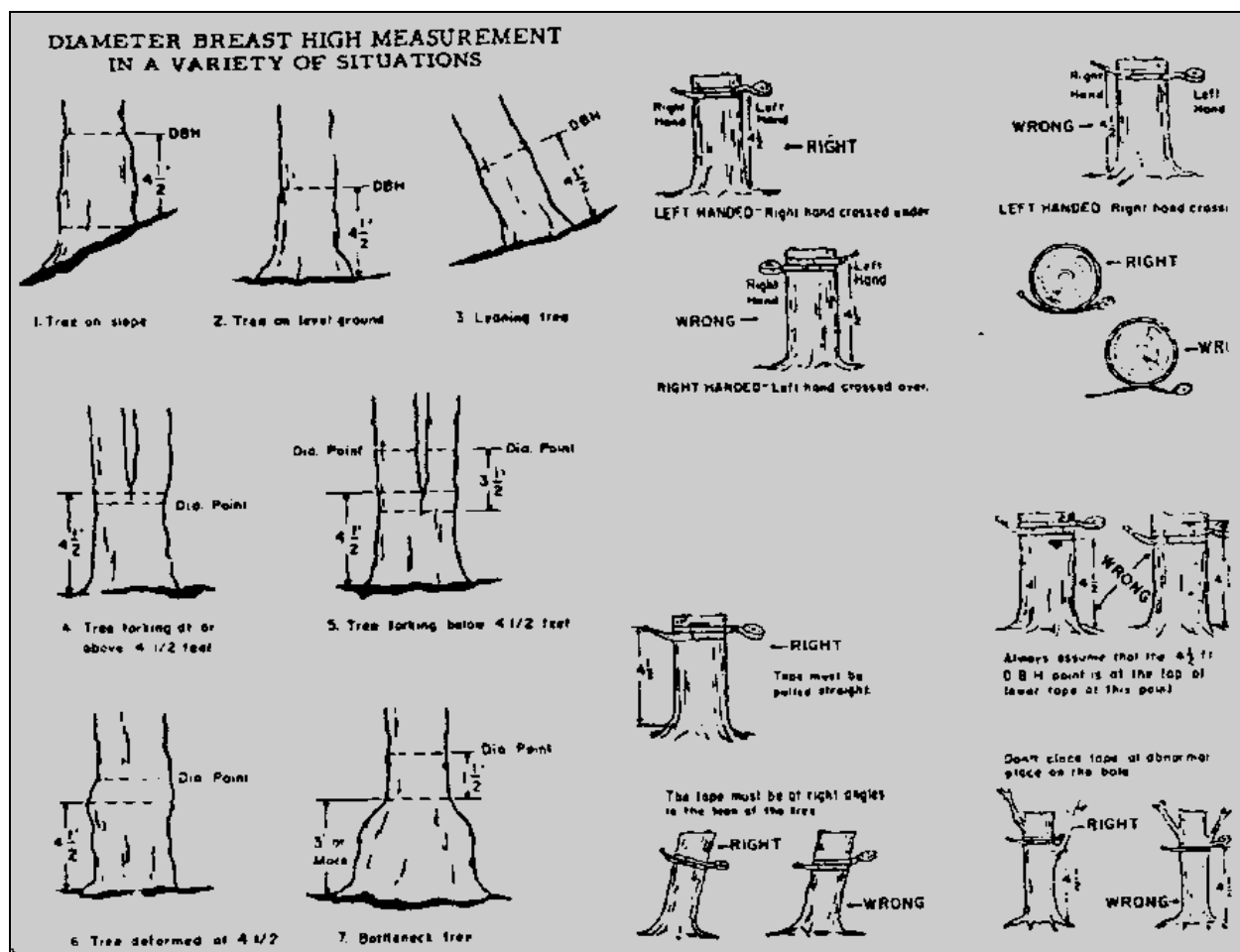


Figure 14. Irregularities in DBH measurement

Trunk abnormality at breast height (1.37 m): Take the diameter measurement just below the abnormality if possible. If the abnormality extends far below breast height (1.37 m), then take the measurement just above breast height (1.37 m). Put the height where measured in the Tree Notes.

Missing wood or bark: Do not reconstruct the DBH of a tree that is missing wood or bark. Record diameter of the wood and bark as the tree is, and note that wood or bark was missing in Tree Notes.

Leaning tree: Diameter is always measured perpendicular to the bole axis. Find the point equivalent to breast height (1.37 m) by measuring along the uphill side of the tree. Measure diameter perpendicular to the tree trunk (bole) as shown in Picture 3—Leaning Tree below.

Curved bole: Treat a curved bole as if it were a leaning tree. Measure a straight line from the uphill side of the tree base to 1.37 m. Do not measure along the curve of the tree trunk (bole).

Live windthrown tree: Find the point equivalent to breast height (1.37 m) by measuring from the top of the root collar along the bole.

Swollen bases: Trees with swollen bases rising higher than 0.91 m are measured 0.46 m above the top of the swelling. Trees with swelling below 0.91 m are measured at standard DBH.

Independent trees that grow together: If two or more independent stems have grown together at or above the point of DBH, continue to treat them as separate trees. Estimate the diameter of each, and explain the situation in Tree Notes.

Forked tree: Trees which fork at or above breast height (1.37 m) are tallied and measured as one tree. Diameter should be measured below the point at which forking affects DBH (see Figure 17 above). For trees that fork below breast height (1.37 m), each trunk ≥ 10 cm is tallied as a separate tree. Measure the diameter of each trunk at 1.0 m above the fork (see Figure 17). Multiple stems should be recorded from left to right when facing the trees from plot center. Note the spatial relationship of forked trees to each other in Tree Notes.

Data Fields:

Data on all trees (dead and alive)					Data on live trees only						Data for dead standing trees	
Module #	Tree #	Species	DBH (10+	Tree Status	Crown Class	Tree Vigor	Tree Dieback	Tree Conditions / Damage	Foliage conditions	Foliage %	Decay class	Snag height (estimated)
	1											
	2											
	3											
	4											
	5											
	6											
	7											
	8											
	9											
	10											
	11											
	12											
	13											
	14											

Tree Status: 0=No status; 1=Live tree; 2=standing dead; 3= removed; 4=fallen dead

Crown class: 1=opengrown; 2=Dominant; 3=Co-dominant; 4=Intermediate; 5=Overtopped

Tree vigor: 1=Healthy; 2=Light Decline; 3=Moderate Decline; 4=Severe Decline; 5=Functionally dead

Tree dieback: 0-10, 10-25, 25-50, 50-75, 75-100

Common damage codes: DTOP = dead top; FIRE = fire scar; HOLW = Hollowed out; SPRT = epicormic sprouting

Equipment List

DBH Tape (in cm) and meter stick
Biltmore stick
Small binoculars
Hand lens (optional)
Tree identification references
Plant press and newspapers (should not be carried in the field)
Zip seal plastic bags in case you need to collect plant specimens
Compass

References

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- Perles, S., J. Finley, and M. Marshall. 2010. Vegetation and soil monitoring protocol for the Eastern Rivers and Mountains Network, Version 2. Natural Resource Report NPS/ERMN/NRR-2010/183. National Park Service. Fort Collins, Colorado.
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<http://cvs.bio.unc.edu/protocol/woody-stems-protocol-summary-v4..pdf>

SOP 7: Herbaceous Plant and Seedling/Sapling Measurements

Version 0.0 (January 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

Time allotted: 45 minutes

Overview

This SOP documents data collection for overall plant species diversity and tree seedling/sapling counts in nested quadrats within the 20 m x 20 m plot. Quantitative data are collected in eight sets of nested subplots, and the entire 20 m x 20 m plot following a modified Carolina Vegetation Survey approach (Lee et al. 2008). As opposed to the tree and soils data, these data will potentially give us a much more sensitive set of measures. As stressors affect the vegetation, seedling and herbaceous species composition and structure will respond more quickly than will large trees, coarse woody debris, or other measures we are taking. The data will help to discern trends including invasive exotic plant species numbers and seedling regeneration of key canopy tree species.

Most of the monitoring SOPs can be completed with basic plant identification skills. However, this SOP requires at least one team member to be familiar with the full diversity of vascular plant species in the park and to be able to quickly identify each plant species as data is collected. This protocol may be applied either in the spring (late March to early June) or summer (mid-June to late September) sampling periods. Efforts should be made to revisit plots during the same time of year during which they were initially sampled, e.g., plots initially sampled in mid-June should be revisited in mid-June. To avoid over-trampling of the vegetation in the quadrats, all crew

members must be aware of the corner nested quadrat locations and, to the extent practical, avoid trampling these areas.

Definitions

Height of a seedling is the distance from the ground to the top of the terminal bud (the large bud at the top of the stem). Do not include leaves or needles in this measurement. Seedling height is determined from stems as they are naturally growing. Height is measured vertically from the ground to the tip of the terminal bud, not along the axis of the stem. Stems should **not** be straightened for measurement.

Seedlings are live juvenile **trees** with at least two true leaves that are less than 1.37 meters (4.5 feet) tall. A seedling is counted only if it is rooted in the nested subplot. Seedlings <5 cm (2 inches) in height are not counted in the tally. Refer to the Master Plant List to determine which species are considered trees. A one page example sheet from the Master Plant List will be provided to field crews. This sheet will list examples of those plants for which the life form is not obvious. This will make it easier to quickly determine the correct life form for plants for which life form is confusing.

Saplings are live juvenile **trees** that are more than 1.37 m (4.5 feet) in height but <10.0 cm DBH. Saplings are alive if there are any living parts (i.e., leaves, buds, cambium) at or above 1.37 m (breast height). Saplings that have been temporarily defoliated are considered alive. A sapling is counted only if it is rooted in the nested subplot. Refer to the Master Plant List to determine which species are considered trees.

Vines are not tallied. Presence of vine species is recorded in the nested subplots (depths 3 and 2), and 10 m x 10 m modules (depth 1) along with other plant species.

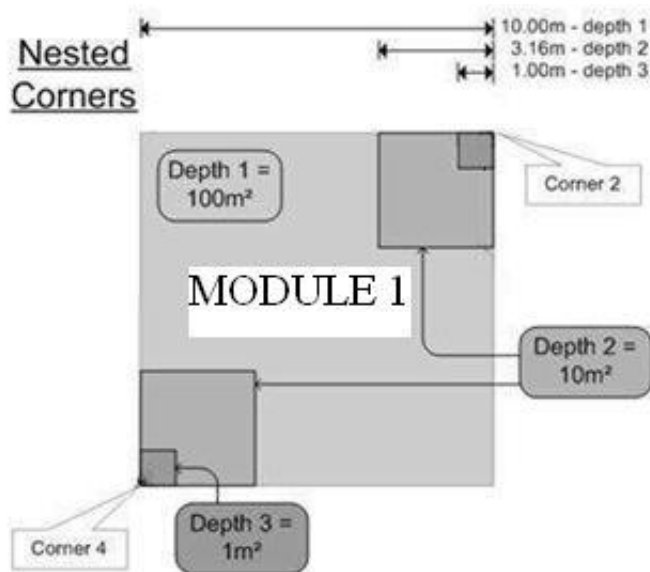


Figure 15. Diagram showing placement of sampled corners in module 1 (Lee et al. 2008).

Step by Step Instructions

Step 1. Each of the 10 m x 10 m modules (1-4) contains 4 numbered corners. We will be sampling two of the corners of each module (for a total of 8 corners). It is important for the field crew to keep themselves oriented, so that the correct corners are completed and documented. Once at the nested corner location, take two meter sticks and use them along with the previously laid out tapes to form a perfect square 1.0 m² nested subplot (depth 3 in diagram) in the corner. Record the number of corners you plan on sampling (8 is the default) and the name of the corners sampled (<module#>-<corner#>).

Following the Carolina Vegetation Survey protocols (Lee et al. 2008), nested subplots in 8 corners are sampled in a particular pattern. This is so that each corner sampled is not adjacent to another sampled corner and there is a permanent post anchoring each intensive module. These are, in module 1, corners 2 and 4, in module 2, corners 2 and 3, in module 3, corners 2 and 4, in module 4, corners 2 and 3 (Figure 19). The corners are indicated at the top of the columns on the datasheet, as pairs, module number and corner number.

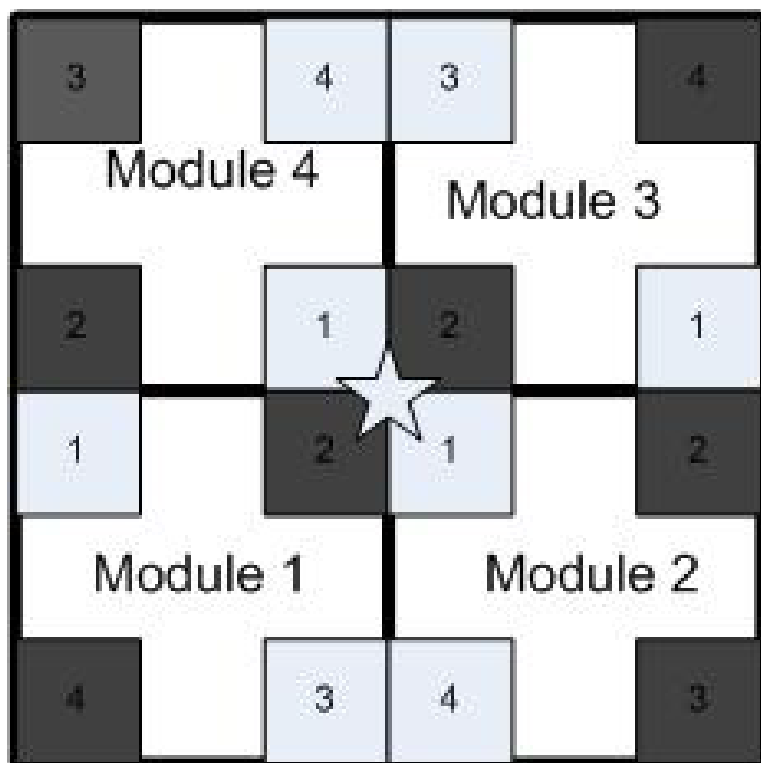


Figure 16. Module with all corners numbered (shaded corners are the corners that are sampled).

Step 2. Once the 1.0 m² corner nested subplot is laid out, species presence data is collected. First, identify and record all plant species in the 1.0 m x 1.0 m nested subplot for module 1, corner 2 as laid out in figure 20. Write down the 7-8 letter species code (see SOP 14 for detailed information on species nomenclature) then make sure to record your confidence in the identification value under the field of **ID conf** (table 13). In the box for the nested subplot on the datasheet, mark a “3” to indicate that the species is present in that module 1, corner/subplot 2 at the 1.0 m x 1.0 m level.

Table 13. Confidence Level Codes

Certain	The person(s) making the taxon interpretation has a high confidence in the accuracy of the field or herbarium identification.	C
Probable	The person(s) making the taxon interpretation has a moderately high confidence in the accuracy of the field or herbarium identification, but uncertainly is typically recorded as “cf” or “?” (e.g., taxon is most likely the species named; occasionally another taxa may be listed as a possibility –it can be named in a comments field)	P
Uncertain	The person(s) making the taxon interpretation has only moderate confidence in the accuracy of the field or herbarium identification, as shown by “??” or other comments about uncertainty. (For example, taxon may be one of two or more species and although one name is chosen, it could as easily be another.)	U

Data Fields:

# of corners sampled during this part of project: number between 4 and 8	
Name of corners sampled during this part of the project (just in case not all corners were sampled):	

Species Diversity Datasheet

<u>Species Name</u>	<i>ID conf</i>	<i>Collected?</i>	<i>1-2</i>	<i>1-4</i>	<i>2-2</i>	<i>2-3</i>	<i>3-2</i>	<i>3-4</i>	<i>4-2</i>	<i>4-3</i>	<i>Cover class 20 m x 20 m</i>

Key to presence depth: 1 m x1 m=3; 3.16 m x 3.16 m=2; 10 m x 10 m=1; overhanging = 0

Key to “ID conf”: Confidence in ID is C = certain; P = probable, U = unknown. Default is “C”.

