



Vegetation and Soil Monitoring Protocol for the Eastern Rivers and Mountains Network, *Version 2*

Natural Resource Report NPS/ERMN/NRR—2009/XXX



ON THE COVER

View of the New River from Long Point in the New River Gorge National River.

Photo Credit: S. Perles.

Vegetation and Soil Monitoring Protocol for the Eastern Rivers and Mountains Network, *Version 2*

Natural Resource Report NPS/ERMN/NRR—2009/XXX

Stephanie Perles², James Finley¹, Matthew Marshall²

¹Pennsylvania State University
School of Forest Resources
302 Forest Resources Building
University Park, PA 16802

²National Park Service
Eastern Rivers and Mountains Network
403 Forest Resources Building
University Park, PA 16802

June 2009

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

The National Park Service, Natural Resource Program Center publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate high-priority, current natural resource management information with managerial application. The series targets a general, diverse audience, and may contain NPS policy considerations or address sensitive issues of management applicability. All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received formal, high-level peer review based on the importance of its content, or its potentially controversial or precedent-setting nature. Peer review was conducted by highly qualified individuals with subject area technical expertise and was overseen by a peer review manager.

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

This report is available from the Eastern Rivers and Mountains Network (<http://science.nature.nps.gov/im/units/ERMN/>) and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/NRPM>).

Please cite this publication as:

Perles, S., J. Finley, and M. Marshall. 2009. Vegetation and Soil Monitoring Protocol for the Eastern Rivers and Mountains Network, Version 2. Natural Resource Report NPS/ERMN/NRR—2009/XXX. National Park Service. Fort Collins, Colorado.

NPS XXXXXX, June 2009

Contents

	Page
Figures.....	v
Tables.....	vii
Appendixes	ix
Acknowledgements.....	xv
Executive Summary	xvii
Background and Objectives	1
Background and History	1
Rationale for Monitoring this Resource	3
Measurable Objectives.....	4
Sampling Design.....	7
Sampling Design Rationale	7
Site Selection	7
Sample Frequency and Replication	10
Recommended Number of Sampling Sites.....	13
Detectable Levels of Change	14
Field Methods	17
Plot Design.....	17
Details for Taking Measurements.....	18
Data Handling, Analysis, and Reporting	21
Metadata Procedures.....	21
Overview of Database Design	21
Data Entry, Verification, and Editing.....	21
Recommendations for Routine Data Summaries and Analysis	21

Recommended Reporting Schedule and Format	22
Data Archival Procedures	23
Personnel Requirements and Training	25
Roles, Responsibilities, and Qualifications	25
<i>Plant Ecologist</i>	25
<i>Vegetation Crew Leader</i>	25
<i>Field Crew Members</i>	26
<i>ERMN Data Manager</i>	26
<i>ERMN Network Coordinator</i>	26
<i>Training Procedures</i>	26
Operational Requirements	27
Annual Workload and Field Schedule	27
Facility and Equipment Needs.....	27
Startup Costs and Budget Considerations.....	27
References.....	29

Figures

	Page
Figure 1. Location of parks in the Eastern Rivers and Mountains Network.	1
Figure 2. Plot design for ERMN Vegetation Monitoring protocol.	18

Tables

	Page
Table 1. Information on the regular grid of sample points created for each park's sampling design.	9
Table 2. Area of vegetation types and land uses in ERMN parks.	11
Table 3. Schematic for a four-year panel design.	12
Table 4. Schematic for a hypothetical connected panel design.	12
Table 5. Anticipated sample size and distribution of vegetation monitoring plots among ERMN parks.	15
Table 6. Sample size needed to detect 20% change in some key parameters with power = 0.80 and alpha = 0.10, based on plot-to-plot variability among plots sampled in 2007.	15
Table 7. Effect of post-stratification by vegetation domains (i.e., analyzing plots that fell in xeric terrestrial forest separately) on desired sample size.	16
Table 8. Species that will be monitored as potential indicators of deer browse, along with citations for research that suggests or recommends that the species in an appropriate indicator of deer browse.	20
Table 9. Some parameters that will be analyzed annually to provide information on the status of vegetation in the parks.	23
Table 10. Estimated yearly costs for one field crew to implement data collection portion of the ERMN vegetation monitoring protocol.	28

Appendixes

	Page
Appendix A: Standard Operating Procedures.....	35
<i>Overview</i>	37
<i>Staff</i>	37
<i>Planning and Coordination</i>	37
<i>Maps</i>	38
<i>Schedule</i>	38
<i>Logistics</i>	38
<i>Training</i>	39
<i>Communication and Crew Oversight</i>	40
<i>Equipment</i>	41
ERMN Vegetation Vital Sign Protocol Using the Global Positioning System (GPS) Version 3.0 (March 2009).....	45
<i>Overview</i>	45
<i>Getting Started</i>	45
<i>Uploading Plot Locations</i>	45
<i>Additional Antenna</i>	46
<i>Navigating</i>	46
<i>Recording a New Location</i>	46
<i>Downloading Recorded Location to ArcGIS</i>	47
<i>Suggested Reading</i>	47

ERMN Vegetation Vital Sign Protocol Site Selection and Plot Establishment Version 3.0 (March 2009).....	49
<i>Overview</i>	49
<i>Definitions</i>	49
<i>Establishing Plot Center</i>	50
<i>Establishing Transects</i>	50
<i>Establishing Microplots</i>	51
<i>Data Collection</i>	52
<i>Revision History</i>	53
ERMN Vegetation Vital Sign Protocol Photopoint Version 3.0 (March 2009)	55
<i>Overview</i>	55
<i>Data Collection</i>	55
<i>Data Collection</i>	56
<i>Revision History</i>	56
ERMN Forest Vital Sign Protocol Stand Measurements Version 3.0 (March 2009)	57
<i>Overview</i>	57
<i>Data Collection</i>	57
<i>Literature Cited</i>	63
<i>Revision History</i>	64
ERMN Vegetation Vital Sign Protocol Coarse Woody Debris Version 3.0 (March 2009)	65
<i>Overview</i>	65
<i>Definitions</i>	65
<i>Transect Set Up</i>	65
<i>Tally Rules for CWD</i>	66

<i>Data Collection</i>	67
<i>References</i>	71
ERMN Vegetation Vital Sign Protocol Groundstory Diversity Version 3.0 (March 2009)	73
<i>Overview</i>	73
<i>Quadrat Set Up</i>	73
<i>Data Collection</i>	74
Quadrat Characterization	76
Species Data.....	77
Unknown Plants.....	77
Deer Browse Indicators	78
Plot Species.....	79
<i>References</i>	83
<i>Revision History</i>	83
ERMN Vegetation Vital Sign Protocol Tree Regeneration and Shrubs Version 3.0 (March 2009).....	85
<i>Overview</i>	85
<i>Definitions</i>	85
<i>Microplot Set Up</i>	85
<i>Data Collection</i>	86
<i>Revision History</i>	88
ERMN Forest Vital Sign Protocol Tree Measurements Version 3.0 (March 2009)	89
<i>Overview</i>	89
<i>Caution</i>	89
<i>Definitions</i>	89

<i>Procedure</i>	89
<i>Data Collection</i>	90
<i>References</i>	101
<i>Revision History</i>	101
ERMN Vegetation Vital Sign Protocol Data Quality Assurance and Quality Control Version 3.0 (March 2009)	103
<i>Overview</i>	103
<i>Training</i>	103
<i>Data Collection</i>	103
Field computer	103
Datasheets	104
<i>Data Entry</i>	104
<i>Data Verification</i>	104
<i>Data Validation</i>	105
<i>Observer Bias</i>	105
<i>Revision History</i>	105
ERMN Vital Sign Protocol Soil Measurements and Sampling Version 3.0 (March 2009)	107
<i>Overview</i>	107
<i>Definitions</i>	107
<i>Sampling Location</i>	108
<i>Soil Sampling Procedure</i>	109
<i>Soil Sampling Procedure on Remeasurement Plots</i>	112
<i>Data Collection</i>	112
<i>Sample Drying</i>	113
<i>Sample Analysis</i>	114

<i>Sample Archives</i>	114
<i>Revision History</i>	114
Appendix B: Field Data Sheets.....	115

Acknowledgements

This protocol was developed based on the work of several other Inventory and Monitoring Networks. We are very thankful to be able to build on their experiences and benefit from their expertise. Specifically, we are indebted to Geri Tierney, Kathryn Miller, and Brian Mitchell of the Northeast Temperate Network; Pat Campbell and John Paul Schmit of the National Capital Region Network; Jim Comiskey and Kristina Callahan of the Mid-Atlantic Network; and Suzanne Sanders of the Great Lakes Network.