Key to 20 m x 20 m cover class: 1=trace, 2=0.1-1%, 3=1-2%, 4=2-5%, 5=5-10%, 6=10-25%, 7=25-50%, 8=50-75%, 9=75-95%, 10=>95%

Step 3. Once you have collected species data at the 1.0 m x 1.0 m level (depth 3), then move on to the tree seedling and sapling tallies at the 1.0 m x 1.0 m level (keep the species datasheet handy, because we will come back to it). Take out the tree seedling and sapling datasheet (see example below). Identify tree species and tally (by species) all individual seedlings in the 1.0 m x 1.0 m nested subplot that are 5-50 cm tall or are 50-137 cm tall. Tally all saplings as well (0-1.0 cm dbh, 1.0-2.5 cm dbh, 2.5-5 cm dbh, and 5-10 cm dbh). Use the dots and square method described at the bottom of the seedling and sapling datasheet to most easily document numbers of seedlings. Keep this sheet handy as we will come back to it.

Record the first 4 letters of genus and first 3 letters of species of each sapling. Certain species have ambiguous 7 letter codes, so eight letter codes are provided for these species on the species list. They include species such as *Acer saccharum*, *Acer saccharinum*, *Carya ovata*, *Carya ovalis*, *Polygala nuttallii*, *Polytaenia nuttallii*, *Polygonum hydropiper*, *Polygonum hydropiperoides*, *Polygonum virginianum*, and *Polypodium virginianum*). If the species cannot be determined in the field, collect a twig sample with foliage, buds, cones, or flowers, and/or a photograph to make a positive identification later. If possible, collect samples outside the plot from similar specimens and make a note to correct the species code later. Put a check in the Collected column on the data sheet, to indicate that a specimen was collected.

Tree seedlings that originate at a common root collar (i.e., branch under the leaf litter) are independent seedlings. If a tree seedling forks or branches above ground, measure the height of the tallest terminal bud and count the seedling as one. Do not count stump sprouts from a live tree as seedlings. A tree is considered live if it has any living parts (i.e., leaves, buds, cambium) at or above breast height (1.37 m). Tally stump sprouts from standing dead trees, counting each sprout as a separate seedling. A standing dead tree has no living parts (i.e., leaves, buds, cambium) at or above breast height (1.37 m).

Seedling and Sapling Datasheet

-	Module and Corner sampled	Specimen #	TREE SEEDLINGS BY HEIGHT CLASSES (1.0 m ² FROM DEPTH 3 NESTED SUBPLOTS)		SMALL TREE SAPLINGS BY DBH (10 m ² FROM DEPTH 2 NESTED SUBPLOTS)			
			5 - 50 cm tall	50 -137 cm tall	0-1.0 cm dbh	1.0-2.5 cm dbh	2.5-5 cm dbh	5-10 cm dbh
<u>Species Name</u>								

Tally Method	 = 1	 = 2	 = 3	 = 4	 = 5	 = 6
	 = 7	 = 8	 = 9	 = 10	 = 11	 = 12, etc.

Step 4. At this point, you have completed the 1.0 m x 1.0 m nested subplot but still must complete the 3.16 m x 3.16 m nested subplot in the same corner. The 3.16 m x 3.16 m (depth 2) nested subplot includes the 1.0 m x 1.0 m (depth 3) nested subplot that was already examined, so you simply need to expand the size to 3.16 m on each side (there are various ways to lay this out, such as to place meter sticks and pin flags at the module corners). Once laid out, then identify and write down any new species that were not already documented on the Species Diversity Datasheet in the 1.0 m x 1.0 m (depth 3) nested subplot. Instead of writing a “3” in the box for the corner to indicate presence, write a “2” to indicate the depth. (modified from Lee et al. 2008)

Step 5. Collect tree sapling data for the 3.16 m x 3.16 m plot and tally numbers of each tree sapling. Do this in a similar manner to step 3. **Do not** collect any data on **seedlings** (woody plants below 1.37 m tall) for the 3.16 m x 3.16 m nested subplot and only tally saplings which are 0 – 10 cm dbh. Remember that you already tallied saplings in the 1.0 m x 1.0 m nested subplot, so you just need to continue taking that data for the rest of the 3.16 m x 3.16 m nested subplot.

Step 6. Take up all nested subplot markers and repeat steps 1-5 in the second nested subplot for the module.

Step 7. Move on to the whole 10 m x 10 m module, which is called depth 1. Now identify and write down any new species that were not already documented on the Species Diversity Datasheet in the 3.16 m x 3.16 m nested subplot. This time, instead of writing a “2” in the box for the corner to indicate presence at that depth, write a “1” to indicate depth of 1. (modified from Lee et al. 2008). This **step must be completed in 5 minutes or less**. If it is taking longer than that, go ahead and move on to the next module and come back to it last if you have time.

Step 8. Move on to the next 10 m x 10 m module and repeat steps 1-7 until you have completed all 4 modules data collection.

Step 9. After all the nested corner work is complete for all 4 modules, and plants have been documented at depth 1 for each module, cover classes need to be assigned for each plant. Cover classes are assigned to approximate the total percent cover of each plant across all 4 modules, the entire 20 m x 20 m vegetation plot. The cover classes are assigned rapidly using the same percent cover class scale used by NatureServe and the Carolina Vegetation Survey for vegetation plots (Lee et al. 2008, <http://cvs.bio.unc.edu/protocol/cvs-eep-protocol-v4.2-lev1-5.pdf>). These data are recorded as classes which represent ranges of percent cover and will be analyzed using multivariate analysis. The cover classes are as follows; cover class 1=trace, 2=0.1-1%, 3=1-2%, 4=2-5%, 5=5-10%, 6=10-25%, 7=25-50%, 8=50-75%, 9=75-95%, 10= >95%. Canopy percent cover is used, not foliage percent cover. Canopy percent cover is the amount of area of the 20 m x 20 m plot covered by the leaves, stems, and trunks of the species being assessed. The assignment of these cover classes is considered accurate, plus or minus one class. Cover classes should be assigned quickly (Step 9 should be completed in 10 minutes or less). Field workers should not spend time equivocating about which of two cover classes to assign. Cover classes are to be assigned as total cover, **do not** assign separate cover classes for the canopy, subcanopy, shrub and herbaceous (field) strata.

See SOP 14 for additional information on how to deal with species nomenclature issues.

Unknown Plants

If a plant cannot be identified to species quickly and confidently, assign the species a specimen number, record genus or family, if possible, and include a short descriptive name. A secondary goal of monitoring efforts should be to enhance plant species lists for each park. Any unusual plant that is suspected of being new to the site should also be collected. Follow these guidelines to determine whether and how to collect a specimen for subsequent identification:

- Do not collect any plants represented by 3 or fewer individuals (i.e., locally sparse) in the general vicinity of the plot. If a plant is considered locally sparse and there are individuals outside of the plot, consider taking your collection from outside of the plot.
- Do not remove entire plants (including roots) from within the quadrats. If the plant occupies greater than 2 % cover and is sufficiently robust, a portion of the plant may be removed from within the quadrat such that the overall cover of the plant within the quadrat is not significantly affected.
- Anytime it is not possible to collect a specimen, take a photograph instead. Place a ruler in the photograph for scale, and allow the camera to automatically select the appropriate aperture for the given light conditions. Use the Macro setting or Super Macro setting to take detailed close up photographs of smaller plants.

- All specimens or photographs that are collected should be sent to "Curatorial Specialist" Brenda Wells, Mammoth Cave, National Park, P.O. Box 8 Mammoth Cave, KY 42259.

Equipment List

DBH Tape (in cm)
2 Meter sticks
Biltmore stick
Camera
Small binoculars
Hand lens
Tree identification references
Vascular plant identification references
Field protocol manual
Plant press and newspapers (should not be carried in the field)
Zip seal plastic bags
Compass
Datasheets for each type of data collected

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SOP 8: Coarse Woody Debris

Version 0.0 (January 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

Time allotted: 15 minutes

Overview

Coarse woody debris includes downed trees and large branches on the ground. Coarse woody debris accumulates in older forests, where trees are not harvested. In severe storms downed trees add to coarse woody debris. 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. On most forests in the eastern United States, trees are harvested for pulpwood or lumber. On areas which are not subject to timber harvest, the trees contribute to coarse woody debris after they die and fall down. The forests on the lands of the National Park Service include extensive areas where most trees contribute to coarse woody debris at the end of their lives. It is an unusual special natural resource value on these lands. In addition to being a special wildlife resource, measurements of coarse woody debris also quantify a type of forest fuel. Knowing about forest fuel loading on the landscape can enable better understanding of wildland fire risk.

For measuring coarse woody debris, use the 40.0 meter centerline and the 40.0 meter crosstape that were laid out in an east/west and north/south direction when establishing the plot, as described in SOP 3: Site Selection and Plot Establishment.

Step by Step Instructions

Starting at one end of the 40.0 meter centerline, tally each piece of coarse woody debris that intersects with the line and record diameter to the nearest centimeter in the data sheet. To be

tallied in this protocol, the CWD piece must be ≥ 7.5 cm diameter and ≥ 1.0 m long. CWD includes dead trees leaning >45 degrees from vertical, measured along the bole (tree trunk).

CWD does not include:

- a. Woody pieces <7.5 cm (3.0 inches) in diameter at the point of transect intersection.
- b. Woody pieces <1.0 m in length.
- c. Dead trees leaning 0 to 45 degrees from vertical, these are recorded as snags, not CWD.
- d. Trees showing any sign of life.
- e. Stumps that are rooted in the ground (i.e., not uprooted).
- f. Bark that is no longer attached to a bole or limb. (Bark attached to a piece is counted.)
- g. Roots or main bole below the root collar.
- h. Very decomposed logs reduced to slightly elevated ‘humps’ on the ground without structural integrity, and less than 12.7 cm (5.0 inches) in height from the surrounding forest floor
- i. The top of a dead tree if it is partially broken and leaning over horizontal to the forest floor, and there is less than a 50% breakage of the leaning dead top with the appropriate lean

Decay classes adapted from Pyle and Brown 1998 and USFS 2005

Class	Bark	Log shape and integrity	Color of exposed wood	Texture of rotten portions	Primary surface substrate	Branches and twigs
1	Firmly attached	Round and solid. Freshly fallen, intact logs	Fresh color, not stained by weathering	Intact, no rot or conks. Stem decay absent.	Sound, tight bark	Branches retain many small twigs
2	If present, decayed, faded and not firmly attached	Round and solid	May be bleached and relatively smooth (like driftwood)	Mostly intact, sapwood partly soft and starting to decay, but can't be pulled apart by hand	Decayed bark and hard wood - impenetrable with fingernail or pen point, may be case hardened with power wood beneath	Branches retain some small twigs, often with peeling bark
3	Generally absent, except in <i>Betula</i> and <i>Prunus</i>	Round and firm, piece supports its own weight	Reddish-brown, or original color	Hard, large pieces of sapwood can be pulled apart by hand.	Soft wood - will spring back if compressed, easily penetrated with fingernail or pen point	No small twigs, but branch stubs will not pull out
4	Absent	Oval or flattened, no longer a solid piece, though some hard chunks remain. Piece does not support its own weight, but maintains its shape	Reddish or light brown	Soft, small blocky pieces, a metal pin can be pushed into heartwood	Very spongy wood - responds to finger pressure and may exude moisture. Powder wood flows through fingers like coarse sawdust	No small twigs, branch stubs pull out
5	Absent	Quite flat or flat with some rounding. Piece no longer maintains its shape, but spreads out on the ground, is at least 12.7 cm high	Red-brown to dark brown	Soft, powdery when dry	Loosely aggregated powder wood	No small twigs. Branch stubs and pitch pockets have usually rotted down

Other data fields for CWD:

DECAY CLASS: Record the decay class number 1-5, from table (above).

HOLLOW: Write “yes” if log is hollow and could provide cover or habitat for a small mammal.

NOTES. Record anything unusual about the transect placement or the pieces of CWD. If the tree species of the CWD can be easily identified, record that information in this space. Use this space to identify which pieces of CWD are connected to each other, or which diameters were measured from the same piece of CWD, if the same piece crosses a transect more than once.

Step 2. Once finished with the first transect of 40.0 m length, proceed to the 40.0 m crossline transect that was laid out and record all coarse woody debris more than 7.5 cm (3.0 inches) dbh along that transect.

Data Fields:

Transect X length (centerline):	40 meters (Default)
Transect Y length (crossline):	40 meters (Default)

Transect	Diameter	Decay Class	Hollow?	Notes

Equipment List

Meter stick

Biltmore stick

2 50 m tapes, also used for plot set up

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SOP 9: U. S. National Vegetation Classification Measure

Version 0.0 (January 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

Time allotted: 10 minutes

Overview

Ecological communities can change over time, especially as succession, climate change, herbivory pressure, disease, and other factors conspire to change the composition of canopy and understory species. Although these changes occur in most cases very slowly, we would like to document any tipping point at which a community's composition changes enough to call it a different community.

A U. S. National Vegetation Classification (US NVC) association is a vegetation classification unit defined on the basis of a characteristic range of species composition, diagnostic species occurrence, habitat conditions and physiognomy (Jennings et al. 2009). Associations reflect topo-edaphic climate, substrates, hydrology, and disturbance regimes (FGDC 2008).

The U. S. National Vegetation Classification (US NVC) is considered to be the Federal Geographic Data Committee vegetation standard (FGDC 2008). Association units of vegetation have been identified for all the NPS units in the Cumberland Piedmont I & M Network. This work was completed by NatureServe and partners, with support from the NPS.

Background

Vegetation can be quickly identified in the field using a document called a vegetation key. The key provides a series of choices pertaining to the species of trees, shrubs, grasses or other plants found at the location of interest and other characteristics of the site. The user identifies the vegetation by following the choices in the key which match the vegetation and other conditions at the site. Association keys are developed for all the NPS units in the Cumberland Piedmont I & M Network, and are listed in the references for this SOP.

Step by Step Instructions

Step 1. To collect this particular data, stand in the middle of the 20 x 20 meter plot and use the latest US NVC field key for that park (provided to each field team at the beginning of each field week) to determine the US NVC association of the plot. The US NVC association may be fairly stable over time, but in the case of early successional types, the US NVC association may change over time as the stand matures. Vegetation may also change as broad climate changes affect the survival and distributions of plants. In many cases, more than one call will need to be made either because the plot falls in an ecotone between more than one association or there is uncertainty about the vegetation association.

Step 2. The keys for each CUPN park are dichotomous and hierarchical. The user is directed through a number of couplets, starting with couplet 1 and should select whichever side of the couplet (a, or b) fits the vegetation best. The user should read **both** sides of the couplet (both a, and b) before evaluating and proceeding. Answers to couplets will lead to either another couplet to be evaluated in progression or to a vegetation association (final answer). Note that there may be more than one path through the key to arriving at an individual vegetation association.

Keys are imperfect. It is always a good idea to confirm a final keyed answer by reading the corresponding vegetation description corresponding to the keyed type. If an answer seems implausible, one should re-key the stand, examining other possible couplets from those selected the first time through the key. If you do not have access to the classification unit descriptions, this step can wait until you return to the office and look up the full classification report for that park.

Also, if the plot seems to cover more than one community type, then focus on the dominants in each distinct community and come up with a second call or even third call of the vegetation association call if needed. In this case, indicate which module is keyed to which vegetation association.

Finally, we need an idea of both fit and confidence. Fit is interpreted as how well the community type you see on the ground “fits” the key. If you had a difficult time getting to the community type because it didn’t seem to key out easily, then fit might be low for that site. In contrast, confidence is the confidence that you personally have about whether your call on the ground is correct, regardless of how well the concept does or does not fit the key.

Step3: Collect data on physiognomy and classification metadata (See fields below).

Data Fields:

Physiognomy (Forest, Woodland, Shrubland, Herbaceous, Nonvascular, or Sparsely Vegetated)	
US NVC association (First call)	
Fit, first call (1=excellent, 2=good, 3=fair)	
Confidence, first call (1=high, 2=medium, 3=low)	
Classifier initials, first call	
US NVC association (Second call, optional)	
Fit, second call (1=excellent, 2=good, 3=fair)	
Confidence, second call (1=high, 2=medium, 3=low)	
Classifier initials, second call	
US NVC association (Third call, optional)	
Fit, third call (1=excellent, 2=good, 3=fair)	
Confidence, third call (1=high, 2=medium, 3=low)	
Classifier initials, third call	
Final US NVC call (if revised later)	
Fit, final call (1=excellent, 2=good, 3=fair)	
Confidence, final call (1=high, 2=medium, 3=low)	
Classifier initials, date, final call	
Classification revision info (name of reviser, date)	

Equipment List

U. S. National Vegetation Classification key for park used to determine the vegetation association

Tree identification references

U. S. National Vegetation Classification document for the park

References

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SOP 10: Soil Measurements

Version 0.0 (January 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

Time allotted: 20 minutes

Overview

This SOP serves to characterize forest soil nutrients, micronutrients, texture, and other standard soil testing information and their changes over time. This SOP may best capture effects of atmospheric deposition on soil chemistry and provide insight into the soils ability to sustain its current physiognomic structure into the future. This SOP includes a rapid assessment of forest floor condition as well.

Three soil samples approximately 10×10×10 cm in size will be collected every 8 years. Soil samples from different horizons are collected separately.

Regulations Governing Sample Collection

The National Historic Preservation Act of 1966 (as amended) provides for the protection of historical and cultural artifacts. Due to the random placement of the vegetation monitoring plots, a plot may be located on a site of prehistoric or historical significance. Field crews are required to obtain permission to collect soil samples from the park archeologists or cultural resource specialists prior to field visits. If cultural artifacts are encountered at a plot where permission to sample has been granted, do not take a soil sample. Record why a soil sample was not taken.

Definitions

Horizons are layers which develop in soil under the influence of climate, living organisms, and other soil forming factors. Major horizons from top to bottom include the O (organic), A, E (eluviated), B, and C horizons.

Litter is intact or partially decomposed organic material that is easily identified (e.g., leaves, stem, twigs, etc.). Other names for the litter layer include the Oe horizon or the L horizon.

Mineral soil consists predominantly of products derived from the weathering of rocks (i.e., sands, silts, and clays). As soil develops under the influence of climate, living organisms, and other soil forming factors, it typically develops layers or horizons. Typical mineral soil horizons include the A, E, and B horizons.

Step by Step Instructions

Step 1. The soil sampling frames are hypothetical 2 meter radius circles that occur above modules 3 and 4. Locate the soil sampling frames just outside the plot adjacent to modules 3 and 4 (see figure 20). To determine the location of the middle soil sampling frame, extend the line delineating the boundary between modules 3 and 4 another 2 meters slope distance beyond the end of the plot (2 meters beyond the module corner). Place a chaining pin at this point. This is the center of Soil Sampling Frame 2 (see figure 20). If you have already laid out the 40 m coarse

woody debris plot, then use that to measure the diameter of the first circle.

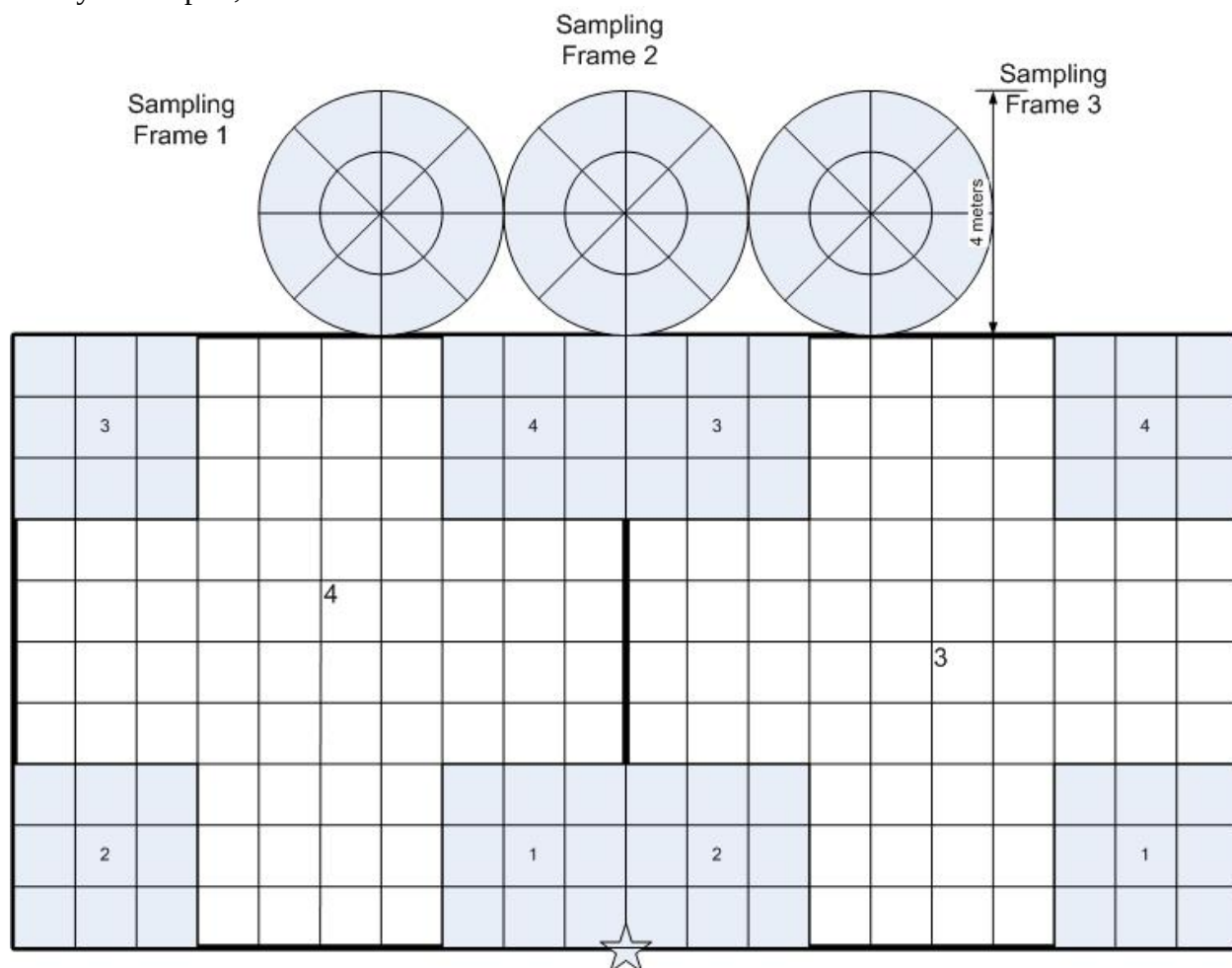


Figure 17. Soil sampling frames in relation to modules 3 and 4.

Step 2. From the first chaining pin, measure 4 m slope distance parallel to the length of the plot in both directions. This is the center of Soil Sampling Frame 1 and 3 (Figure 22). The three chaining pins should be in a straight line.

The soil sampling frames should be free from obstructions (e.g., boulderfields, cliffs, standing water) and generally representative of the forest floor through the plot. Soil sampling frames should not include tree tip-ups, large animal burrows, historic house foundations, fire rings, etc., unless these features are widespread throughout the plot and generally representative of the site conditions. If soil cannot be sampled at this location due to obstructions or site anomalies, abandon these samples and instead choose the area just outside of the plot between modules 1 and 2 and repeat the process above to establish the plots (figure 21). If soil cannot be sampled in that location either, then pick a different location either between modules 2 and 3 or between modules 1 and 4 (see diagram below). In these cases, note the location of the sampling frames in “Frame Location” field on the datasheet.

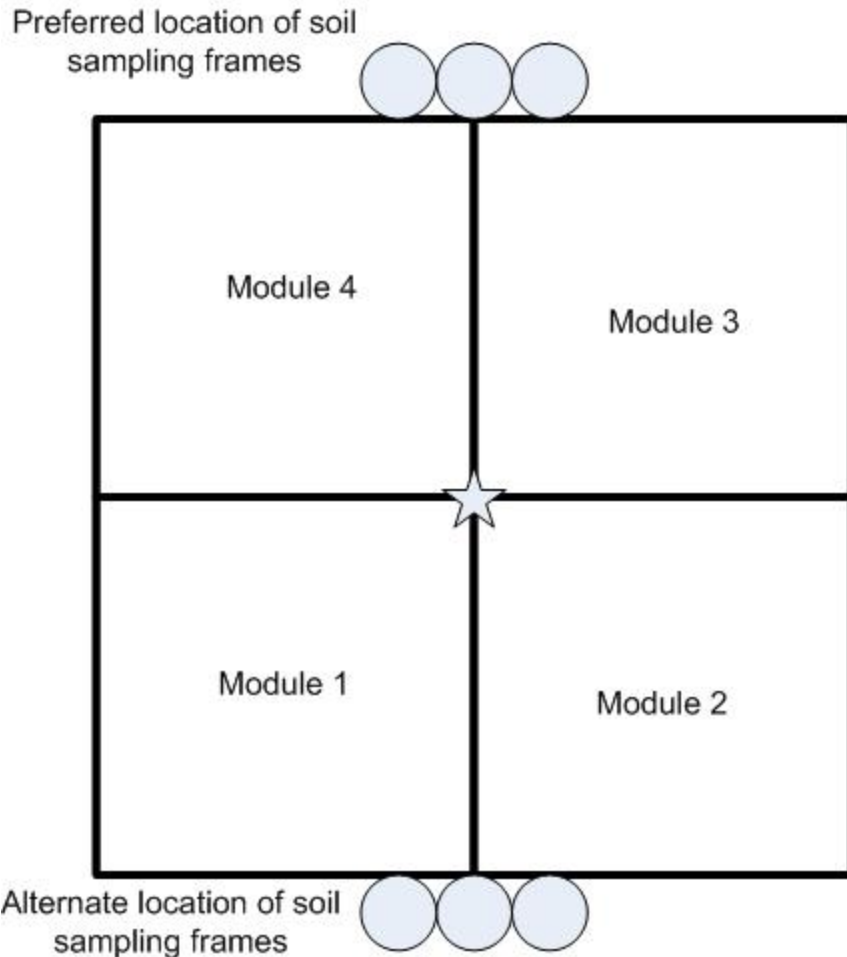


Figure 18. Preferred location of soil sampling frames and alternative location should first location not be feasible.

Step 3. First, select a 10×10 cm area within Sampling Frame 1 to place the sampling quadrat. The objective is to collect a soil sample, so select a location for the quadrat that is relatively free of rocks, roots, or other obstructions that prevent soil sampling. Do not toss the quadrat into the sampling frame to “randomly” decide the quadrat location.

Visually divide the sampling frame into 16 sections as shown on the datasheet (Figure 22). Determine which sector of the sampling frame contains the selected quadrat sampling area. Use the 2 m rope to help determine the sample area sector. Place an “X” on the datasheet in the appropriate sector to indicate the location of the soil sample. Write the last two digits of the current year (e.g. “11”) adjacent to the “X”. Do not place an “X” on any of the lines in the frame diagram; the “X” must be inside one of the sectors.

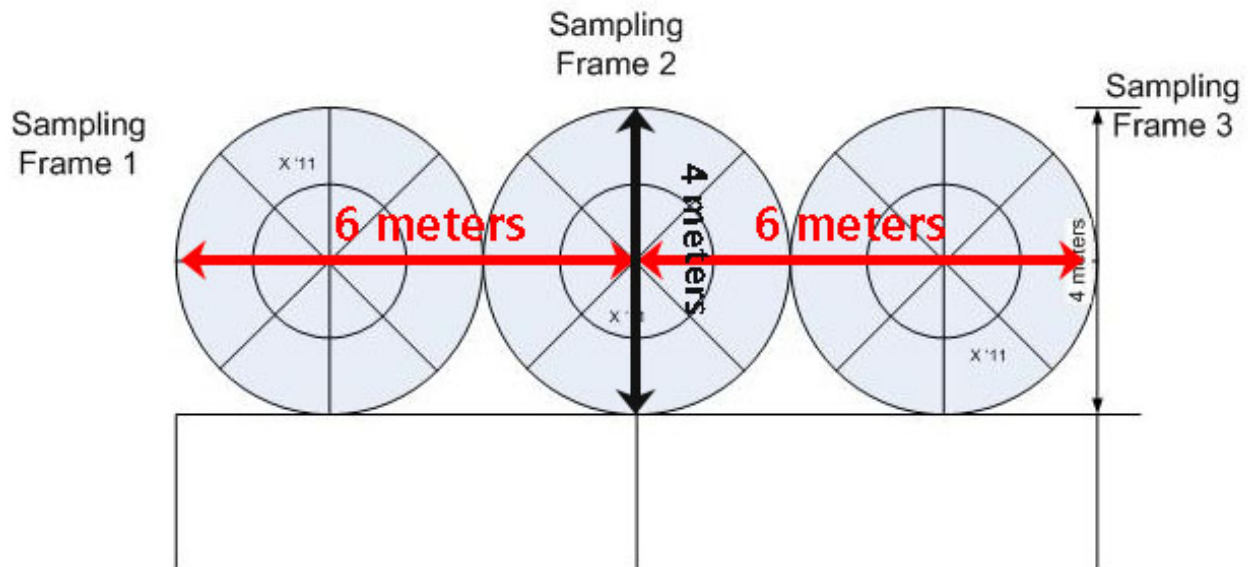


Figure 19. Soil sampling frames with X and year marking each (hypothetical) sample taken in 2011.

In the selected area, place the 10 x 10 cm sampling quadrat carefully on the ground to avoid compacting the forest floor. If the ground is level, select two opposite sides of the quadrat on which to measure litter depth, using a clear ruler. If the ground is sloped, measure the litter depth on the up-slope side and the down-slope side of the quadrat, using a clear ruler. The bottom of the litter layer is distinguished as the boundary where plant parts (e.g., leaves or needles) are no longer recognizable as such because of decomposition. Record the litter layer depth on the data sheet to the nearest 0.5 cm.

Using a pair of clippers, carefully remove all live vegetation from the sample area. Clip living mosses at the base of the green, photosynthetic material. Next, use a sharp knife or keyhole saw to carefully cut through the unconsolidated litter and the forest floor along the inner surface of the quadrat. Then collect all unconsolidated litter (e.g., leaves, bark, wood fragments) within the quadrat. Place the unconsolidated litter in a plastic bag labeled with Collection Date (YYYY-MM-DD), Park (Four letters), Vegetation Monitoring Plot Number, Soil Sampling Frame Number (1, 2, or 3), and Litter, as shown in the following example: GUCO.052, Frame 1, Litter, 2011-JUN-03. If possible, mark both sides of the bag with this information just in case ink on one side runs. Do not remove consolidated litter which has begun to compress and decompose. Do not include any animal scat in the litter sample. Deer droppings can be common and should not be collected.