In addition, we would like to 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 to the field crews.

We have received indispensable statistical consultation from Durland Shumway at Pennsylvania State University and Tyler Wagner at US Geological Survey's Pennsylvania Cooperative Fish & Wildlife Research Unit.

We also thank William H. McWilliams, Charles "Chip" Scott, Robert P. Long, and Ronald E. McRoberts of the USDA Forest Service's Northern Research Station, Alan H. Taylor of the Pennsylvania State University School of Forest Resources, and David A. Orwig of Harvard University for reviewing this document and providing constructive comments that helped refine the protocol.

Lastly, we would like to thank the forest monitoring field crews that have worked for us over the last three years, including Joseph Pekol, Derrick Etter, Doug Manning, Tom Saladyga, and John Wiley. Their hard work has made this program a success.

Executive Summary

Monitoring of vegetation and associated components provides information on several high-priority vital signs in the Eastern Rivers and Mountains Network (ERMN) parks. The Forest, Woodland, Shrubland, and Riparian Vegetation vital sign was ranked as the highest priority in the vital signs selection process. This protocol primarily details how the Vegetation vital sign will be monitored. However, the protocol will also collect information on two other vital signs: Soil Function and Dynamics; and Status and Trends of Invasive/Exotic Plants, Animals, and Diseases.

This protocol draws on the U.S. Forest Service Forest Inventory and Analysis program and the vegetation monitoring protocols of four other Inventory and Monitoring programs in the eastern United States. The overall goal of this protocol is to monitor indicators of ecological integrity to provide information on the condition of the parks' vegetation and how this condition is changing over time. The locations of the permanent vegetation monitoring plots are determined in each ERMN park through a random, spatially-balanced sampling design. Plots are sampled on a four-year panel design, in which one panel containing one-fourth of a park's total plots is sampled each year. In the field, data are collected on vegetation composition, structure, tree vigor, forest pests and pathogens, tree regeneration, shrubs, groundstory diversity, herbaceous plants sensitive to browse, coarse woody debris, and soils. The field methods and data handling procedures are described in detail in 11 standard operating procedures located in Appendix A.

Background and Objectives

Background and History

This protocol has been developed for the long-term monitoring of vegetation within the National Park Service (NPS) Eastern Rivers and Mountains Network (ERMN), as part of the Inventory and Monitoring Program. The ERMN includes nine parks in New York, New Jersey, Pennsylvania, and West Virginia (Figure 1), that encompass nearly 91,000 ha of land area within the parks' authorized boundaries. The network includes four smaller parks in central and southwestern Pennsylvania that have a primary cultural or historical focus. These cultural parks are Allegheny Portage Railroad National Historic Site (ALPO), Johnstown Flood National Memorial (JOFL), Fort Necessity National Battlefield (FONE), and Friendship Hill National Historic Site (FRHI). The remaining five larger parks are centered around a section of river and generally extend to the ridgetops surrounding the river section. These river parks are Upper Delaware Scenic and Recreational River (UPDE), Delaware Water Gap National Recreation Area (DEWA), New River Gorge National River (NERI), Gauley River National Recreation Area (GARI), and Bluestone National Scenic River (BLUE).

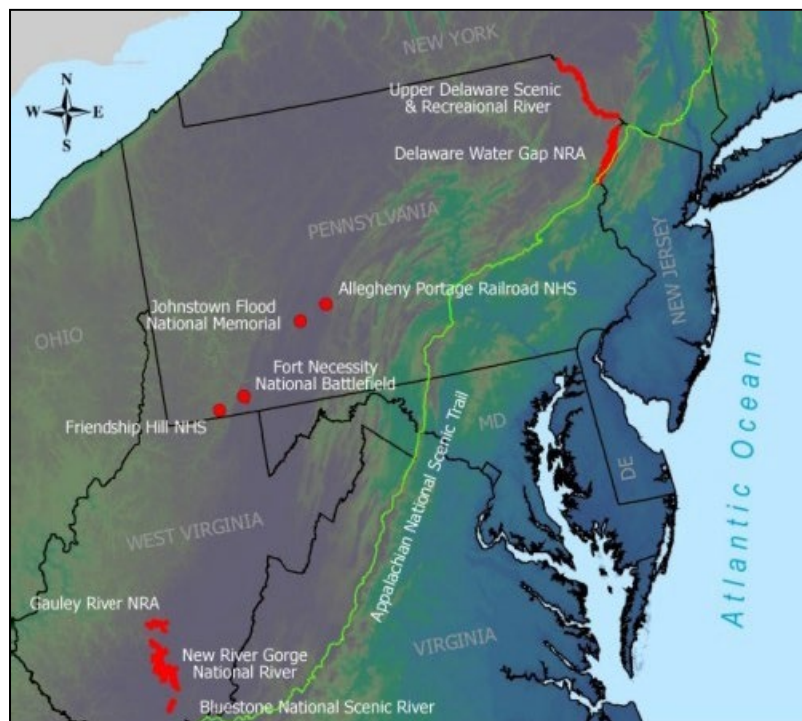


Figure 1. Location of parks in the Eastern Rivers and Mountains Network.

The network spans a large geographic area, and the vegetation within the parks varies with latitude, elevation, geology, and topographic position. However, all of the parks occur in either or both of the Appalachian Plateau and the Ridge and Valley Physiographic Provinces (Fenneman 1938), providing a unifying regional tie among the parks. Some of the major vegetation types in the ERMN include: mixed mesophytic forest on mesic sites in West Virginia, oak-hickory forests on drier ridgetops throughout the network, Allegheny hardwood forest in Pennsylvania, hemlock ravines in DEWA and NERI, as well as plantations and successional

habitats found in several of the historic parks (Perles et al. 2006a, b, c; Perles et al. 2007a, b; Vanderhorst et al. 2007; Vanderhorst et al. 2008).

Numerous ecological and anthropogenic forces affect the parks' vegetation. The effects of and interactions among these forces are discussed in detail in the Terrestrial Ecosystem conceptual model developed for ERMN (Rentch 2006), and are briefly summarized here. Ecological factors such as geology, soil nutrient availability, weather, and disturbance patterns directly influence the structure, composition, and dynamics of the vegetation. Some anthropogenic stressors are easily identified, such as visitor overuse or loss and fragmentation of habitat due to development inside and outside of the parks. Many changes in forest vegetation over time are often linked to several interacting ecological and anthropogenic factors. Exotic species, white-tailed deer (*Odocoileus virginianus*), acid and nutrient deposition, climate change, and altered disturbance regimes are also some important factors affecting the parks' vegetation.

The introduction and spread of exotic insects, diseases, and plants is a serious threat to the parks' vegetation. Some prominent exotic forest pests already established in or near some ERMN parks include hemlock woolly adelgid (*Adelges tsugae*), emerald ash borer (*Agrilus planipennis*), gypsy moth (*Lymantria dispar*), beech scale insect (*Cryptococcus fagisuga*, inciting agent of beech bark disease), and elongate hemlock scale (*Fiorinia externa*). Between 1996 and 2001, intense mortality-causing insect and pest activity was recorded by the United States Forest Service (USFS) Forest Health Protection's aerial surveys in parts of the Allegheny Mountains and the Northern Ridge and Valley in West Virginia. Also during this time period, intense defoliation-causing agent activity occurred in the Northern Ridge and Valley and Northern Unglaciaded Allegheny Plateau in Pennsylvania where gypsy moth activity was relatively high (Coulston et al. 2005). Other pathogens and insects such as sudden oak death (*Phytophthora ramorum*), Asian longhorned beetle (*Anoplophora glabripennis*), and Sirex woodwasp (*Sirex noctilio*) may pose significant future threats to the ERMN parks (Keefer et al 2009).