Once the unconsolidated litter is removed, visually examine the quadrat to assess and record the presence (1) or absence (0) of earthworm casts and burrows. If the examination is inconclusive, record 9.

Next, use a sharp knife or keyhole saw to carefully cut through the consolidated litter along the inner surface of the quadrat to separate it from the surrounding soil. Using inward scooping motions, carefully collect and bag the consolidated organic horizon to expose the top of the mineral soil. Place the organic material in a plastic bag labeled with Collection Date (YYYY-

MMM-DD), Park (Four letters), Vegetation Monitoring Plot Number, Soil Sampling Frame Number (1, 2, or 3), and Horizon (O), as shown in the following example: GUCO.052, Frame 1, O Horizon, 2010-JUN-02. Discard all recognizable woody debris and rocks greater than 2 mm in diameter. This includes pine cones, large pieces of bark, partially decomposed wood, rocks, or pebbles. Soil samples will be sieved in the lab to remove all particles greater than 2 mm in diameter, thus crew members need not spend a lot of time removing all particles from the soil sample in the field. If a trowel was used to collect the O horizon sample, wipe the trowel clean on a rag before collecting the next sample.

Measure to the nearest 0.5 cm the thickness of the O horizon. The O horizon thickness is the distance from the top of the consolidated litter to the top of the mineral soil. The boundary between the O horizon and the underlying mineral soil is detected by soil texture and weight. The O horizon is light in weight and has a greasy feel. The underlying mineral soil may vary in color or have a dark color similar to the O horizon and contain a mix of organic and mineral particles which is heavier in weight and may feel gritty. Record the color of the O horizon (e.g., “dark brown”, “grayish brown”). If there is no consolidated leaf litter, do not collect an O horizon sample, and make a note in Soil Notes.

After collecting the O horizon, use a trowel to carefully remove the mineral soil and place it in a plastic bag labeled with Collection Date (YYY-MM-DD), Park (Four letters), Vegetation Monitoring Plot Number, Soil Sampling Frame Number (1, 2, or 3), and Horizon (A), as shown in the following example: GUCO.052, Frame 1, A Horizon, 2011-JUN-02. Continue carefully removing soil until a color change is observed in the soil. If a color change is observed, expose the soil profile along the edge of the sample area. Examine the exposed profile for distinct color changes that identify the boundary between the A horizon and underlying soil. The E horizon, if present, will be a band of markedly lighter colored soil between the overlying A and underlying B horizons. If no E horizon is present, it may still be possible to note a distinct color change between the dark brown A horizon and the lighter brown or pale B horizon underneath. If the lower boundary of the A horizon is distinct and apparent, carefully measure and record the depth of the A horizon to the nearest 0.5 cm as the distance from the bottom of the O horizon to the top of the B horizon. Record the color of the A horizon (e.g. “light brown”, “dark gray”). Circle “Y” next to “Observed Bottom of A Horizon”. Record the color of the underlying B horizon (e.g. “light brown”, “grayish brown”).

If the lower boundary of the A horizon is not observed, do not collect more than 15 cm in depth of A horizon soil. Measure the depth of the exposed A horizon to the nearest 0.5 cm as the distance from the bottom of the O horizon to the bottom of the soil pit. Under “A Horizon Thickness” on the datasheet, write a “>” symbol before the observed thickness. For example, record “>11.5 cm” if the observed depth of exposed A horizon soil was 11.5 cm. Record the color of the A horizon (e.g. “light brown”, “dark gray”). Circle “N” next to “Observed Bottom of A Horizon”.

If the A horizon is <5cm in depth, carefully measure and record the depth of the A horizon to the nearest 0.5 cm. Record the color of the A Horizon (e.g. “light brown”, “dark gray”). Circle “Y” next to “Observed Bottom of A Horizon”. Wipe the trowel clean on a rag before collecting the next sample. Then, carefully remove the B horizon soil and place it in a plastic bag labeled with

Collection Date (YYYY-MMM-DD), Park (Four letters), Vegetation Monitoring Plot Number, Soil Sampling Frame Number (1, 2, or 3), and Horizon (B), as shown in the following example: GUCO.052, Frame 1, B Horizon, 2011-June-08. Continue carefully removing soil until a maximum depth of 15 cm from the bottom of the B horizon. Record the color of the underlying B horizon (e.g. “light brown”, “grayish brown”). Carefully measure and record the depth of the B horizon to the nearest 0.5 cm. Circle “Y” next to “Collected B Horizon”. Wipe the trowel clean on a rag before collecting the next sample.

Repeat this entire procedure in the remaining two soil sample plots. For each vegetation monitoring plot, take only one set of soil samples in each soil sampling frame (i.e., in each 2-m radius circle).

Note: If a crew member smokes cigarettes or chews tobacco, s/he must wear gloves while handling the soil samples. Soils handled directly by smokers will report artificially high nitrogen levels.

Data Fields:

Soil sample 1:	Soil sample 1	Soil sample 2	Soil sample 3
Litter sample collected:	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
Litter thickness up-slope			
Litter thickness downslope			
*Earthworms present?:	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
O horizon collected?:	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
O horizon thickness			
O horizon color			
A horizon collected	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
A horizon thickness			
A horizon color			
Observed the bottom of A horizon?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
B horizon collected:	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
B horizon thickness:			
B horizon color			
Observed the bottom of B horizon?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
Soil notes (Note which, if any, horizons are absent. If soil was not collected from certain horizons, note why. If it was difficult to find a suitable soil location, record the reason. Record any unusual soil)			

Soil Sampling Procedure on Remeasurement Plots

Soil samples will be measured only every 8 years. On subsequent remeasurements, use the same soil sampling frames. Read the Frame Location notes from the previous visit's datasheet. Reestablish the center points of the three sampling frames at the appropriate location using the instructions from above.

Using the previous visit's datasheet, determine which sampling frame sectors were previously sampled. Select a sector not previously sampled and follow the soil sampling procedure outlined above. Place an "X" on the datasheet in the appropriate section of the soil sampling frame to show the sampling location. Write the last two digits of the current year (e.g. "11") adjacent to the "X". Do not place an X on any of the lines in the frame diagram; the X must be inside one of the sectors.

Sample Drying

Upon return from the field, leave soil sample bags open in a safe location to air-dry until the soil no longer appears moist. Bags should not be sealed until they are dry or else anaerobic activity may bias the sample. To test dryness, gently squeeze the soil through the bag to break clumps, and arrange the sample so it has maximum exposure to the air (fold back the bag lip, move soil out of bag corners, and let the sample lay as flat as possible). For this to work properly, use flexible plastic soil sampling bags that are wider at the opening than they are long. As the soil dries, check and mix the sample by gently squeezing from outside the bag.

Some soil samples may contain considerable moisture from ground water or recent rain. These wet soils will not dry properly in plastic bags. Wet soil samples should be spread out on wax paper or a metal pan to dry completely before being returned to plastic bags. If there is access to a soil drying oven for soils, this would speed the process up and keep from contaminating the soil with mildew and other organisms that might alter the final analysis.

Prior to sending samples to the lab, prepare a master list of sample information. Assign each sample a unique number from 1 to n, and mark this number prominently on the bag (using a different color ink than other info on the bag and circling this number). Create a list identifying which sample number corresponds to which park, plot number, frame number, soil horizon, and date collected. Print a copy of this list for CUPN, and include a copy with the samples when shipped or delivered to the testing lab. Also send a digital copy to CUPN staff.

Sample Analysis

Soil tests will include a determination of soil nutrients, micronutrients, texture, percent carbon, and other standard soil testing information. Brookside Laboratories does soil analysis on samples collected by the Carolina Vegetation Survey and may be a good choice for the work here.

Brookside Laboratories provides some guidance in this document:

http://www.blinc.com/worksheet_pdf/SoilSampleRequirements.pdf

The lab should prepare samples by passing each through a 2 mm sieve to remove larger particles. Analysis should include (list is still undergoing additions and changes):

Total carbon and total nitrogen by dry combustion

NH₄Cl extractable ions including Ca and Al

Sample Archives

When samples are sent to the laboratory, coordinate with the contractor's lab staff to ensure that all unused portions of the samples are retained. Request that all leftover soil be returned in the original bags. Each sample that is returned from the lab should be archived for later analysis. Each soil sample should be placed in a clean, new, pint-sized cardboard ice cream container. The sample label should be written clearly on the container and the lid. Archived samples can be stored at room temperature in a safe location.

Equipment List

Chaining pins
Rag for cleaning trowel
Meter stick
Trowel
Spade with heavy handle
Key saw
Plastic bags with wide tops

References

- Lee, M.T., R.K. Peet, S.D. Roberts, and T.R. Wentworth. 2008. CVS-EEP Protocol for Recording Vegetation, All Levels of Plot Sampling. Version 4.2. Carolina Vegetation Survey. <http://cvs.bio.unc.edu/protocol/cvs-EEP-protocol-v4.2-lev1-5.pdf>
- Perles, S., J. Finley, and M. Marshall. 2010. Vegetation and soil monitoring protocol for the Eastern Rivers and Mountains Network, Version 2. Natural Resource Report NPS/ERMN/NRR-2010/183. National Park Service. Fort Collins, Colorado.
- Tierney, G. and D. Faber-Langendoen. 2007. NETN Forest Vital Sign Protocol, Soil Measurements and Sampling, Version 2.1 in NPS Northeast Temperate Network Long-term Forest Monitoring Protocol. SUNY College of Environmental Science & Forestry and NatureServe. Syracuse, NY.

SOP 11: Data Quality Assurance and Quality Control

Version 0.0 (January 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

Overview

Careful, accurate data collection and stewardship are critical to the success of the vegetation monitoring program. This SOP describes data quality assurance and quality control (QA/QC) procedures for the vegetation monitoring process. Ensuring data quality must be a priority during training, and throughout the data collection, entry, verification, and validation process.

Step by Step Instructions

The lead vegetation ecologist/crew leader is responsible to ensure that all crew members can:

- correctly identify plant species,
- understand all field protocols,
- understand data fields and values on paper field forms and in the database.

Crew members are responsible for learning species identification, field protocols, and all data fields and values on paper field forms and in the database. In addition, each crew member is responsible to do the following whenever they are unsure or unclear about the protocol:

- Do not guess.
- Ask** the crew leader or other crew members.
- Call the supervisor.
- Take copious and clear notes about the uncertainty.
- Follow through to securing guidance and correcting the uncertainty.
- Err on the side of collecting too much data.

Data Collection

Field data is collected by entering data onto a series of paper datasheets. Field data may in the future be collected using handheld devices.

Regardless of the data collection method, all data values shall be called out by the “measurer” and repeated by the recorder when one crew member is measuring and one crew member is recording. The measurer shall clearly call out the value record. The recorder shall clearly repeat the value aloud as it is recorded, to ensure that the value was heard and recorded accurately. If the measurer does not hear a response from the recorder, the measurer shall repeat calling out the measurement until a response is obtained. If the measurer hears a different value from the value measured, the measurer must immediately correct the value.

Datasheets

Carry datasheets within an enclosed clipboard. **Print legibly** all information on datasheets using pencil.

At the end of every plot, before the crew leaves the site, crew members must review all sections of the paper datasheets to ensure all fields are complete and no obvious errors exist. Each data sheet must be reviewed by someone other than the person who originally recorded the data on that sheet. Once it has been determined that the data sheet is complete, a crew member will sign his or her initials in the “DATA QC” box in the upper right hand corner of the page. The most common data omissions are:

- Decay Class for standing snags on the Tree sheet
- Any data associated with the last few trees in the plot
- Coarse woody debris data for both transects

Produce a photocopy, or scanned electronic file (i.e. pdf) of the original paper datasheets on acid-free paper within one week of data collection, and check to ensure all original data are present and legible. Deliver these copies to the Network Data Manager to store them in a building separate from the original datasheets.

Data Entry

If paper datasheets are used, data must be entered into the Vegetation Monitoring Database. The database will incorporate many functions and utilities to help reduce data entry errors such as look-up fields and appropriate upper and lower bounds for fields.

After each section of data is entered, the person entering the data must sign their initials and write the date in the margins of the data sheet using a red pen. If there are any uncertainties about an entry (e.g., data are illegible or inconsistent with the database), **do not guess**. Instead, mark the data sheet with a Post-it Note. Describe the illegible or inconsistent entry on the Post-it Note with an arrow pointing to the questionable item. The crew leader or a supervisor will review and attempt to reconcile these Post-it Note questions before data verification.

Data Verification

Following data entry, network staff will review 10% of all entered data to ensure values present on a representative sample of paper field forms are accurately and completely entered into the

database. After each section of data is verified, the person doing the verification will initial the form and write the date in the data sheet margins using a blue pen. If data verification finds significant problems with the data entry for any one park, this will trigger a full review of all data entered for that park.

Data Validation

Following data verification, summarize and review the data to identify any potential mistakes. Verification can include:

- Run summary, queries, and tallies on the data
- Identify out-of-range values
- Evaluate outliers
- Compare plot location coordinates in database with coordinates in GIS files from GPS unit.

Observer Bias

To determine whether the plots are being measured consistently, we will randomly choose a portion of the plots sampled in each year for a return visit. Before the beginning of each field season, the GIS Specialist will randomly choose two plots in each of three randomly chosen park units (5% of all plots sampled in any given year) to be resampled that field season. The logistics will be worked out through the Network Coordinator, such that a different project leader will be responsible for fieldwork to complete the QA plots, which could involve a contract botanist or exchanging staff between the teams. Each year, a new selection process will take place so that the same plots will not be used every year for data quality assessment. This data will be analysed and compared with the data collected by the primary team to make sure that measurement techniques yield consistent results. If significant discrepancies are noted between the two teams that have measured the same plots, a re-evaluation of sampling techniques and training will be undertaken and adjustments will be made in future years to try to address the discrepancy.

To control trampling impacts, remeasurement should not occur on plots which are particularly sensitive (e.g, high moss cover, steep unstable slopes), and no plot should be measured more than three times in four years.

If consistent observer biases are seen, there are a few options:

- 1) mid season training if the problems are caught early
- 2) renewed focus on training for the measures that were off in future years
- 3) “disqualification” of some data if they are inconsistent between observers.

References

- Chapman, A.D. 2005. *Principles of Data Quality*, version 1.0. Report for the Global Biodiversity Information Facility, Copenhagen. <http://www2.gbif.org/DataQuality.pdf>
- Perles, S., J. Finley, and M. Marshall. 2010. Vegetation and soil monitoring protocol for the Eastern Rivers and Mountains Network, Version 2. Natural Resource Report NPS/ERMN/NRR-2010/183. National Park Service. Fort Collins, Colorado.
- Wagner G. 1999. Basic approaches and methods for quality assurance and quality control in sample collection and storage for environmental monitoring. University of the Saarland,

Centre of Environmental Research, Institute of Biogeography, 66041, Saarbrücken,
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Standard Operating Procedure (SOP) # 12

SOP 12: Data Management

Version 0.0 (January 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

This SOP describes tasks to be performed for data management. The crew leader must check, shortly after the event, that all data management activities have been completed (data have been entered from field forms, GIS data have been processed from GPS units, voucher specimen data have been processed, etc).

Introduction.