Earthworms are another group of exotic pests that could adversely impact the parks' vegetation. Earthworms are native to North America south of the extent of the Wisconsinan glaciation (Hendrix and Bohlen 2002), and thus native earthworms are likely to occur in all ERMN parks except DEWA and UPDE. However, introduction of exotic earthworms can have profound effects on the soil and vegetation, including alteration of soil mineral horizons, elimination of the soil organic horizon, changes to the rate at which leaf litter is cycled, alteration of the soil microbial and fungal communities, significant reductions in herbaceous plant diversity and cover, shifts in herbaceous species composition, reduction in tree seedling density, and introduction of pathogens (Proulx 2003; Hale et al. 2006). The most dramatic effects of exotic earthworms have been recorded in ecosystems previously devoid of earthworms (such as DEWA and UPDE). In areas inhabited by native earthworms, exotic earthworms have successfully invaded only after soil or vegetation disturbance (Hendrix and Bohlen 2002).

Invasive exotic plants also threaten the vegetation in ERMN parks. These nonnative species are often competitive with native plant species or dramatically change the vegetation structure of a site, often affecting wildlife habitat. 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 soil development (Vitousek 1990; Mack et

al. 2000; Pimentel et al. 2000). Since invasive plants are inherently difficult to control, the management of these species and the effects on vegetation can challenge park resource managers.

Changes in land use and land management over the previous decades have led to expanded native white-tailed deer populations (Latham et al. 2005). The effects of selective browsing by deer on forest ecosystems include reduced species richness, altered species composition towards dominance of non-preferred and browse-resilient species, competitive exclusion of native species, regional biotic homogenization, reduction in plant growth rates, and reduced survival of tree seedlings and saplings (Russell et al. 2001; Horsley et al. 2003; Rooney et al. 2004; Kirschbaum and Anacker 2005; Latham et al. 2005). In particular, browse pressure from deer has reduced the abundance, growth, and/or fecundity of many native plant species in the lily (Liliaceae), arum (Araceae), and orchid (Orchidaceae) families (Anderson 1994; Augustine and Frelich 1998; Ruhren and Handel 2003; Kirschbaum and Anacker 2005). Conversely, the spread of less-palatable species such as hay-scented fern (*Dennstaedtia punctilobula*) and striped maple (*Acer pensylvanicum*) can interfere with desirable tree species regeneration and herbaceous species diversity (Latham et al. 2005).

Acid deposition in the Appalachian Mountains is primarily a result of emissions from electrical power generation and heavy manufacturing in the Midwest. Acid deposition 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). In addition, the long-term effects of excess nitrogen deposition and mobility in forested systems is also a concern (Aber et al 2003). Compared to the other northeastern states, Pennsylvania experiences a relatively high rate of nitrogen deposition. Excess nitrogen deposition can lead to reductions in surface water quality through increased nitrate leaching. Soil data also show decreasing ratios of soil carbon to nitrogen with increased nitrogen deposition (Aber et al 2003).

Many temporal changes in vegetation can be linked to interacting ecological and anthropogenic factors. For example, the decreased prominence of oaks (*Quercus* spp.) and the increased prominence of red maple (*Acer rubrum*) in Pennsylvania and West Virginia over the last century can be attributed to fire suppression, differential white-tailed deer browsing, and the ability of red maple to thrive after disturbances (Abrams 1998). It is also unclear how global climate change will affect the composition of the region's forest. 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).

Rationale for Monitoring this Resource

Through the vital sign prioritization process for the ERMN, Forest, Woodland, Shrubland, and Riparian Plant Communities was identified as the highest priority vital sign (Marshall and Piekielek 2007). The vital sign process highlighted the importance of plant species diversity and functional plant communities as natural resources critical to the parks. These vegetation communities can also serve as an integrated measure of terrestrial ecosystem health by

expressing information about climate, soils, and disturbance. Further, vegetation itself serves as a base for other trophic components such as wildlife. Because of this interwoven relationship between vegetation and both biotic and abiotic components, this protocol incorporates the Network's monitoring plans for vegetation as well as those of related vital signs: Status and Trends of Invasive/Exotic Plants, Animals and Diseases; and Soil Function and Dynamics.

Depending on the successional stage, disturbance history, and the site it occupies, there are certain parameters within which a terrestrial vegetation ecosystem can be described as "healthy" (Tierney and Faber-Langendoen 2007b). By measuring taxonomic, structural, and demographic features, an assessment can be made as to whether or not the ecosystem's parameters fall within expected or accepted norms and ranges of variability. These measures serve as indicators of ecological integrity that can be explicitly linked to park management. Thus, this protocol will provide park managers with comprehensive long-term data about the condition of the parks' vegetation resources and how this condition is changing over time.

The concept of "ecological integrity" is increasingly being used as a measuring tool to assess the state of ecosystems and the effectiveness of land management actions upon those ecosystems (Karr 1993; Woodley 1993). 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). "Ecological integrity" has been defined as a measure of the composition, structure, and function of an ecosystem in relation to the system's natural or historical range of variation and the perturbations imposed upon it by natural or anthropogenic agents of change (Karr and Dudley 1981). "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).

Measurable Objectives

The overall goal of this protocol is to monitor indicators of ecological integrity to provide information on the condition of the parks' vegetation and how this condition is changing over time. Towards this end, we will monitor status and trends in the structure, function, and condition of the vegetation in ERMN parks in order to inform management decisions affecting those systems.

In general, we have not designed this monitoring program to investigate a single question or test a specific hypothesis. Rather, we are attempting to collect objective and scientifically defensible data to answer wide-ranging broad hypotheses, some of which may not be finalized at the outset. Data collected through this and other protocols will contribute to our understanding of how environmental factors, ecosystem processes, land use, resource management activities, and ecological and anthropogenic stressors affect vegetation in the parks. Three broad questions guide the monitoring program:

- How are vegetation composition, structure, and demography changing over time in relation to weather, climate, landscape dynamics, invasive species, deer browse, and natural processes such as gap formation and succession?
- How are soil and soil fertility changing in relation to acid and nutrient deposition?
- How do park and network status and trends compare to regional trends, historical data, desired future conditions and/or management objectives?

Specifically, we will assess the ecological integrity of the parks' vegetation and detect changes in that integrity over time by determining the status and documenting long-term trends in the following variables:

- Canopy, subcanopy, and shrub species composition, diversity, and nativity.
- Tree growth and mortality rates, and density of snags.
- Tree species regeneration and seedling establishment.
- Forest structural stage and/or vegetation successional stage.
- Coarse woody debris volume.
- Composition, diversity, and nativity of herbaceous species, guilds, or communities.
- Number, composition, and proportion of nonnative and/or invasive species.
- Presence, growth, and reproduction of select indicator plants most palatable to white-tailed deer.
- Basic soil chemistry, with a focus on Ca:Al and C:N ratios.

Sampling Design

Sampling Design Rationale

The ERMN Vegetation Monitoring Program is designed to monitor the ecological integrity of the parks' vegetation in a standardized and cost-efficient manner. This protocol must contribute to statistical inferences of status and trends within and across parks with sufficient power to detect change. The use of permanent plots increases power to detect trends over time. The protocol will also facilitate comparison of ERMN data with other NPS networks and regional data such as that from the United States Forest Service (USFS) Forest Inventory and Analysis (FIA) Program.

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 (<http://fia.fs.fed.us/>). Adopting the widely used FIA protocols allows us to take advantage of data collected from forests within or near the ERMN parks. For these reasons, ERMN has chosen to use FIA protocols as a starting point for its vegetation monitoring protocol. However, the FIA protocols have been adjusted to fit ERMN parks and objectives and to be cost-effective. Thus, while FIA is the basis of the ERMN protocol, not all of the data collected on FIA plots will be collected on ERMN plots.

In addition, at least four other I&M networks in the eastern U.S. (Northeast Temperate Network, Mid-Atlantic Network, National Capital Region, and Great Lakes Network) are using the FIA protocols as a basis for their vegetation monitoring protocol (Sanders et al. 2006; Schmit et al. 2006; Tierney and Faber-Langendoen 2007a). Therefore, ERMN chose this model to maximize the benefits of data sharing. The ERMN protocol has drawn heavily from the protocols developed in these other networks and has benefited from their experiences implementing those protocols.

Site Selection

Plot locations for vegetation monitoring have been selected from a regular grid of potential plot locations in each ERMN park using a generalized random-tessellation stratified (GRTS) design (McDonald 2004; Stevens and Olsen 2004). 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, restricted randomization is used to randomly 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 USFS FIA Program (Brand et al 2000).

There are three main advantages to a 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. This allows potential sites to be rejected if they are determined inappropriate or additional sites to be added or removed if funding is increased or decreased, or our objectives shift. The third asset of the GRTS method is that it is a probabilistic sampling design, whereby sampling points are randomly chosen from among those in a systematic grid, eliminating site selection bias, and allowing inference to the entire sampling frame. This also provides additional flexibility for post-stratification of plots based on ecological system, vegetation association, or other criteria, as needed (Stevens and Olsen 2004).