There are three database components to manage in vegetation monitoring:

Field Data: MSAccess/NRDT format. This template structure was developed by the NPS-IM Program (NPS 2006) and helps to standardize database development across Networks. The custom tables needed for vegetation communities will be under development in FY10. Databases from other networks (e.g., ERMN) will be used as examples and/or starting points in the development of the database to be utilized by CUPN. Table structure will closely adhere to NRDT standards.

GIS data: ArcGIS format. The spatial component of vegetation monitoring will be managed in ArcGIS with metadata according to procedures outlined in the CUPN data management plan (Moore et al 2005). The GIS layers will be created from the NRDT tables that hold spatial coordinates, tblLocations and tblSites. These tables link to

monitoring events and species data so that spatial queries can be conducted on each park.

Voucher and Archival Data: The Interior Collection Management System (ICMS) format will be used for plant vouchers, photographs, and other archival materials. ICMS is a collection management system for museum collections in all bureaus and units of the U.S. Department of the Interior. It is used to catalog objects, specimens, and archival materials. This is the NPS museum standard and will be followed according to guidelines established by that program. Plant specimens, digital photographs, and archival material will be handled according to procedures established in the NPS museum handbook. Final storage location will be at NPS-park designated repositories using loan agreements where needed or with NRInfo.

Data Entry, Verification, Validation.

Field monitoring will involve one week at each park, annually, during May through August. Before leaving the fieldsite, the field crew leader will check the field data forms for completeness and accuracy. Following completion of the review, hardcopy sampling forms and voucher specimens/photographs will be submitted to the CUPN office at Mammoth Cave, Ky. The data manager/interns will recheck the data forms for accuracy, and will then enter data into the MS Access database designed in 2011 to capture our data. Once all the data are entered, a random 10% will be compared to hardcopy forms (verification) by data manager and specially designed queries/forms/reports will be used for a validity check (validation) by project leader to find erroneous entries. After certifying the validity of the data content for each sampling *trip* (i.e., Event Group), the data will be appended to the master, validated dataset, which is located in the project's Validated_Data folder. The CUPN biological/curatorial specialist will handle the voucher specimen data entry into ICMS, and the CUPN GIS specialist will process the ArcGIS layers with metadata.

Database Administration

Data Maintenance

Datasets are rarely static. They often change through additions, corrections, and improvements made following the archiving of a dataset. There are three main caveats to this process:

- *Only make changes that improve or update the data while maintaining data integrity.
- *Once archived, document any changes made to the dataset.
- *Be prepared to recover from mistakes made during editing by keeping backup copies in the data archive from previous editing sessions.

Any editing of archived data is accomplished jointly by the project leader and data manager. Every change must be documented in the edit log and accompanied by an explanation that includes pre- and post-edit data descriptions.

Data Organization

CUPN has established a template directory structure, composed of seven folders and four subfolders for each vital sign monitoring project that we plan to undertake (Figure 24). Project files which are being modified, considered draft, and/or certain files currently in use (e.g., a copy of the field data form) should reside within this directory. A similar directory structure will contain archived files (\CUPN_Archive\). Both the working and archive directories will be accessible via the MACA Local Area Network (LAN), with access permissions maintained by the data manager(s) and/or MACA Information Technology (IT) Staff.

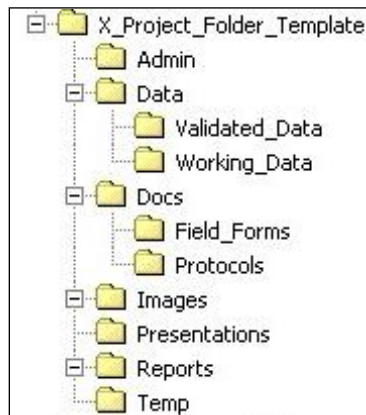


Figure 20. Data folder structure

The data tables utilized for data entry and validation reside within the “Working_Data” folder. Once data in these tables are validated by the project leader, the data manager will append the records to the data tables in the “Validated_Data” folder and the “working” data tables will be emptied. As indicated, the data tables containing the master protocol-specific data for the project are contained in the “Validated_Data” folder. These data have been validated and are available as read-only except to CUPN data manager.

Data Security and Integrity

As many different users will be accessing the database, it is imperative that the data remain secure. Although MS Access provides a means for allowing User-Level Securities to different groups of uses, CUPN staff have determined that it will be more effective to create user groups within the local area network operating system that will have different security levels. Generally, three levels of users will be given different sets of permissions. CUPN staff will have all permissions, including insert, delete, and modify for all folders in the folder structure. Project leader/network manager will have the same permissions as the data manager except for read-only permission to the shared data tables and archived data. Those entering the data will have insert and modify permission to the observation data and read-only permission to the lookup and shared data tables.

Version Control

Prior to any major changes of a dataset, a copy is stored with the appropriate version number. This allows for the tracking of changes over time. With proper controls and communication, versioning ensures that only the most current version is used in any analysis. Versioning of archived datasets is handled by using a file name with data in the following format

(YYYYMMDD). Frequent users of the data are notified of the updates, and provided with a copy of the most recent archived version.

Data Logs and Backups

Once the data are archived, any changes made to the data must be documented in an edit log. From this point forward, original field data forms should not be altered. Field forms can be reconciled to the database through the use of the edit log. Secure data archiving is essential for protecting data files from corruption. Once a dataset has passed the specified QA/QC procedures, the data manager will make a formal entry in the IM NRPortal. Subsequently, an electronic version of the dataset is maintained in a read-only format on the program server. Incremental or differential tape backups of all project databases are regularly conducted. Backup copies of the data are maintained in a secure alternate location.

IV. Data Availability

In addition to the “standardized” data dissemination strategies noted in Chapter IX of the DMP, data will be made available for research and management applications on request (per the framework established in the DMP). Data requests should be directed to the CUPN Program Manager.

References

- Moore, W. J., R. Byrd, and T. Leibfreid. 2005. Data management plan for the Cumberland Piedmont Network and Mammoth Cave National Park Prototype monitoring program. USDI National Park Service. Mammoth Cave, KY. 81pp.
- NPS, Washington Support Office, Inventory and Monitoring Program. 2006. Natural Resource Database Template Revised Documentation. National Park Service. Fort Collins, CO.

SOP 13: Analysis and Reporting

Version 0.0 (January 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

Key Products:

Summary and Scorecard of Data Collected for Vegetation Communities (published for each park every 2 years)

Status Report on Vegetation Communities (published for each park and the network every 4 years)

Key Tools:

Statistical package such as R (to be selected in 2011)

Database (Microsoft Access) – Database core based on the I&M Programs Natural Resource Database Template (NPS 2007).

Tools for summarizing data

This SOP describes how data collected as part of this project are processed, how ecological integrity is assessed, and how change analysis is conducted using data collected as part of this project. This section will continue to be edited throughout 2011 and 2012 as we begin data collection and refine our methods for summarizing and analyzing data. CUPN staff will use data collected on quantitative measures to keep track of and report out on statistically significant changes over time in measures park-wide. In addition, CUPN staff will use a combination of collected data, models, and expert opinion from literature and personnel to interpret key metrics and choose cutoffs for each metric that assign values of “Good”, “Caution”, and “Significant Concern” for forested ecosystems.

Data Analysis Flow Diagram

Draft 1.0 Wednesday, February 23, 2011

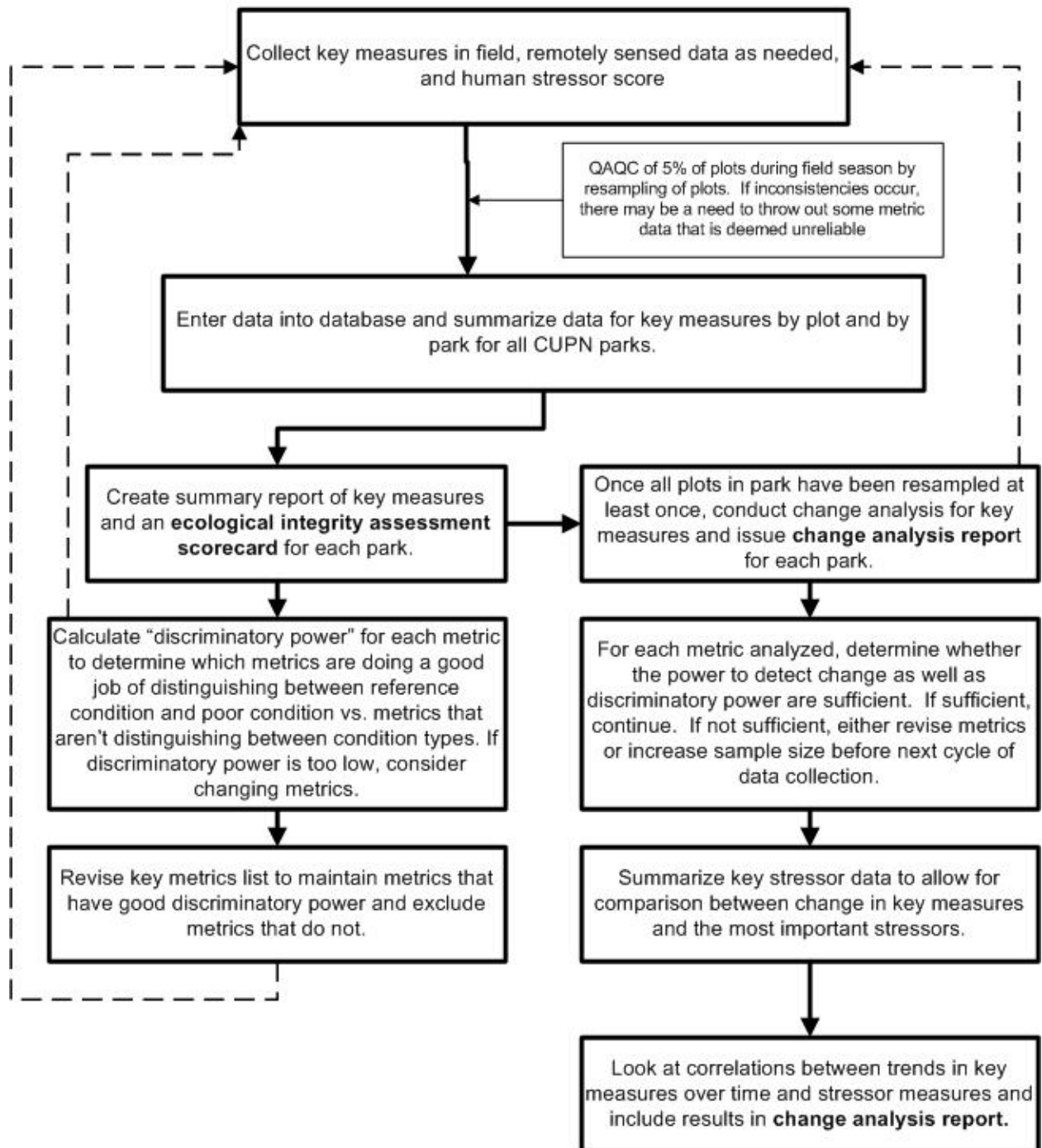


Figure 21. Sample flow chart for handling data summary and analysis for the CUPN vegetation monitoring project.

Although we have not yet finalized the details of the approach, figure 25 broadly illustrates the overall concept behind 1) developing a scorecard with summary information about each park's forested communities and 2) reporting out on change over time in key metrics.

Ecological Integrity Scorecard/ Summary

The specific measures that will be summarized and reported on every two years as part of the scorecard are outlined in this SOP with steps for calculating both the quantitative measures and the EIA scores based on acceptable or desired ranges of variation for each metric. Much of this work is based on information received from the Northeast Temperate Network's vegetation monitoring group (Tierney et al. 2009). For the EIA scores, the acceptable or desired ranges of variation have been derived from knowledge of the natural or historical range of variation for each metric, or in some cases, trend towards or away from perceived natural or historic conditions. The interpretation of ecological integrity is a useful but developing conservation application, and ratings should be reviewed and updated as new information becomes available. A scorecard format is outlined in this SOP that may serve to clearly and concisely report the integrity of CUPN forests to intended audiences (see table 14).

The concept of "ecological integrity" has been used as a tool to measure the health of ecosystems and the effectiveness of land management actions upon those ecosystems (Karr 1993, Woodley 1993, Tierney et al. 2009). Building upon the related concepts of biological integrity and ecological health, ecological integrity is a broader and more useful conceptual endpoint for ecological assessment and reporting (Czech 2004). "Integrity" is defined as the quality of being unimpaired, sound, whole or complete. To have integrity, an ecosystem should be relatively unimpaired and complete across a range of characteristics and scales (DeLeo and Levin 1997). "An ecological system ... has integrity ... when its dominant ecological characteristics (e.g., elements of composition, structure, function, and ecological processes) occur within their natural ranges of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human disruptions" (Parrish et al. 2003).

Selecting Metrics for EIA

The first step in determining ecological integrity is identifying a limited number of key attributes or metrics of an ecosystem that best differentiate between a highly impacted/degraded state and a relatively unimpaired, complete and functioning state. Key attributes may be properties that typify a particular ecosystem (Keddy and Drummond 1996, Parrish et al. 2003) or attributes that change predictably in response to anthropogenic stressors (Karr and Chu 1999). The suite of attributes (see Appendix B) selected should be comprehensive enough to incorporate composition, structure and function of an ecosystem across a range of spatial scales (Andreasen et al. 2001).

A conceptual ecological model delineating known linkages between key ecosystem attributes and stressors is a useful tool in identifying and interpreting metrics. CUPN has relied on overarching forest ecosystem models developed in the CUPN Monitoring Plan (Leibfreid et al. 2005) to identify key attributes and stressors and understand agents of change acting upon terrestrial ecosystems (see discussion about stressors in main document). Justification for the selection of each metric is included below within the Metrics and Ratings section.

Rating Metrics

A second step in determining ecological integrity is distinguishing acceptable from undesired condition for each metric. Determination of acceptable versus undesired conditions should consider both current management goals as well as natural or historic variability. CUPN parks are managed for a variety of values, both cultural (historical) and ecological. For some metrics, it is unrealistic or impossible to expect "natural" ecological condition at these small cultural parks.

However, there are several reasons to consider natural or historic variability in determining acceptable condition. First, estimates of historical or natural variation in ecosystem attributes provide a useful reference for gauging impacts of current anthropogenic stressors. Second, it has been proposed that maintaining historical or natural variation provides a coarse-filter approach for sustaining biological diversity in the absence of full understanding of stressor impacts, particularly on less well known species (Hunter et al. 1988). Third, management within natural or historic variability often is easier and requires fewer external inputs and unforeseen side-effects than management outside the natural bounds of the ecosystem (Allen and Hoekstra 1992). Finally, the concept of natural or historic range variability recognizes the inherent natural variation in ecosystems across space, time and ecological succession and incorporates this variability into the development of acceptable conditions (Landres 1999).

Of course, current knowledge of historic or natural conditions is limited. Insight into natural or historic conditions comes from historical studies and records, paleoecological reconstructions of past conditions, current studies of relatively pristine ecosystems, and efforts to model ecosystem dynamics. While all these efforts provide useful insight, our understanding of historic or natural conditions in many ecosystems relies on a limited number of key studies, and care must be taken when applying data from these studies to other sites. **For these reasons, ratings should be reviewed and updated as our knowledge of the historic or natural variation and ecosystem response to perturbation increases over time.**

Following the NPS national Vital Signs rating system, three ratings are used - Good, Caution and Significant concern. "Good" represents acceptable or desired conditions; "Caution" indicates a problem may exist; "Significant concern" indicates undesired conditions in need of management correction. For several metrics, we have not defined conditions that merit "significant concern" either because more research is needed, or to provide natural resource managers with greater flexibility to balance the potential conflict between cultural values and ecological integrity at this group of small and primarily cultural parks.