Vegetation types and land area of ERMN parks vary considerably. Thus, to provide park resource managers with park-specific information about trends in vegetation condition, a separate sampling design was developed for each park. Sample size varied by park to ensure statistical inferences can be made for the smaller ERMN parks, while allocating sufficient resources to the larger parks.

One park, the Upper Delaware Scenic and Recreational River, was not included in the vegetation monitoring program due to its limited area of publicly owned land. The authorized boundary of UPDE encompasses approximately 26,000 ha, however, only approximately 12 ha are owned by the National Park Service. Furthermore, only 5% of the land within the authorized boundary (approximately 1,225 ha in total) is held by public entities (i.e., federal government, Commonwealth of Pennsylvania, State of New York, or Sullivan County Parks). Establishing plots on private lands involves some risk of lost investment since the National Park Service will have little control over the land use. In addition, data collected from plots on select publicly or privately owned parcels will not necessarily be representative of the park as a whole, making it difficult to draw inferences and guide management decisions (Urquhart et al. 1998).

For the eight other network parks, a regular triangular grid of points covering the extent of a park's authorized boundary was created using Hawth's Tools' Regular Point Generation Tool (Beyer 2004) in ArcGIS 9.1 (ESRI 1999–2005). Each point indicates the location for the center of a potential monitoring plot. The distance between points varied by park as a function of park size (Table 1). From this regular grid, points were removed if they occurred on:

- privately owned land;
- non-vegetated land, including transportation corridor, built-up land, river, pond, etc;
- intensively managed lands, such as agricultural fields, regularly mowed grasslands, areas maintained as non-forest in perpetuity for cultural or historic purposes;
- slopes $\geq 30^\circ$ (equivalent to $\geq 58\%$ slope)¹ as calculated from digital elevation models within the parks.

¹ For the safety of the field crew and to avoid severe disturbance to the soil and vegetation on steep slopes during plot installation and data collection, plots that occurred on very steep slopes could not be included in the sampling design. Steep slopes, including vertical cliffs, are prevalent in the three West Virginia parks. Thirty degrees (58%) was selected as the steep slope cut-off because it provided for crew safety, while removing a reasonable number of points from the regular grid of points. Reducing the steep slope cut-off to 25 degrees removed a significantly larger number of points from the regular grid of points. The decision to use 30 degrees as the cut-off was made in consultation with park resource managers, ecologists who have worked in the West Virginia parks, and other NPS I&M networks.

Table 1. Information on the regular grid of sample points created for each park's sampling design.

	DEWA	ALPO	JOFL²	FONE³	FRHI	GARI	NERI	BLUE
Total Park Area (ha)	27,944	518	76	373	280	4,557	29,203	1,755
Distance between Points (meters)	750	250	100	250	250	250	750	250
Number of Points in Park Boundary	499	90	79	58	43	730	523	281
Number of Points on Private Land Removed	19	0	0	0	0	452	127	1
Number of Points on Non-vegetated / Managed Land Removed	55	10	55	11	6	12	11	12
Number of Points on $\geq 30^\circ$ Slopes Removed	13	0	0	0	0	37	78	113
Number of Points Entered into GRTS	412	80	24	47	37	229	307	155
Number of Points Selected from GRTS	150	30	15	30	30	100	150	80

The number of points removed by each of these criteria is shown in Table 1. The remaining points and their coordinates were entered into the GRTS software. The number of points selected from GRTS (Table 1) was determined by overestimating the projected number of plots that could be sampled, based on park size and the estimated capacity of a summer field crew (for additional discussion on sample size see “Recommended number of sampling sites” below). Thus, the number of points selected from GRTS includes 50%–100% more plots than will likely be sampled.

The GRTS program generates an ordered list of potential plot sampling locations. Plots will be assigned to sampling panels (see Sample Frequency and Replication section below) in the order they occur on the list. In New River Gorge National River, for example, the first 25 plots on the list will be assigned to panel 1, the second 25 plots on the list will be assigned to panel 2, and so forth. Plot locations may be rejected if they are deemed unsuitable by the field crew (see the Site Selection and Plot Establishment SOP in Appendix A for rejection criteria and procedures), in which case the next location on the list is chosen.

² In JOFL, points located on the historic lakebed, the dam, and the mowed area around the visitor center were removed because this area will be maintained as open to preserve the viewshed and facilitate historical interpretation. Through consultation with the park's natural resource manager (Kathy Penrod, personal communication, April 2007), it was decided that the only areas of the park that should be monitored are the picnic area, the woodlot south of the road across from the picnic area, the wooded area southeast of the lakebed, and the shrubby field south of the visitor center. Points were left in these areas and from these remaining points the GRTS selection was drawn.

³ In FONE, points located in the hayfields on the Rush property were removed since these fields are regularly mowed. The remainder of the points on the Rush property were included in the sampling design, since permission to conduct vegetation monitoring on the Rush property was granted by Mrs. Rush in 2008 (Marie Rush, personal communication, March 2008). In addition, points located in the Great Meadow were removed because this area will be maintained as open to retain its historical character and viewsheds.

This sampling design includes all vegetation types not intensively managed (as defined above). Thus, terrestrial, palustrine, and riparian vegetation types, regardless of whether they are dominated by trees, shrubs, herbaceous, or graminoid plants, are included. Successional vegetation developing in abandoned agricultural fields or other previously disturbed areas is also included. Submerged aquatic vegetation is not included in this sampling design due to the spatial and temporal variability of those vegetation types and the difficulty in mapping and locating them (in rivers and ponds).

With the exception of JOFL, the majority of the vegetation in all of the ERMN parks is terrestrial forest or woodland (Table 2). Once all of the plots have been established, we will reassess whether our sampling design provides sufficient information on non-forested and/or non-terrestrial vegetation types. If the number of plots located in non-forested and/or non-terrestrial vegetation types is too small to allow statistical inferences (both in the precision of estimates and the power to detect trends over time), then those plots may be removed from the monitoring program. We would likely then limit additional future plot locations to those in “forest” (as defined by the FIA program). The FIA guidelines require 10 percent minimum stocking by tree species to classify an area as “forest” and to establish a monitoring plot. The 10 percent requirement allows that the site can either be stocked by that amount at the time of sampling, or will likely return to that level in the future. As such, areas recovering from wind disturbance will be included, as will abandoned grasslands returning to forest. In addition, FIA plots will only be placed in forest stands at least 36 meter (120 feet) wide within land parcels that are at least 0.4 hectares (one acre) in size (USFS 2007).

Stratification based on ecosystems, vegetation associations, landscape features, or geology has not been incorporated into this monitoring program. Stratification on a dynamic variable such as vegetation type has been problematic. As the plots’ vegetation changes over time, the original strata assignment is compromised, resulting in analytical errors (Diefenbach and Mahan 2002). Further, a sampling design with strata based on vegetation types prevents inferences about those vegetation types not sampled. An alternative to stratification by vegetation type is stratification based on a more permanent landscape feature such as elevation, slope, aspect, or geology. In the smaller ERMN parks, this sort of stratification is unnecessary because the landscapes are somewhat homogeneous. In the larger, more diverse ERMN parks, stratification on landscape features would create numerous strata, so many that it would be difficult to attain a sample size in each strata that would provide sufficient statistical power to detect trends over time. However, preliminary analyses have shown that, during analysis, post-stratification into domains by ecosystem or vegetation type reduces plot-to-plot variability, and thus increases the detectable level of change (see Detectable Levels of Change section below).

Sample Frequency and Replication

Vegetation monitoring will occur annually but each plot will not be measured every year. Yearly plot measurements can affect soil compaction and understory trampling which would bias the monitoring data (Urquhart et al. 1998). Additionally, yearly changes in trees and soil are likely sufficiently small as to warrant a longer sampling return interval. Therefore, plots will be sampled on a four-year panel design (Table 3), in which one panel containing one-fourth of a park’s total plots is sampled each year. Thus, some plots will be established or revisited in each park during each year. Sampling will take place during the summer months (May–September)

Table 2. Area (in hectares) of vegetation types and land uses in ERMN parks. These figures were derived from vegetation maps produced by the Pennsylvania and West Virginia Natural Heritage Programs (Perles et al. 2006a, b, c; Perles et al. 2007a, b; Vanderhorst et al. 2007; Vanderhorst et al. 2008). Since a draft vegetation map has not been developed for GARI, figures for GARI were derived from the U.S. Geological Survey National Land Cover Database Zone 53 Land Cover Layer, available at <http://wvgis.wvu.edu/>.

	UPDE	DEWA	JOFL	ALPO	FONE	FRHI	GARI	NERI	BLUE
Vegetation Type									
Terrestrial Forest / Woodland	19,509.74	21,544.57	26.95	430.20	275.61	191.80	4,118.24	24,277.47	1,486.08
Riparian Forest / Woodland	397.73	193.48				31.73		319.59	146.16
Palustrine Forest / Woodland	50.92	861.27					15.85		
Terrestrial Shrubland	50.28	1,103.65			64.06	5.88	0.45		
Riparian Shrubland	28.92	29.18		0.44					
Palustrine Shrubland	3.76	103.60							
Terrestrial Herbaceous / Graminoid	147.76	558.15		35.55			10.90		
Riparian Herbaceous / Graminoid	402.43	55.92		3.17				308.54	
Palustrine Herbaceous / Graminoid	22.07	124.63		0.98	16.36	2.07	1.44	63.95	
Terrestrial Sparse Vegetation		142.47					0.90	7.04	
Land Use									
Not Vegetated (Developed Land / Roads / Open Water)	4,598.00	1,959.12	12.64	48.00	17.18	23.92	395.49	4,226.13	122.44
Managed Grassland / Agriculture	939.80	1,268.52	36.06			24.93	13.96		
Total Area of Vegetation in Park (Vegetation Type Area – Land Use Area)	20,613.61	24,716.92	26.95	470.34	356.03	231.48	4,147.78	24,976.59	1,632.24
Total Park Area	26,151.41	27,944.56	75.65	518.34	373.21	280.33	4,557.23	29,202.72	1,754.68
Percent of Park Currently in Terrestrial Forest or Woodland	74.6%	77.1%	35.6%	83.0%	73.8%	68.4%	90.4%	83.1%	84.7%

Table 3. Schematic for a four-year panel design.

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

when foliage and understory plants are fully developed. A four-year rotation is a good balance between sampling too frequently, where plot trampling can occur, and sampling too intermittently, which reduces the ability to detect change over a given time period. Sampling at four-year intervals will allow time for some change to occur, yet provide relatively frequent feedback to park natural resource managers. This design will provide information on trends in the key parameters after five years, however, our confidence in the estimates of these trends may be low. Our ability to detect trends will increase with subsequent revisits (Urquhart et al. 1998).

If funding permits, ERMN could increase the power to detect trends by employing a connected sampling design at the four large parks (DEWA, GARI, NERI, and BLUE) (Table 4). In this design, each panel would be subdivided into three subpanels of equal size. One subpanel would be resampled the year after its panel was sampled, thus providing connectivity between panels. This connectivity provides increased power to detect trends by allowing for the estimation of site-by-year variance earlier in the sampling design (Urquhart et al. 1998; Urquhart and Kincaid 1999). However, this design would incur increased cost, may reduce the total number of plots that could be sampled, and would expose plots to additional sampling impacts.

Table 4. Schematic for a hypothetical connected panel design.

Panel	Year											
	1	2	3	4	5	6	7	8	9	10	11	12
1a	X	X			X				X			
1b	X				X	X			X			
1c	X				X				X	X		
2a		X	X			X				X		
2b		X				X	X			X		
2c		X				X				X	X	
3a			X	X			X				X	
3b			X				X	X			X	
3c			X				X				X	X
4a				X	X			X				X
4b				X				X	X			X
4c	X			X				X				X

Each panel has 3 subpanels. One subpanel resampled each year provides connectivity.

To evaluate the actual costs and benefits of a connected panel design, we experimented with a preliminary connected panel design during the 2008 field season. Fourteen plots originally sampled in 2007 in the 4 large parks were revisited during the 2008 field season. These data were analyzed using mixed linear models to quantify the spatial and temporal sources of variation. However, it was determined that these data were insufficient to adequately estimate the different components of variation. Thus, in 2009, we will continue to implement the connected panel design, revisiting 28 plots from the 2007 and 2008 panels. With these additional data, we hope to be able to better quantify the spatial and temporal sources of variation and thus assess the power of our sampling design.

Recommended Number of Sampling Sites

Several factors should be considered in determining the total number of sites sampled in each park. The primary driver of sample size should be the power to detect change over time in the key parameters that provide information towards the program's objectives. Two factors that influence our ability to detect change over time are alpha and beta (Irwin 2008). Alpha is the probability of detecting a "false change," or falsely detecting a change when it did not occur. Beta is the probability of "missed change," or wrongly concluding no change occurred when it actually did. Power is equal to $1 - \beta$. The NPS I&M Program is typically more concerned about "missed change" than "false change" and therefore may specify a beta smaller than the alpha. Common accepted values of alpha and beta range from 0.01 to 0.2 (Irwin 2008).

Currently, we using a preliminary connected panel design (see Sample Frequency and Replication section above) to collect data that will allow us to estimate the temporal variability of the key parameters. With the data we have previously collected, we can assess the plot-to-plot variability, but have limited data on temporal variability. The plot-to-plot variability will be inherently greater than the temporal variability and thus does not provide accurate information on required sample size. Despite the conservative nature of this analysis, the plot-to-plot variability of several key parameters from the 2007 plot data was analyzed to conservatively examine the number of samples needed and the detectable levels of change (see following section).

Other important factors affecting sample size are budgetary and logistical constraints such as length of growing season and availability of qualified crew members. The ERMN Vegetation Monitoring Program budget currently contains sufficient funds for one crew of three people over 15 weeks (the length of most university summer breaks). Based on the preliminary experiences of other NPS networks that have implemented vegetation monitoring programs, ERMN estimated that our crew could realistically sample between 300 and 400 plots over a four-year

cycle. Thus, we divided a projected 350 total plots among the network's parks to ensure a minimum sample size for statistical inference in the smaller ERMN parks, while allocating sufficient resources to the larger parks (Table 5).

Detectable Levels of Change

Realistic and appropriate values for alpha and beta will be determined as more data is collected. However, this monitoring program should ideally be able to detect a 20 percent change in key parameters over five or ten years (i.e., two or three plot revisits), with a power of 0.80 and an alpha of 0.1. A power analysis can be used to determine the sample size needed to detect a set level of change in a parameter at a particular power and alpha level. Performing this analysis for the ERMN forest monitoring protocol presents some challenges. Multiple measurements are taken on each plot, so the design may provide an adequate sample size for some measurements, but may not be adequate for others. Additionally, 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).

With little data on vegetation change on the monitoring plots over time, it is difficult to assess how well the sampling design captures temporal change. To conduct a power analysis, we used the plot-to-plot variability among the plots sampled from the first panel (2007) as a surrogate for temporal variability of each plot over time. Table 6 provides power analysis results for several key monitoring program parameters. These results can be interpreted in several ways: 1) our sample size is insufficient to detect the desired level of change for all parameters except live tree basal area and density; 2) a larger level of detectable change, higher alpha, and/or lower power level should be accepted; 3) plot-to-plot variability is a poor surrogate for temporal variability, since the former is much more variable than the latter. Urquhart et al. (1998) posit that variability among sites in one panel has no influence on the sampling designs' ability to detect trends in parameters of interest over time.

Using data collected from the preliminary connected panel design, we are currently attempting to examine the statistical power to detect trends in key parameters using estimates of plot-to-plot and temporal variability derived from the 2007 and 2008 data. However, a thorough assessment of the detectable levels of change should be conducted after the first full panel of plots is revisited in 2011. If this assessment determines the sample size is too small, the program could consider increasing sample intensity by adding plots from the GRTS list and running two vegetation monitoring field crews each summer, one for the Pennsylvania parks and one for the West Virginia parks. Furthermore, even if the sample size does not provide adequate power after the first repetition of the panels, it may provide adequate power after several repetitions of panels.

Another strategy for increasing the detectable level of change is post-stratification into domains during analysis, using either ecosystems or vegetation types as the domains. Grouping plots of similar vegetation should reduce plot-to-plot variability. Preliminary analyses (Table 7) indicate that post-stratification will reduce the required sample size for some parameters, especially in parks that contain diverse vegetation types, such as DEWA.