Summary Data and Scorecards

CUPN will use a combination of 1) data summaries of quantitative data and 2) ecological integrity scorecards to clearly and concisely report ecological integrity to a wide audience. A successful ecological scorecard should transparently convey status and trend in key ecological parameters in a way that is meaningful to the public, managers and other stake-holders (Harwell et al. 1999)

We developed a scorecard reporting framework (Table 14) that heavily borrows from the Northeast Temperate Network model (Tierney et al. 2007) to visually convey status and trends in

each metric of integrity. This symbology uses color to convey integrity rating - Good, Caution and Significant concern are conveyed respectively as green, yellow or red circles - and uses an embedded arrow to convey the direction of trend observed across sampling intervals (increasing, stable or decreasing). For transparency, actual data values will be reported in addition to ratings.

Table 14. Example of a biannual ecological integrity scorecard for terrestrial forested ecosystem (ratings are only for demonstration purposes)

Metric type / Ecological Attribute	Metric	Rating for Park
Landscape Context and Size	Landscape Connectivity	Good
	Patch size	Good
Structure	Vegetation structure	Caution
	Stocking index	Good
	CWD Volume	Caution
Composition	Biotic homogenization / FQI	TBD
	Indicator exotic plant species richness	Good
	Forest pest species presence	TBD
	Tree growth and mortality rates	TBD
	Soil chemistry - acid stress	Significant Concern
Function	Soil profile disturbance and soil chemistry	Caution

Metrics and Ratings

Metrics and ratings are summarized in Table 15. The quantitative measures behind these metrics are used both to populate the scorecard/summary for each park and to determine change over time in key measures. The text that follows provides an overview, justification, calculation description, scaling rationale, and suggested level of confidence for each metric.

Table 15. Summary of draft metrics with ratings for CUPN parks (full descriptions of each metric continue below the table.

	Metric	Ecosystem	Rating		
			Good	Caution	Significant Concern
Biotic condition	Tree regeneration/deer browse	Forest (Upland and Wetland)	Seedling ratio ≥ 0	Seedling ratio < 0	Stocking index outside acceptable range (< 25)
Biotic condition	Tree growth and mortality	Forest (Upland and Wetland)	Growth $\geq 60\%$ mean and Mort $\leq 1.6\%$	Growth $< 60\%$ or Mort $> 1.6\%$	
Biotic condition	Tree condition	Forest (Upland and Wetland)	Foliage problem $\leq 10\%$ AND no HWA, BWA, BBD, BC, ALB, EAB, SOD	Foliage problem 10-50% OR HWA, BWA, BBD, BC	Foliage problem $\geq 50\%$ OR ALB, EAB, SOD
Biotic condition	Snag abundance	Forest (Upland and Wetland)	$\geq 10\%$ standing trees are snags and $\geq 10\%$ trees of > 25 cm dbh are snags	$< 10\%$ standing trees are snags OR large snags underrepresented	< 5 med-lg snags/ha
Biotic condition	CWD Volume	Forest (Upland and Wetland)	$\geq 15\%$ live tree volume	$< 15\%$ live tree volume	
Biotic condition	Biotic homogenization / floristic quality	All	No increasing trend of biotic homogenization and Ave. coefficient of C > 3	Increasing trend of biotic homogenization and ave. coefficient of C between 1.5 and 3	Ave. coefficient of C < 1.5
Biotic condition	Indicator species – invasive exotic plants	All	No high priority invasive exotic species in plot	1 to 3 high priority invasive exotic species in plot or $> 10\%$ relative cover of exotic species in plot.	4 or more high priority invasive exotic species in plot or $> 25\%$ relative cover of plot
Biotic Condition	Stand structural class	Varies by type	Late-successional	Mid-successional	Early successional
Abiotic condition	Soil chemistry (optional)	All	Additional research needed	Additional research needed	Additional research needed
Abiotic condition	Soil layering	All	Additional research needed	Additional research needed	Additional research needed
Landscape Context	Landscape connectivity	All	Core area (100 ha) and supporting area (1000 ha) are at least 90% non-human influenced.	Core area (100 ha) is 90% “non-human influenced” but supporting area is less than 75% “non-human influenced”	Core area is less than 90% “non-human influenced” or supporting area is less than 75% non-human influenced
Size	Patch size of occurrence	All	> 50 hectares contiguous forest/woodland	1-50 hectare contiguous forest/woodland	Less than 1 hectare contiguous forest/woodland

Change Analysis

The goal of the ecological integrity/summary report is to give readers a snapshot of the condition status of a community at any given time. In addition to knowing status, managers also need to

understand trends (i.e., is the measure indicating stability, decline, or increased health over time). To document trends over time, we will use repeat visits to the same plots to look at change over time and to develop reports that illustrate the overall trends for key measures over time. Although this process is not fully fleshed out at the moment, our team will work over the next four years to fully develop our approach of change detection and document that approach in future iterations of this protocol.

Metrics Discussion

Tree Regeneration Metric / Deer Browse Metric

Overview: This metric assesses the quantity and composition of advance tree regeneration in the forest understory. Tree seedlings and saplings (>5 cm tall) are quantified by species and size class in eight 1.0 m² nested subplots within the larger full plot. This metric should be used for forest sites only.

Metric Justification: Shade tolerant forest trees typically regenerate from seedling banks of advance regeneration present in the forest understory prior to disturbance. The quantity and species composition of advance regeneration will impact future canopy structure and composition. Regeneration can be affected by a variety of stressors, including air pollution, invasive exotic pressure, disturbance regime disruption, and climate change. Most notably, sustained, selective browsing by a historically high population of white-tailed deer is currently impacting seedling establishment, growth and composition in many parts the US (Gill 1992, Rooney 2001, Russell et al. 2001, Cote et al. 2004). Significant impacts on forest tree regeneration are associated with deer densities of greater than 8.5 per km², well above presettlement estimates of 3-4 deer per km² for the northeast US and Eastern US in general. (Russell et al. 2001, Augustine and DeCalesta 2003).

Calculation and Scaling Rationale: Within CUPN forests, deer most likely selectively browse seedlings of preferred species that are at least 30 cm and less than 75 cm tall (Gill 1992, Kay 1993, Cornett et al. 2000). Sweetapple and Nugent (2004) developed a simple ratio of seedling diversity in browsed and unbrowsed size classes to assess ungulate impacts of forest understories. Adapting this approach for CUPN forest monitoring, a simple ratio of seedling species richness in heavily browsed size classes (50 - 137 cm tall) versus shorter size classes (5-50 cm tall) of preferred species will serve as an indicator of impacts on tree regeneration. Browse impacts on tree regeneration vary with species tolerance to browsing, and also with deer browse preference which varies seasonally and regionally. Potential deer browse impacts on tree species are estimated as High, Medium, and Low and are found on our comprehensive species list. Most species rated Medium are not preferred, but can be heavily browsed when other choices are not available. Using only species with High to Medium deer impact ratings, the ratio is calculated as:

$$(\text{tall}-\text{short})/(\text{tall}+\text{short})$$

where *tall* and *short* are species richness, respectively, of tall (50-137 cm) and short seedlings (5-50 cm) of browsed species.

While this seedling ratio approach can be useful in detecting moderate impacts due to deer browsing, it will be less effective at detecting severe browsing impacts, which are likely to affect even seedlings < 50 cm tall, as well as impacts on tree regeneration from other stressors, such as air pollution and climate change. An alternative approach by McWilliams et al. (2005) quantifies whether current seedling quantities are sufficient to restock a forest stand with canopy trees. Their index, called the stocking index and developed for hardwood stands in Pennsylvania, awards and sums points for seedlings by size class within 2-m radius circular microplot. Over the next two years, we will be developing a stocking index for stands in CUPN based on stocking

indices calculated in the region for high quality reference sites and low quality highly disturbed sites. Only seedlings of native species that typically form the high canopy in forested sites are counted (Table 16); this excludes shrub species such as *Vaccinium* spp. (blueberry species), *Amelanchier* sp. (serviceberry), *Cercis canadensis* (redbud), *Carpinus caroliniana* (American hornbeam), *Cornus florida* (flowering dogwood), and *Ostrya virginiana* (hornbeam), in addition to *Crataegus* sp. (hawthorns), *Hamamelis virginiana* (witchhazel), and exotic species such as *Lonicera* spp. (bush honeysuckles), and *Ligustrum sinense* (Chinese privet).

Good = Seedling ratio ≥ 0

Caution = Seedling ratio < 0

Sig Concern = Stocking index < 25

Confidence: Medium. Metric should be tested and fine-tuned. McWilliams et al. (2005) developed their stocking index for PA hardwood stands subject to harvest, so it must be refined to apply to CUPN systems.

Table 16: Potential deer browse impact to tree species

Species	Potential Deer impact (combination of Deer Preference and Plant Tolerance to Deer Herbivory)	Source (see footnotes)	Note
Cucumbertree (<i>Magnolia</i> <i>spp.</i>)	High	2	
Eastern hemlock (<i>Tsuga</i> <i>canadensis</i>)	High	2	
Flowering dogwood (<i>Cornus florida</i>)	High	1	
Hackberry (<i>Celtis</i> <i>spp.</i>)	High	3	In Piedmont bottomlands
Red maple (<i>Acer rubrum</i>)	High	2	
Sassafras (<i>Sassafras</i> <i>albidum</i>)	High	1	
Sugar maple (<i>Acer</i> <i>saccharum</i>)	High	2	
Tulip poplar (<i>Liriodendron tulipifera</i>)	High	2	
Ashes (<i>Fraxinus</i> <i>spp.</i>)	Medium	2	High preference but medium browse tolerance
Black gum (<i>Nyssa</i> <i>sylvatica</i>)	Medium	3	In Piedmont bottomlands
Black walnut (<i>Juglans</i> <i>nigra</i>)	Medium	1	
Elms (<i>Ulmus</i> <i>spp.</i>)	Medium	1	
Hickories (<i>Carya</i> <i>spp.</i>)	Medium	2	High preference but

Species	Potential Deer impact (combination of Deer Preference and Plant Tolerance to Deer Herbivory)	Source (see footnotes)	Note
			medium browse tolerance
Oaks (<i>Quercus spp.</i>)	Medium	2	High preference but medium browse tolerance
Sycamore (<i>Platanus occidentalis</i>)	Medium	3	In Piedmont bottomlands
Witch hazel (<i>Hamamelis virginiana</i>)	Medium	1	
Beech (<i>Fagus grandifolia</i>)	Medium/Low	2	Medium preference but high browse tolerance
White pine (<i>Pinus strobes</i>)	Medium/Low	1	Low choice but heavily browsed if needed
Black cherry (<i>Prunus serotina</i>)	Low	2	
Black locust (<i>Robinia pseudoacacia</i>)	Low	1	
Hop hornbeam (<i>Ostrya virginiana</i>)	Low	1	
Ironwood (<i>Carpinus caroliniana</i>)	Low	1	
Red cedar (<i>Juniperus virginiana</i>)	Low	1	
Sweetgum (<i>Liquidambar styraciflua</i>)	Low	3	
1 NYS DEC. A preference list of winter deer foods. http://www.dec.state.ny.us/website/dfwrnr/wildlife/deer/foodlist.html 2 USFS 2003. Forest inventory and analysis. Northeast Field Guide, Version 1.7, App. 12. 3 Castleberry et al. 1999. Deer browse preferences in a southern bottomland hardwood forest. S. Jour. App. Forestry. 23 (2)			

Tree Growth and Mortality Metric

Overview: Canopy tree growth and mortality rates provide an integrative, quantitative metric of tree health and vitality. Relative basal area growth rate (% basal area / year) of canopy trees is calculated from repeated measurements of bole diameter at breast height (dbh) measurements. Annual mortality rate (% stems / year) of canopy trees is also calculated from repeated observation.

Metric Justification: Tree growth rates can decline in response to environmental factors or anthropogenic stress, and tree mortality is often preceded by some years of reduced tree growth (Ward and Stephens 1997, Pedersen 1998, Dobbertin 2005). Tree basal area stem growth is affected by stress sooner than more critical growth of foliage or roots (Waring 1987), and is more straightforward to measure. Decreased growth or elevated mortality rate in trees of a particular species can indicate a particular health problem for that species, such as sugar maple decline (Duchesne et al. 2003, Hyink and Zedeker 1987); while altered vital rates for multiple species across a region may indicate regional environmental stress (Steinman 2004, Dobbertin 2005).

Calculation and Scaling Rationale:

Typical growth and mortality rates vary by site, stand structural stage and by tree species, size and crown class (i.e., tree position in the canopy). For this reason, vital rates will be calculated by species and plot using only canopy trees (e.g., dominant, co-dominant or intermediate crown class) in stands that have succeeded to a mature or late-successional stage (see structural stage metric).

Relative basal area growth rate (% basal area / year) has been shown to be a useful predictor of tree mortality risk (Bigler and Bugmann 2003, Bigler et al. 2004). It will be calculated from successive dbh measurements as the percent change in basal area converted to an annual basis. For each live canopy tree, growth rate (*GR*; % basal area / year) is calculated as:

$$GR = ((BA_{t2} - BA_{t1}) * 100) / (BA_{t1} * \text{time})$$

where BA_{t2} and BA_{t1} are, respectively, basal area (m^2) for the present cycle and the previous cycle, and *Time* is the duration (years) between measurements. For each canopy tree, basal area (BA in m^2) is calculated from dbh (cm) as:

$$BA = \pi * (\text{dbh} / (2 * 100))^2$$

Growth rate is then averaged for canopy trees across the plot, and also by species within the plot.

Choosing an appropriate reference for tree growth rate is complicated by variation in growth rate across regions, stand structural stages, species and tree crown class. Steinman (2004) reported net growth rates for forests in the northeastern US from USFS Forest Inventory and Analysis (FIA) data, using 5 categories: > 2, 2.0-1.6, 1.5-1.1, 1.0-0.6, and <0.6 %, with the first class considered good and the lower classes indicating cause for concern. As part of our ongoing work, CUPN staff will look at USFS FIA data for the Southeast to help interpret relative ecological integrity.

Annual mortality rate (*MR*; % stems / year) is calculated from successive observations as the percent of stems that died during an interval converted to an annual basis. This rate should be calculated for each plot, and also for individual species within a plot as:

$$MR = (\text{Stems_died}_{t1-t2} * 100) / (\text{Stems_alive}_{t1} * \text{Time})$$

where $\text{Stems_died}_{t1-t2}$ is the number of stems that died during a measurement interval, and Stems_alive_{t1} is the number of stems that were alive during the measurement prior to the interval.

Typical annual tree mortality rates in old-growth forest range from 0.3% to 1.6% (Busing 2005, Runkle 2000, Woods 2000).

Good = Growth rate $\geq$ 60% of mean for region or species and Mortality rate $\leq$ 1.6 %; for plot and all individual species

Caution = Growth rate $<$ 60% of mean for region or species or Mortality rate $>$ 1.6%; for plot or any individual species

Tree Condition

Overview: Qualitative observation of specific tree health problems and canopy foliage condition can provide an early warning indicator of problems or decline in canopy trees of a particular species or region. Some prominent exotic forest pests already established in or near CUPN parks include dogwood anthracnose (*Discula destructiva*), chestnut blight fungus (*Cryphonectria parasitica*), and hemlock woolly adelgid (*Adelges tsugae*). Other pathogens and insects such as sudden oak death (*Phytophthora ramorum*), emerald ash borer (*Agrilus planipennis*), Asian longhorned beetle (*Anoplophora glabripennis*), and European gypsy moth (*Lymantria dispar*) may pose significant future threats to CUPN parks.