Table 5. Anticipated sample size and distribution of vegetation monitoring plots among ERMN parks.

	DEWA	JOFL	ALPO	FONE	FRHI	GARI	NERI	BLUE	Total
Total Park Area	27,944.56	75.65	518.34	373.21	280.33	4,557.23	29,202.72	1,754.68	64,706.72
Hectares of Vegetation on Publicly Owned Land in Park Boundary	23,973.36	26.95	470.34	356.03	231.48	1,663.70	20,738.27	1,614.97	49,075.10
Percent of Total Network-wide Vegetation Area	48.9%	0.1%	1.0%	0.7%	0.5%	3.4%	42.3%	3.3%	
Estimated Total Number of Plots (over 4 years)	100	10	20	20	20	40	100	40	350
Estimated Plot Density (# of hectares / 1 plot)	239.73	2.70	23.52	17.80	11.57	41.59	207.38	40.37	
Estimated Percent of Total Network-wide Number of Plots	28.6%	2.9%	5.7%	5.7%	5.7%	11.4%	28.6%	11.4%	
Number of Plots Sampled in 2007	26	1	3	5	5	12	20	12	84
Number of Plots Sampled in 2008	26	3	6	5	5	9	29	9	92

Table 6. Sample size (number of plots) needed to detect 20% change in some key parameters with power = 0.80 and alpha = 0.10, based on plot-to-plot variability among plots sampled in 2007.

Parameters	DEWA	GARI	NERI	BLUE
Live Tree Basal Area (m²/ha)	137	28	43	26
Live Tree Density (trees/ha)	95	43	35	40
Snag Density (snags/ha)	214	407	216	160
Sapling Density (saplings/ha)	1,034	364	184	158
Understory Richness (# of species)	304	262	110	93
Volume of Coarse Woody Debris (m³/ha)	515	672	1,362	279
Planned sample size over one cycle (4 years)	100	40	100	40

Table 7. Effect of post-stratification by vegetation domains (i.e. analyzing plots that fell in xeric terrestrial forest separately) on desired sample size. Table shows the number of plots needed to detect 20% change in some key parameters with power = 0.80 and alpha = 0.10, based on plot-to-plot variability among plots sampled in 2007.

Parameter	DEWA All Plots (n=26)	DEWA Xeric Forest Plots (n=14)	NERI All Plots (n=20)	NERI Xeric Forest Plots (n=14)
Live Tree Basal Area (m ² /ha)	137	45	43	30
Live Tree Density (trees/ha)	95	31	35	24
<i>Quercus prinus</i> Basal Area (m ² /ha)	476	155	332	175
<i>Quercus prinus</i> Density (trees/ha)	616	216	395	235
Snag Density (snags/ha)	214	93	216	200
Sapling Density (saplings/ha)	1034	1013	184	107
Understory Richness (# of species)	304	247	110	100
Volume of Coarse Woody Debris (m ³ /ha)	515	280	1362	1263

Field Methods

Field methods for ERMN vegetation monitoring use FIA protocols as a starting point; however, ERMN has tailored FIA protocols to fit the network's objectives and to be cost-effective. ERMN has collaborated with several other NPS Vital Signs Networks in the eastern U.S., building primarily on the standards and protocols developed by the National Capital Region Network and the Northeast Temperate Network (Schmit et al. 2006; Tierney and Faber-Langendoen 2007a).

The standard operating procedures (SOPs, Appendix A) provide detailed instructions for the ERMN vegetation monitoring protocol. These SOPs include instructions on field season preparation, necessary equipment, field work schedule, plot establishment, data collection, data management, and analysis. It is essential for successful long-term monitoring to establish standard methods such as these and to carefully follow them. Changes to established protocols should be clearly justified, documented and dated to ensure their use in subsequent years.

Plot Design

ERMN will monitor an extensive network of permanent plots, measuring a suite of site, stand, tree, understory, and soil variables. The plot design includes several imbedded sampling units (Figure 2). Tree, stand, and site measurements are collected within fixed-area, circular plots, 15 m in radius. This plot area (707 m²) is nearly equivalent to the combined total area of the four standard FIA subplots (673 m²) where that program collects tree data (USFS 2007).

Tree regeneration and shrub measurements are collected on four 2-m radius circular microplots embedded within each plot. This number of the microplots was determined statistically optimal for assessing tree regeneration by the FIA Pennsylvania Regeneration Study (McWilliams et al. 2001; McWilliams et al. 2005).

Data on coarse woody debris are collected using line intersect sampling (Van Wagner 1964) along six 15-m transects. Total transect length in this protocol (90 m) is nearly equivalent to the total transect length for coarse woody debris used in the FIA plot design (88 m total, from four sets of three transects, with each transect 7.3 m in length) (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).

With the arrangement of the six transects shown in Figure 2, pieces of coarse woody debris are more likely to intersect multiple transects than in the tradition 3-transect design used by FIA and several other NPS I&M Networks. The ERMN coarse woody debris SOP requires recording the intersection of a piece of coarse woody debris with multiple transects. Thus, data from the multiple intersections could be removed from the analysis at some future time. However, Woodall and Monleon (2008) demonstrated that the line intercept sampling estimator is unbiased regardless of the shape in which any cluster of transects is arranged. This means that each intersection of a transect with a piece of coarse woody debris should be counted, regardless of whether the piece has intersected a transect elsewhere in the plot (Woodall and Monleon 2008).

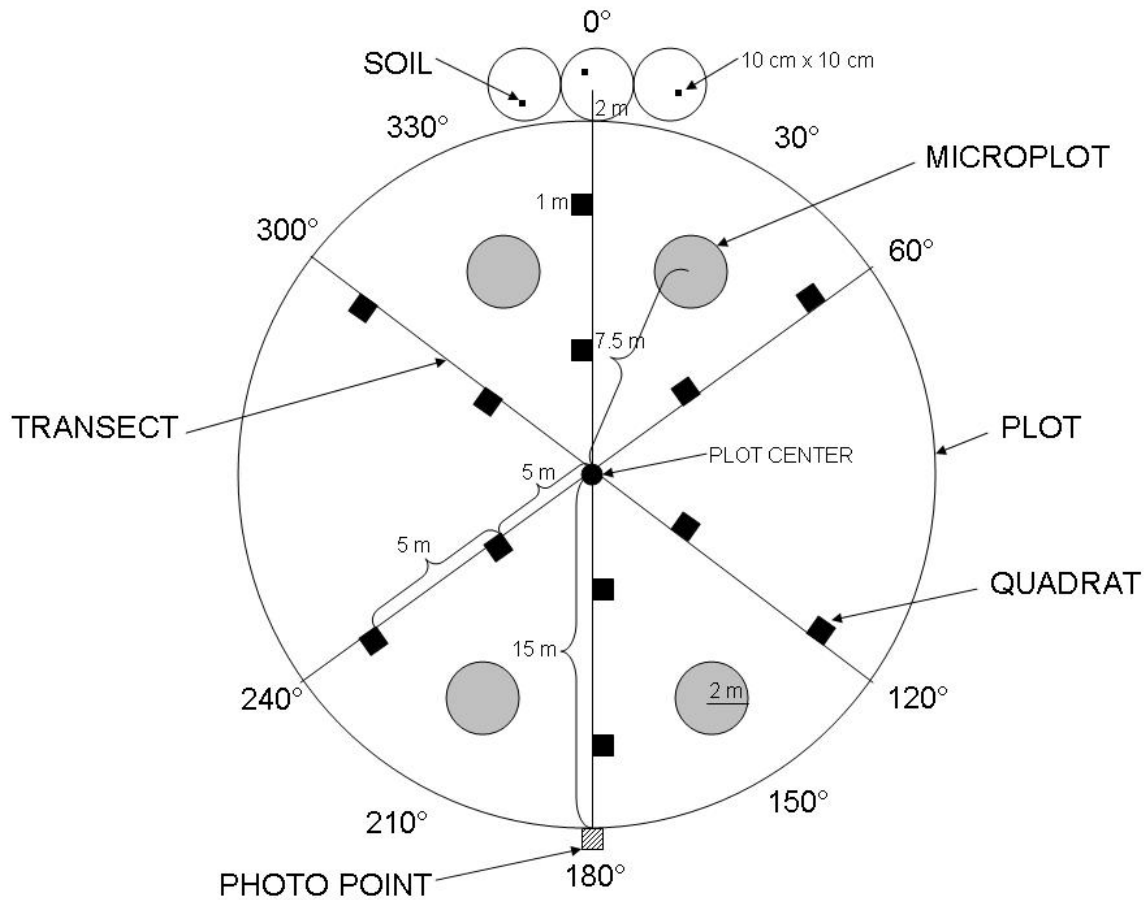


Figure 2. Plot design for ERMN Vegetation Monitoring protocol.

Data on understory plant composition and the diversity of herbaceous, graminoid, and vine species are monitored using twelve 1-m² quadrats set along the six transects. A photograph of the plot is taken from the plot's southern edge to document change in vegetation structure over time. Three soil samples are collected from sampling frames located adjacent to the plot's northern edge.

Details for Taking Measurements

Detailed instructions on data collection and definitions for all data fields are provided in the Standard Operating Procedures in Appendix A. However, the general types of data that will be collected are described briefly here.

Within each plot, the crew collects basic information describing the site (e.g., slope, aspect, elevation, and terrain position). Stand structure and disturbance are qualitatively assessed using visual inspection. Each tree ≥ 10 cm diameter-at-breast-height (DBH) on the plot is scribed and its species, DBH, status (live/dead), crown position, and vigor class are recorded. The presence of selected pest, pathogens, damage, and defects are also recorded for each tree. These data will yield information on tree growth, mortality, and condition, as well as stand structure and

composition. Tree seedlings are quantified by species and size class on the microplots to assess advanced regeneration and deer browsing. The percent cover and number of individuals of shrub species are also collected on the microplots. The vegetation within the microplots is also characterized by percent cover class within the following groups: nonvascular, herbaceous, vine, graminoid, and fern.

On the transects, the diameter at the point of intersection and the decay class is measured and recorded for each piece of coarse woody debris >7.5 cm in diameter and >1 m in length. Intersections of one piece of coarse woody debris on more than one transect is noted. The percent cover of all herbaceous, graminoid, and vine species on 1-m² quadrats is recorded to provide information on understory species composition, presence of exotic species, and biotic homogenization.

The number, height, and reproductive activity of specific herbaceous species sensitive to deer browse are also recorded. Table 8 lists the indicator species selected based on research that suggests or recommends the species is an appropriate indicator of deer browse. The list includes numerous genera to account for the floristic diversity among the parks and the vegetation diversity within the larger parks. Fairybells (*Prosartes* spp.) was fairly common in NERI during the first year of data collection using this protocol and was added to the list of potential indicator species. The reproductive activity of these plants is recorded, because several studies found that reproductive activity is a more suitable indicator of deer browse than frequency or plant height (Ruhren and Handel 2000; Fletcher et al. 2001). For example, the ratio of flowering to non-flowering Canada mayflower (*Maianthemum canadense*) may be a suitable indicator of forest conditions (Diefenbach and Fritsky 2007). However, on state forest lands in Pennsylvania, mean height of Indian cucumber (*Medeola virginiana*) was the most precise deer browse indicator in a study that also evaluated Canada mayflower, Jack-in-the-pulpit (*Arisaema triphyllum*), and trilliums (*Trillium* spp.) (Diefenbach and Fritsky 2007).

Monitoring the effects of deer herbivory on a landscape scale (as is proposed in the larger parks) may be difficult (Russell 2001; Kirschbaum and Anacker 2005). In a large landscape, deer density can vary by season, year, and site, depending on the distribution and abundance of preferable food sources. It is unclear whether this variability will mask trends in deer browse indicator plants over time. In addition, confounding environmental factors may affect both deer density and plant survival, further increasing the observed variability (Russell 2001; Kirschbaum and Anacker 2005).

Three separate soil samples are collected adjacent to the plot. Each sample is collected by genetic horizons (e.g., O, A, and/or B), storing soil from each horizon separately. These samples are chemically analyzed to provide information on the effects of atmospheric deposition and the ability of these soils to support forested ecosystems. Although a suite of chemical analyses will be conducted, calcium to aluminum ratios and carbon to nitrogen ratios are the focus of the soil monitoring effort.

Table 8. Species that will be monitored as potential indicators of deer browse, along with citations for research that suggests or recommends that the species is an appropriate indicator of deer browse.

Scientific Name	Literature
Preferred Browse Species	
<i>Actaea</i> spp. (<i>A. pachypoda</i> , <i>A. podocarpa</i> , <i>A. rubra</i> , <i>A. racemosa</i>) [formerly <i>Cimicifuga racemosa</i>]	Webster and Parker 2000
<i>Arisaema triphyllum</i>	Webster and Parker 2000 Ruhren and Handel 2000 Fletcher et al. 2001
<i>Maianthemum canadense</i>	Rooney 1997 Kirschbaum and Anacker 2005 Diefenbach and Fritsky 2007
<i>Maianthemum</i> spp. (<i>M. racemosum</i> , <i>M. stellatum</i>)	Fletcher et al. 2001 Augustine and deCalesta 2003 Webster et al. 2005
<i>Medeola virginiana</i>	Webster et al. 2005 Diefenbach and Fritsky 2007
<i>Osmorhiza</i> spp. (<i>O. claytonia</i> , <i>O. longistylis</i>)	Webster and Parker 2000
<i>Podophyllum peltatum</i>	(Browse preference is debated)
<i>Polygonatum</i> spp. (<i>P. biflorum</i> , <i>P. pubescens</i>)	Fletcher et al. 2001 Augustine and deCalesta 2003 Webster et al. 2005
<i>Prosartes</i> spp. (<i>P. lanuginosa</i> , <i>P. maculata</i>)	
<i>Trillium</i> spp. (numerous)	Anderson 1994 Augustine and Frelich 1998 Kirschbaum and Anacker 2005
<i>Uvularia</i> spp. (<i>U. grandiflora</i> , <i>U. perfoliata</i> , <i>U. puberula</i> , <i>U. sessilifolia</i>)	Fletcher et al. 2001 Webster et al. 2005
Species that are Avoided	
<i>Ageratina altissima</i>	
<i>Dennstedtia punctilobula</i>	Horsley et al. 2003
<i>Thelypteris noveboracensis</i>	Williams et al. 2000, Horsley et al. 2003

Data Handling, Analysis, and Reporting

Metadata Procedures

Any dataset compiled by the ERMN must be accompanied by metadata. This includes both spatial and non-spatial datasets. For metadata associated with geospatial data, we abide by Executive Order 12906, which mandates that every federal agency document all new geospatial data it collects or produces using the Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (CSDGM; www.fgdc.gov/metadata/constan.html). All GIS data layers will be documented with applicable FGDC and NPS metadata standards. The Network will also generate FGDC-style metadata for non-spatial datasets that meet this standard, without the geospatial-specific elements.

Overview of Database Design

The vast majority of data collected by the ERMN Vegetation Monitoring Program will be stored in the Vegetation Monitoring Database. This database is compliant with the Natural Resources Database Template (NRDT) and is similar to vegetation monitoring databases developed in other I&M networks in the eastern U.S. The ERMN Vegetation Monitoring Database was developed in Microsoft Access 2003.

Data Entry, Verification, and Editing

Accurate collection and stewardship of data are critical to the success of the vegetation monitoring program. Ensuring data quality must be a priority during crew training, and throughout the data collection, entry, verification and validation process.

Data will be entered into the ERMN Vegetation Monitoring Database in two ways. First, field crews may enter data directly into a field copy of the database running on a rugged tablet computer. The database incorporates many functions and utilities to help reduce data entry errors and promote data integrity. Entering data in this manner eliminates the need to transfer data from paper field forms into a project database, and thus reduces data entry errors. Alternatively, field crews may record data on paper field forms (Appendix B) and enter data into the project database at a later time.

Regardless of the data collection method, a crew member must review all paper data sheets or all sections of the field database before the crew leaves each plot. The crew leader is responsible for ensuring that all datasets undergo complete quality assurance and quality control procedures. A detailed description of the data quality assurance and quality control procedures are provided in the Data Quality Assurance and Quality Control Standard Operating Procedure (Appendix A).

Recommendations for Routine Data Summaries and Analysis

Data from the ERMN Vegetation Monitoring Program will be analyzed in three ways:

1. Annual summaries on the status of the vegetation in each park,
2. Analysis of changes in key parameters over time, typically summarized every four years,
3. Evaluations of relationships between environmental parameters and the vegetation structure, demography, and species composition.