Metric Justification: Several exotic pests and pathogens are seriously impacting forest composition or structure in CUPN parks. The hemlock woolly adelgid (HWA) has caused widespread and rapid mortality of hemlock across the eastern US since introduction here in the 1950s, and threatens to rapidly and substantially reduce or eliminate eastern hemlock throughout much of its range, especially at Cumberland Gap NHS (Orwig et al. 2002).

An exotic scale insect has caused the widespread occurrence of beech bark disease (BBD) throughout the northeast. Caused by the interaction of this insect and a native fungus, beech bark disease has caused substantial mortality to American beech throughout the region, though most immature and some mature trees have some resistance to the disease. In areas of high beech mortality, increased sprouting of beech suckers can dramatically alter forest structure (Le Guerrier et al. 2003).

Butternut (*Juglans cinerea*) is being killed throughout its range by an exotic fungus that causes butternut canker (BC) (Furnier et al. 1999). Butternut is now far less common than it was even two decades ago because of the high mortality associated with this fungus.

Several other species pose grave threats if they advance into the region. The Asian longhorned beetle (ALB) poses an enormous threat to maple and other species if it invades rural and forested areas from its current documented occurrences in and near New York City and other East Coast

and Midwest locales (Haack et al. 1997). Likewise, the emerald ash borer (EAB) is of high concern, though it has not yet been documented in any CUPN parks, it has been found near Abe Lincoln Birthplace and Boyhood Home in northern Kentucky and in northern Middle Tennessee near Interstate 65. It quickly kills all native species of ash, and will have dramatic impacts as it continues to spread into the southeastern United States (BenDor et al. 2006).

Finally, the fungal pathogen that causes sudden oak death (SOD) has been reported to be present on Long Island, NY, and could have dramatic impacts on oaks and other trees if it spread down the east coast (Venette and Cohen 2006).

If a forest pest or pathogen that is new to the park being monitored is detected, or suspected of occurring, a specimen of the pest, or a photo of the pest or symptoms should be made. These vouchers should be provided as quickly as possible to:

Kurt Helf, Invertebrate Ecologist
Mammoth Cave National Park
P.O. Box 8,
Mammoth Cave, KY 42259

This information can then be used to help with the early detection of forest pests.

This metric also assesses canopy foliage in canopy trees (e.g., dominant, co-dominant or intermediate crown class). As the season progresses, most trees will develop minor foliage problems (e.g., insect damage, chlorosis, etc.). However, more extensive damage to canopy foliage is indicative of tree health problems within a species or across a region.

Calculation and Scaling Rationale:

Specific tree health problems and the condition of canopy foliage are qualitatively observed. For each tree, the amount of canopy foliage affected by various foliar problems (insect damage, chlorosis, etc.) is visually estimated within broad classes (0-10, 10-50, 50-90 and 90-100%). To assess EI, specific health problems are tallied per plot, and foliage condition class is averaged across trees with a stand overall, as well as by species within the plot. Good condition is defined as minor foliage problems averaged across a stand and within individual species (represented by at least 2 individuals), and no evidence of damage by these specific invasive exotic pests and pathogens. More extensive foliage problems (10 - 50%) or evidence of damage by one of several invasive exotic pests and pathogens already widespread in the CUPN region (HWA, BWA, BBD, BC) indicate some cause for concern. Foliage damage above 50% averaged across a stand or within an individual species (represented by at least 2 individuals) indicates a more serious problem. Likewise, evidence that certain invasive exotic pests and pathogens of high concern for extensive mortality to trees (ALB, EAB, SOD) have reached CUPN forests indicates a significant concern which might still be controlled by management action.

Good = Average foliage problem $\leq 10\%$ and no HWA, BWA, BBD, BC, ALB, EAB or SOD
Caution = Average foliage problem 10 - 50 % for stand or species or evidence of HWA, BWA, BBD or BC

Sig. concern = Average foliage problem $\geq$ 50% for stand or species or evidence of ALB, EAB or SOD

Confidence: Medium. New exotic pests and pathogen threats to our forests arise with increasing frequency. This list of key health problems should be regularly reviewed and updated. The recognition of some specific forest health problems can readily be taught to seasonal staff (e.g., HWA, BBD). Other forest health problems will have a lower probability of detection by seasonal staff (e.g., ALB, EAB and SOD). Analysis must consider that foliage damage will typically increase as the field season progresses.

Snag abundance and Coarse Woody Debris Volume

Overview: Dead wood, in the form of standing dead trees (snags) and fallen coarse woody debris (CWD) are important structural features of forest stands that provide habitat for wildlife and fungi. This metric assess the density of snags and volume of CWD in relationship to live tree density and volume.

Metric Justification: Snags and CWD provide important habitat for arthropods, herptiles, birds, small mammals and fungi. Snag retention is important for the federally endangered Indiana bat. Snags are particularly important for cavity-nesting birds, and the density and size of snags is indicative of habitat availability for those species (Dickson et al. 1983, Zarnowitz and Manuwal 1985, Schreiber and deCalesta 1992). Coarse woody debris is particularly important for herptiles and small mammals (DeGraaf and Rudis 1986, Petranka et al. 1994). Coarse woody debris continues to be used by wildlife as it breaks into smaller pieces over time, thus CWD volume can be a useful indicator of habitat availability. Large diameter snags persist longer than smaller diameter snags (Morrison and Raphael 1993, Garber 2005) and provide habitat for a greater number of vertebrate species (Conner et al. 1975, Cline et al. 1980, DeGraaf and Shigo 1985). Silviculture, land management and hazard tree removal can reduce the quantity or quality of these features; however, thoughtful land management can maintain or enhance snags and CWD (Keeton 2006).

Calculation and Scaling Rationale: Density of snags and volume of CWD in mature and late-successional stands varies substantially across ecosystems and with site conditions (Tyrrell et al. 1998). However, positive relationships between live and dead tree density and volume can be used to indicate expected snag and CWD levels (Sippola et al. 1998, Ferguson and Archibald 2002, Stewart et al. 2003).

For snags, Nilsson et al. (2003) have calculated a ratio of 1:9 standing dead:live trees for the boreal forest, while Ferguson found about 15% of standing trees were dead in the boreal forest. Goodburn and Lorimer (1998) report that 11% and 16% of standing trees were dead, respectively in MI/WI northern hardwood and hemlock northern hardwood stands. Since larger diameter snags tend to persist longer than smaller diameter snags (Garber 2005) and some studies report snag diameter distributions in late-successional stands which meet or exceed live tree diameter distributions (Goodburn and Lorimer 1998, Spetich et al. 1999, Nilsson et al. 2003), we can expect that these relationships should hold for large snags. Thus we can suggest both overall

(>10 cm dbh) and medium-large (≥ 30 cm dbh) snag density should be at least 10% of overall and medium-large live tree density.

To develop a minimum snag density requirement, we reviewed recommendations based on land management and wildlife needs. Keddy and Drummond (1996) suggest at least 4 large (>50 cm) snags per 10 hectares for temperate deciduous forest. Other recommendations range from 0.35 to 2.5 large (>45 cm) snags per hectare to support wildlife (Tubbs et al. 1987). These recommendations suggest a minimum of at least 5 medium and large snags per hectare.

To calculate snag density, the number of snags within a plot is summed, and converted to a per hectare basis as:

Snags / Plot_size

where *Snags* is the number of snags in a plot and *Plot_size* is the plot size in hectares (.04 for a 15-m or 20-m square plot).

For snags,

Good = At least 10% of all standing trees are snags and at least 10% of all medium-large (≥ 30 cm dbh) standing trees are snags

Caution = Less than 10% of standing trees are snags or large snags underrepresented relative to live trees

Sig. concern = Fewer than 5 medium-large snags (≥ 30 cm dbh) per hectare

Huber's formula can be used to estimate CWD volume from line intersect transect data using the diameter of each CWD piece measured at the point of intersection with the transect line

(Marshall et al. 2000). This formula can be simplified to calculate CWD volume per hectare (m^3 / ha) as:

$$(\pi^2 / (8 * \text{Horiz_length})) * \sum \text{Diam}_i$$

where *Horiz_length* is the horizontal length of the transect in meters and *Diam_i* is the recorded diameter in centimeters of each piece of coarse woody debris. Please note that conversion factors for length (10,000) and areal units (also 10,000) have canceled out of this simplified equation and thus are not shown.

However, this calculation must be slope-corrected by converting the slope-length of each line intersect transect (15 m) to its equivalent horizontal distance (Van Wagner 1982). Inserting a correction factor into the formula above allows calculation of CWD volume per hectare (m^3 / ha) as:

$$\text{CWD} = \pi^2 (\text{Sqrt}(1 + (\% \text{Slope} / 100)^2) / (8 * \text{Slope_length})) * \sum \text{Diam}_i$$

where *%Slope* is slope percent of the transect rounded to the nearest 5%, and *Slope_length* is the slope length of the transect in meters (i.e., 15 m).

This calculation must be made for each of the two transects in a plot. Then, CWD volume per hectare at each plot is calculated as the average from both transects in a plot.

For comparison and rating, a simple, conservative estimate of live tree (stem and branches ≥ 10 cm dbh) volume will be made from individual tree measurements and stand height using the geometric formula for a paraboloid. This calculation is conservative because volume from both stem and branches (≥ 10 cm diameter) should exceed paraboloid volume; this will provide additional confidence that ratings of caution or significant concern are warranted. While more nuanced equations exist for calculating stem volume from dbh and height measurements for different species, those equations do not include volume of large branches. Thus, those more complex calculations are unlikely improve accuracy in this case.

Tree volume (v in m^3) is calculated for each live tree in the plot as:

$$v = (\text{dbh} * h_c) / 400$$

where dbh is the diameter at breast height of the tree (cm), and h_n is an estimate of tree height (m) from stand height adjusted for tree canopy position. For codominant trees, h_c is equivalent to measured stand height. For dominant trees, intermediate and sub-canopy trees, respectively, h_c will be estimated as 1.1, 0.8 and 0.5 stand height, respectively.

Volume of all live trees in the stand is then summed and converted to a per hectare basis to yield an estimate of stand volume (V in m^3/ha):

$$V = \sum v_i / \text{plot_size}$$

where plot_size is the plot size in hectares (0.04 for a 20-m square plot).

Volume of dead wood in boreal stands has been reported to range from about 20-40% of total (live and dead) wood volume (Linder et al. 1997, Kuuluvainen et al. 1998, Siitonen et al. 2000, Sippola et al. 1998, Karjalainen and Kuuluvainen 2002), of which about 70% is downed CWD (Siitonen et al. 2000, Sippola et al. 1998). Stewart et al. (2003) found dead wood to be 20-28% of live tree volume in late-successional hemlock-spruce-pine and northern hardwood stands, of which about 70% was downed CWD.

For CWD

Good = CWD volume $\geq 15\%$ of live tree volume

Caution = CWD volume $< 15\%$ of live tree volume

Confidence: Medium. Since CUPN plots are not designed to pick up rare features such as snags, snag abundance should be evaluated at the scale of the park only. Some forested systems within CUPN parks are relatively young, and will likely fall short of late-successional CWD and snag benchmarks for some time.

Biotic Homogenization and/or floristic quality

Overview: Biotic homogenization is the process by which regional biodiversity declines over time due to the addition of widespread exotic species as well as the loss of native species (Olden & Rooney 2006). This metric assesses homogenization of forest and woodland biotas by calculating trend over time in Jaccard's similarity index.

Metric Justification: Recognition of the extent, magnitude and implications of biotic homogenization due to human activities is growing (Lockwood & McKinney 2001, Olden 2006). Homogenization occurs when regional floras become more similar due to the addition of widespread exotic species as well as the extirpation of endemic species. While this process has occurred in the geologic past, most notably when previously separate land masses have become contiguous, activities of modern humans have dramatically increased the rate of biotic homogenization (McKinney & Lockwood 1999). This process is driven both by the spread of invasive exotic species associated with human activity, as well as by physical and environmental habitat modification by humans including landuse and climatic change. Tracking the extent and magnitude of biotic homogenization over time provides a useful metric indicative of the effect anthropogenic change is having upon regional biological diversity.

Floristic quality has been used in the Midwest, Northeast, and Southeastern states to more reliably capture decreases and increases in “quality” of vascular plant flora. It attempts to quantify “conservativeness” of the flora of a plot or sample area and can be used to monitor areas to see changes over time.

Calculation and Scaling Rationale:

CUPN will calculate an average Jaccard's similarity index of the total species composition for each plot, as compared to every other plot within the park (Olden & Poff 2003). For any two sites, Jaccard's index is defined as the ratio between species present at both sites (intersection) divided by the total species present at either site (union). The index (J) will be calculated as:

$$J = \frac{|x_i \cap x_j|}{|x_i \cup x_j|}$$

where x_i is the plot in question, x_j represents another plot within the park, and n is the total number of plots at the park. Jaccard's index ranges from 0 (representing no species in common) to 1 (all species in common). Trend will be determined by comparing Jaccard's index between successive measurements.

Good = No increasing trend of homogeneity, average coefficient of $C > 3$

Caution = Trend of increasing homogeneity, average coefficient of C between 1.5 and 3

Sig Concern = Average coefficient of C less than 1.5

Confidence: Medium. Metric should be assessed for sensitivity and fine-tuned when trend data area available.

Indicator Species - Invasive Exotic Plants

Overview: This metric assesses the presence of key invasive exotic plant species within CUPN exotic plant species within NETN forested, woodland and successional ecosystems.

Metric Justification: The effects of invasive exotic species on the structure, composition and function of natural systems have become a chief concern of ecologists and land managers of the last 20 years due to the growing number of species successfully exploiting and altering native habitats (Drake et al. 1989)

Calculation and Scaling Rationale: The average number of key invasive exotic plant species is summed by plot, then averaged across the park. Indicator species were selected based on their potential threats (Miller et al. 2010) and presence data within the the CUPN units (extracted from the NPSpecies database).

Good = No key invasive exotic species present in plot

Caution = 1 to 3 invasive exotic species present in plot or at least 10% relative cover of invasive exotic species compared with total cover of all species in plot

Sig Concern = 4 or more key invasive exotic species present per plot or 25% relative cover of invasive exotic species compared with total cover of all species in plot

Table 17. High priority invasive exotic plant species of CUPN (first draft)

Scientific name	Common name	Habitat
<i>Ailanthus altissima</i>	Tree-of-heaven	Edges, rock outcrops, forest gaps
<i>Albizia julibrissin</i>	Mimosa	Edges and forest interiors
<i>Alliaria petiolata</i>	Garlic mustard	Forest and open habitats
<i>Celastrus orbiculata</i>	Oriental bittersweet	Edges and forest interiors
<i>Centaurea biebersteinii</i>	Spotted knapweed	Open habitats, meadows
<i>Cirsium vulgare</i>	Bull thistle	Open habitats, meadows
<i>Clematis terniflora</i>	Autumn clematis	Wetland and upland forests, edges
<i>Elaeagnus pungens</i>	Thorny elaeagnus	Disturbed forests
<i>Elaeagnus umbellata</i>	Autumn olive	Disturbed forests
<i>Euonymus alata</i>	Burning bush	Forest and successional habitats
<i>Euonymus fortunei</i>	Climbing euonymus	Forest and successional habitats
<i>Ligustrum sinense</i>	Chinese privet	Wetland and upland forests, edges
<i>Lonicera fragrantissima</i>	Breath-of-spring	Open and forest habitats
<i>Lonicera japonica</i>	Japanese honeysuckle	Forest and successional habitats
<i>Lonicera maackii</i>	Amur honeysuckle	Forest and successional habitats
<i>Microstegium vimineum</i>	Japanese stiltgrass	Open and forest habitats
<i>Miscanthus sinensis</i>	Chinese silvergrass	Open and forest habitats

<i>Nandina domestica</i>	Nandina	Open and forest habitats
<i>Paulownia tomentosa</i>	Princess tree	Open and successional habitats, disturbed forests
<i>Sorghum halepense</i>	Johnson grass	Open and successional habitats
<i>Spiraea japonica</i>	Japanese meadowsweet	Open and forest habitats
<i>Rosa multiflora</i>	Multiflora rose	Open and successional habitats
<i>Wisteria floribunda</i>	Japanese wisteria	Open and successional habitats
<i>Wisteria sinensis</i>	Chinese wisteria	Open and successional habitats

Confidence: Medium. The list of key invasive exotic species should be reviewed and updated periodically by CUPN staff and park natural resource managers.

Stand Structural Stage

Overview: This metric assesses the structural stage distribution of forest stands in relation to the expected distribution under natural disturbance regimes. It provides an indicator of altered disturbance regimes, and habitat availability for species dependent on specific structural stages. Stand structural stage is assessed from tree size and canopy position measurements.

Metric Justification: At landscape scales, the distribution of stand structural stage affects the maintenance of biological diversity, particularly of species dependent upon specific structural stages. As multiple stressors including global change and exotic pest and pathogen outbreaks alter disturbance regimes (Dale et al. 2001), structural stage distributions are likely to shift.

Calculation and Scaling rationale: Stand structural class is calculated for each plot from tree size and canopy position measurements using a method similar to that of Frelich and Lorimer (1991) but substituting basal area for exposed crown area (Goodell 2004). Stands are classified as pole, mature, late-successional stage or mosaic based on relative basal area of live canopy trees within pole (10-25.9 cm dbh), mature (26-45.9 cm dbh) and large size (≥ 46 cm dbh) classes. This calculation uses only canopy trees as defined by tree crown class (dominant, sub-dominant or intermediate but not sub-canopy). Trees within the open-grown crown class are also excluded to avoid mis-interpreting early-successional stands dominated by a few, large open-grown trees as late-successional.

To calculate this metric, begin by calculating basal area (BA in m^2) for each live canopy tree in a plot from *dbh* (diameter at breast height in cm):

Next, relative basal area per size class is calculated for the stand by summing the BA of canopy trees within each dbh size class (pole, mature and large as defined above), and then dividing by the total basal area of the plot.

Finally, stand structural stage is assigned to the plot based on the relative basal area distribution as follows:

Pole stage: $\geq 67\%$ BA in pole plus mature sizes, with more basal area in pole than mature size

Mature stage: $\geq 67\%$ BA in pole plus mature sizes, with more basal area in mature than pole size
or $\geq 67\%$ in mature plus large size, with more basal area in mature than large size

Late-successional stage: $\geq 67\%$ BA in mature plus large sizes, with more basal area in large than mature size

Mosaic: Any stand not meeting the above criteria

For oak-hickory forests, Lorimer and White (2003) suggest that multi-cohort stands may have occupied 25 - 40% of the landscape. Park rating is interpreted from ratings of dominant ecosystems at each park.

Good = At least 25% late-successional stand structure, respectively in oak-hickory dominated forests

Caution = Less than 25% late-successional stand structure in oak-hickory dominated forests

Confidence: Medium. Metric can be fine-tuned over time as more data becomes available.

Soil chemistry – acid stress (optional)

Overview: The molar ratio of calcium to aluminum (Ca:Al) in soil or soil solution has been developed as an indicator of acidification stress to forest vegetation (Cronan and Grigal 1995)

Metric Justification: Acidic deposition acidifies soil, leaching important base cations (e.g., Ca^{2+} , Mg^{2+} , K^+) from the soil and increasing availability of aluminum; this deprives vegetation of necessary nutrients, and increases availability of a toxin (Al^{3+}). Broad-scale patterns of wet deposition across the east are well characterized (Driscoll et al. 2001). However, substantial additional acidity can result from dry and occult deposition, and these patterns of deposition are not well characterized.

Calculation and Scaling Rationale: Ca:Al ratio is calculated as the molar ratio of NH_4Cl -

extractable ions (Ca^{2+} and inorganic charged Al). Ca and Al data are typically reported as mg/kg of sample or mg/L of extractant; data reported thus will need to be converted to molar concentrations by dividing each concentration by the molar mass of the element in question (40.08 g/mol for Ca; 26.98 g/mol for Al). The Ca:Al ratio is then calculated as the simple ratio of the molar concentrations.

Cronan and Grigal (1995) critically reviewed the literature to determine the utility of Ca:Al ratio in soil solution as an ecological indicator of acid stress to vegetation. Based on this review, they estimated a 50% risk of adverse impacts on growth or nutrition across a wide range of tree

species when the soil solution Ca:Al ratio is as low as 1.0. However, sensitivity to acid stress varies among species, and Cronan and Grigal (1995) note impacts have been reported at higher Ca:Al ratios for red oak (4-5), sugar maple (2.5), and several conifers (>1); Decker and Boerner (1997) reported a Ca:Al ratio of 4.0 depressed growth, production and nutrient uptake in tulip poplar. Driscoll et al. (2001) suggest that Ca:Al ratio can recover over time if acid deposition levels are reduced, and Ca:Al ratio can be used to judge ecosystem recovery.

For practicality, we will assess exchangeable Ca:Al from soil samples rather than directly sampling soil water. The former is related but not identical to the latter (David and Lawrence 1996) and soil exchangeable Ca:Al ratio been used as a surrogate indicator (Lyon and Sharpe 1999, Wargo et al. 2002). Calcium and aluminum vary substantially through the soil profile (Yanai et al. 2005). Vegetation will be most affected by the Ca:Al ratio of soil in contact with fine roots, the bulk of which are found in the O and A horizons (or in the upper soil depth if not separated by horizon).

Good = Ca:Al ratio $\geq$ 4.0 in O and A horizons or in upper depth

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

Sig. concern = Ca:Al ratio $\leq$ 1.0 in O or A horizon or in upper depth

Confidence: Medium. Spatial and temporal variation in soil properties are typically quite high and may impede detection of significant trends. Yanai et al. (2005) have shown that small differences in separation of soil layers between years are likely to impact Ca:Al ratios.

Soil structure/layers (optional)

To be developed at some future date.

Landscape connectivity/anthropogenic landuse

Overview: This metric assesses the percentage of land in anthropogenic vs. natural landuse in the local neighborhood (50 ha.) of each forested plot.

Metric Justification: Habitat loss and fragmentation have synergistic, cumulative impacts upon remaining natural areas. As more habitat is lost, the remaining fragments become more important to remaining wildlife populations, and are also more likely to be isolated and impacted by surrounding anthropogenic landuse. The Heinz Center (2002) calculated similar neighborhood statistics on immediate (2 ha), local (65 ha) and larger neighborhoods (5000 ha). We will at least plan on assessing at the 50ha and 100 ha scales.

Calculation and Scaling Rationale: Calculation of the percentage of land within the local neighborhood (a 400 m circle from plot center) in anthropogenic vs. natural landuse is made using a combination of the vegetation maps and NLCD as described in the Landscape Context SOP. Plantations of native species will be considered natural landuse, while plantations of primarily exotic species will be considered anthropogenic landuse.

Percolation theory offers a framework for assessing the combined impacts of habitat loss and fragmentation (O'Neill et al. 1997). Simulations show a marked increase in the likelihood of continuous habitat corridors existing in a landscape that has more than 60% natural cover (Gardner et al. 1992).

Good = 10% or less anthropogenic landuse

Caution = 10 - 40% anthropogenic landuse

Sig. concern = 40% or more anthropogenic landuse

Confidence: Medium. This metric may be more relevant at the scale of the park, while forest patch size (above) may provide more useful information at the scale of the plot. It is not clear whether fields that are kept open by mowing but not cropped (and provide habitat for grassland birds) should be considered natural or anthropogenic landuse.

Patch Size

Overview: Forested areas throughout the Southeast within a matrix of managed, rural, and suburban habitat that limit the ability of species to freely forage, interbreed and disperse, and create "edge" habitats which differ from forest interior in environmental conditions, structure and composition and disturbance.

Metric Justification: A large and growing body of scientific literature documents the negative impacts of habitat fragmentation on biodiversity in a wide variety of ecological systems (Fahrig 2003). The impacts of fragmentation have been especially well documented upon avian communities, and population declines of a variety of forest interior avian species are linked to habitat fragmentation (Rich et al. 1994, Austen et al. 2001, Boulinier et al. 2001). In general, large forest patches tend to support larger populations of fauna and more native, specialist, and forest interior species (Harris 1984, Forman 1995).

Calculation and Scaling Rationale: Contiguous forested patch size surrounding each plot is calculated in hectares using GIS as described in the Landscape Context SOP.

Kennedy et al. (2003) reviewed the literature on minimum patch area for a variety of taxa and found minimum patch areas ranged up to 1 hectare for invertebrates, up to 10 hectares for small mammals, up to 50 hectares for the majority (75%) of birds species, and up to over 200,000 ha for large mammals. Since few large mammals are documented to exist in the relatively small parks of this network, ratings herein are based on the needs of birds, small mammals and invertebrates.

Good = At least 50 hectares

Caution = Less than 50 hectares

Sig concern = Less than 1 hectare

Confidence: Medium. While patch size and fragmentation impacts on particular species have been well documented, developing an overall rating for an ecosystem or group of ecosystems is more complex, and may be refined over time.

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SOP 14: Recording Species Nomenclature and Reference

Version 0.0 (January 2011)

Revision History Log:

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #

Introduction

A high quality plot record is based on a high level of confidence in the species list **as a whole**, particularly for the dominant or most common species. It is not required to have **every single** species identified with high confidence, although having every species identified to species is helpful when looking at species diversity and biotic homogenization metrics.

Regardless of one's ability to put a scientific name on a plant, one should always put a name on every distinct plant species seen. If necessary, use ad hoc names such as "*Carex* fuzzy red base" and "*Carex* green base". This is more useful than lumping them together into simply "*Carex* spp". This requires you to suspect these are two distinct species. This approach is important to provide an accurate account of species diversity.

Collect plant specimens, as needed, to help correctly identify the species back in the office. Use your best judgment as to when collecting is most valuable. **Do** collect all unknown species which are dominant or common in a plot. It may be possible to find that same unidentified plant, nearby but outside the plot. If you are confident that it is the same plant as what was identified in the plot, collecting from outside the plot will help maintain the integrity of the vegetation plot for long-term monitoring purposes.

In the field

Whenever a species name is written on a field form, the presumption is that you are reasonably certain of the name. For each species, please use the 7-8 letter code that corresponds to the full scientific name for that species (see full list of all species for CUPN parks for more information on the codes). The code consists of the first 4 letters of genus and first 3 letters of species for the genus and species of that plant plus an extra fourth letter or number as a “tiebreaker” where two species have similar names. When in doubt or in a hurry, write the full scientific name with no abbreviations. No other variations will be accepted. Use neat block letters. If the person doing data entry cannot read your writing, then the data quality is undermined and the work is wasted. Some plant species have identical codes, so the full species names must always be written out (i.e. *Acer saccharum*, *Acer saccharinum*, *Carya ovata*, *Carya ovalis*, *Polygala nuttallii*, *Polytaenia nuttallii*, *Polygonum hydropiper*, *Polygonum hydropiperoides*, *Polygonum virginianum*, *Polypodium virginianum*, *Quercus marilandica*, *Quercus margarettae*).

If the team leader is not comfortable with the use of 7 letter codes, then always spell out the entire genus and species name. If the genus begins “Poly...” it is a good idea to spell out the entire genus and species names. Subspecies are typically **not** required for this project. Your team leader may provide additional guidance on this.

There may be times when you may be less certain of the name. The following provides guidance on how to record levels of uncertainty.

Record your level of confidence in the species identification for each plant.

Your confidence in the identification is independent of the level of taxonomic specificity. You could be very confident in a plant identified only to family, (e.g. Species = Orchidaceae; Confidence = C) because you are sure that it is in that family, but have no idea which genus it is. Similarly, you could be not very confident in a genus- or species-level identification (e.g. Species = *Dryopteris* sp.; Confidence = U) for obscure, small, or un-collectable individuals (table 18).

Table 18. Confidence Level Codes

Certain	The person(s) making the taxon interpretation has a high confidence in the accuracy of the field or herbarium identification.	C
Probable	The person(s) making the taxon interpretation has a moderately high confidence in the accuracy of the field or herbarium identification, but uncertainly is typically recorded as “cf” or “?” (e.g., taxon is most likely the species named; occasionally another taxa may be listed as a possibility –it can be named in a comments field)	P

Uncertain	The person(s) making the taxon interpretation has only moderate confidence in the accuracy of the field or herbarium identification, as shown by “??” or other comments about uncertainty. (For example, taxon may be one of two or more species and although one name is chosen, it could as easily be another.)	U
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Also include indicators of uncertainty in how you write the species name, as follows:

Simply record “CORNFOE” or “*Cornus foemina*” if species level is certain, and “*Cornus* sp.” if only genus level is certain. If you’re not certain of the species identification, give some indication of your uncertainty using the confidence level codes:

If the specimen might be one of two or a few species, record the two or three that it might be. Indicate, if possible, which one is most likely. If you’re not sure, indicate that as well. For example, *Viola* spp. (*conspersa* or *rostrata*)

If there are several distinct species within a genus, and you are uncertain of their name, but you can clearly see they are distinct, do use ad hoc names to separate them, such as “*Carex*- fuzzy red base” vs. “*Carex* - green base”. They will be entered as *Carex* sp. 1 and *Carex* sp. 2 along with your description.

If you don’t know the genus or species, record family if known. Beyond family, simply use broad growth forms, such as *tree* sp., *shrub* sp., *herb* sp., *aquatic* sp., *moss* sp., *lichen* sp., *algae* sp., or *vine* sp. Record some additional note characterizing the plant. *Shrub* sp (opp lv).

Where there is uncertainty noted with the species identification, as indicated by “cf.” or “?” in the species names, or by other comments, use the **Confidence Level** field to record that the identification is **Probable**.

Where there is greater uncertainty indicated, e.g., multiple species are listed, even though one is designated as the primary name, record the identification as **Uncertain**. Field crews should always indicate which name is primary, if more than one is listed.

Follow a Nomenclature Standard

Species names must follow a nomenclature standard. The project standard is the Integrated Taxonomic Information System (<http://www.itis.gov/>). The standard is referenced or cited as:

Retrieved [month, day, year], from the Integrated Taxonomic Information System on-line database, <http://www.itis.gov>.

The nomenclature standard will be recorded on the field data sheets, i.e. ITIS Retrieved [month, day, year] and will have to be enforced as part of the data quality assurance / quality control.

This can include both use of the standard in the field, as well as in the data entry and project data management. The implementation of the nomenclature standard will promote efficient project data analysis and reporting. The project data can be brought up to date, to the current standard on a regular basis, perhaps annually or once every several years. Before the project dataset is updated to new nomenclature, the old dataset must be saved and archived.

At the end of the field day, or later in the office, be sure to review your list and make the nomenclature and levels of certainty as clear as possible.

Appendix D: Field DataSheets.

See PDF document.

Appendix E: “Field Guide” to CUPN Potential Forest Pests, Pathogens and Invasive Exotic Plant Species of Concern

See separate PDF document.

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

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