After each field season, data will be analyzed to produce annual summaries on the status of vegetation by park. Some parameters that will be summarized annually are listed in Table 9. These annual summaries will provide park managers and the Network with current status information relevant to policy and management decisions. Other analytical approaches may be utilized to assess the status of vegetation structure, demography, and species composition.

ERMN will also analyze temporal change for parameters listed in Table 9. These analyses will typically take place every four years, after the plots in each panel are revisited. After two or more complete sampling cycles, analyses can evaluate any trends in the data. These analyses can use 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.

ERMN also plans to collect and analyze covariate data on environmental parameters associated with vegetation. Data collected for other ERMN 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) and key ecosystem drivers and stressors.

Furthermore, ERMN is collaborating with other NPS I&M Networks to determine appropriate regional analyses that can be conducted with the vegetation monitoring data from our networks. In the future, ERMN plans to work with other regional partners, such as the US Forest Service FIA program and the Northeastern Soil Monitoring Network, on regional data analyses. Contributing towards regional analyses will provide context for conditions and trends observed in ERMN parks and strengthen our understanding of regional trends.

Recommended Reporting Schedule and Format

Two types of reports will be produced for the ERMN Vegetation Monitoring Program. Annual summary reports that provide information on the status of vegetation will be produced each year. Park superintendents and resource managers are the primary audience for the annual summary reports. These summaries will document the efforts of the Vegetation Monitoring Program and convey findings of the previous field season.

In addition to annual summary reports, detailed reports in which data are analyzed and synthesized will be produced on a periodic basis, typically every four years, after the completion of each sampling cycle. They will follow a format appropriate for a scientific journal and will contain in-depth analyses. Further, 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, the ERMN, and other I&M Networks. Outside of the park service, the target audience can include the state departments of natural resources, the U.S. Forest Service, and the broader scientific community.

Table 9. Some parameters that will be analyzed annually to provide information on the status of vegetation in the parks.

Type of Vegetation Data	Parameter
Trees	Total Live Basal Area Total Live Density Relative Live Basal Area for select species Relative Live Density for select species Species Richness, Shannon Index, Berger-Parker Index Histograms of Diameter class distribution Snag Basal Area Snag Density Ratio of Number Snags : Number Live Trees
Tree Regeneration	Stocking Index (McWilliams et al. 2001, 2005) Total Sapling Basal Area Relative Sapling Basal Area for select species Total Sapling Density Relative Sapling Density for select species Histograms of seedling frequency by height Species Richness
Shrubs	Average Percent Cover by species or species groups Species Richness
Coarse Woody Debris	Volume Ratio of CWD Volume : Live Tree Volume
Herbaceous Plants	Species Richness, Shannon Index, Berger-Parker Index Ratio of Native Species Richness : Exotic Species Richness Ratio of Native Species Percent Cover : Exotic Species Percent Cover Cover of Rhizomatous Ferns
Deer Browse Indicator Species	Frequency by Species Ratio of Number of Reproducing : Nonproducing Individuals Average Height
All Species within Plot	Jaccard's Similarity Index Frequency of Select Invasive Exotics

Data Archival Procedures

During the field season, data collected on the field computer in the field database must be backed up to an external hard disk daily. The field computer and the hard disk shall be stored separately. Furthermore, the field database should be uploaded to another ERMN computer periodically during the field season as directed by the Network Data Manager.

If data are recorded on paper data sheets, a photocopy of the original paper data sheets shall be produced on acid-free paper within one week of data collection. These copies shall be delivered to the Network Data Manager and housed in a separate building from the original data sheets.

The ERMN has entered into a long-term agreement with North Carolina State University to serve as our primary digital archive. This archive, along with a variety of ERMN and I&M national program resources, comprise the various repositories that store and safeguard ERMN products for future use.

Personnel Requirements and Training

Roles, Responsibilities, and Qualifications

The following personnel will be involved in the Vegetation Monitoring Program:

Plant Ecologist

The ERMN Plant Ecologist functions as the Vegetation Monitoring Program Manager and is responsible for coordinating all aspects of the project, including field work, data management, and analysis/reporting. This person functions as a liaison between the ERMN I&M Program and the vegetation field crew collecting data in Network parks. Specific responsibilities of the plant ecologist include:

- develop an annual field schedule
- acquire the appropriate permits
- establish and refine annual and seasonal budgets
- hire seasonal field crew
- prepare, repair, and/or purchase equipment
- prepare database for the field season (review species lists, add crew members names, etc.)
- contact local experts in botany, soils, and entomology to establish working relationships prior to the field season
- arrange and/or conduct field crew training
- oversee field crew during field season, providing logistic and administrative support
- ensure plot work meets quality standards
- ensure adequate numbers of plots are established and/or measured each season at each park
- ensure effective communication between park staff, field crew, and other ERMN staff
- review and revise monitoring protocol and standard operating procedures as needed
- ensure proper data QA/QC and data archival procedures are followed
- data analysis and report writing

Vegetation Crew Leader

The ERMN Vegetation Monitoring Crew Leader will be responsible for managing the vegetation field crew. S/he will work closely with the Plant Ecologist to ensure that all training and permits requirements are met and that project supplies and equipment are in order. The crew leader should be skilled in botany, with a strong knowledge of the flora of Pennsylvania and West Virginia. In addition to the responsibilities of a crew member, the Vegetation Crew Leader will perform the following tasks:

- coordinate directly with park resource managers when conducting field work in each park
- ensure that all field crew members are trained in proper data collection procedures
- identify plants accurately and/or process unknown plants for later identification
- conduct data verification if data from paper field sheets were entered into database
- ensure that all data undergoes the proper QA/QC procedures

Field Crew Members

The field crew members will be responsible for data collection in the field and data entry into the project database. Crew members may be graduates or students who have strong interest or experience in forest ecology and/or natural resources. Crew members must be able to identify common trees and shrubs of Pennsylvania and West Virginia. Between the crew leader and the two crew members, the crew should ideally 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
- collect field data accurately as described in the Standard Operating Procedures
- identify plants accurately and/or process unknown plants for later identification
- ensure plot work meets the desired standards of quality
- enter data accurately into the project database either in the field or from paper data sheets
- 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

ERMN Data Manager

The Data Manager will be responsible for providing database training to the crew leader and field crews. S/he will also ensure that all individuals involved in the project are aware of their data management responsibilities. The Data Manager will be responsible for providing any database assistance and GIS support as needed. Specific tasks that the data manager will be responsible for include:

- create, update, and maintain the structure and functionality of the Vegetation Monitoring Database
- ensure that the Vegetation Monitoring Database is compliant with the NRDT
- provide database and GIS training and support
- coordinate data archival procedures

ERMN Network Coordinator

The Network Coordinator 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 Coordinator will also provide support in budget, personal, and logistical matters.

Training Procedures

Prior to each field season, the ERMN must ensure that all field personnel fully understand the protocol by conducting in-situ training sessions. Training will occur in mid-May and last at least one week. 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 A).

Operational Requirements

Annual Workload and Field Schedule

Plot sampling will begin in late May and extend through the end of August. Since the growing season is longer in West Virginia, the West Virginia parks should be sampled at the beginning and the end of the field season. Sampling will most likely follow this schedule:

- Late May–Early June: NERI
- June–Early July: DEWA
- July: ALPO, JOFL, FONE and FRHI
- August: GARI and BLUE

The fall and winter months are used for data entry and QA/QC, data analysis, and report writing. 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 A). Ideally, the crew will stay in park housing while they are conducting field work. The Plant Ecologist and Vegetation Crew Leader should coordinate housing and transportation needs with park staff. The crew will have a dedicated vehicle for the summer, but may need occasional transportation assistance from park staff to reach certain plots.

Startup Costs and Budget Considerations

This protocol was developed through a cooperative agreement with The Pennsylvania State University's School of Forest Resources. The budget for the first year of protocol development through this agreement was approximately \$102,000, including expenses for the first year of data collection.

Future costs associated with the annual field sampling portion of the vegetation monitoring protocol are detailed in Table 10. This estimate includes salary for the field crew leader, two crew members, transportation, housing, travel costs, and supplies which are used every year, such as rebar, caps, spikes, soil bags, etc. Additional future costs for this program include the salary and benefits for a GS 11/12 Plant Ecologist, estimated to be \$69,500 annually.

Soil sample analysis is also a significant expense for the program. However, the exact cost will depend on the number of samples collected, the temporal frequency of sample collection, and the specific analyses that are conducted. Soil samples collected in 2007 will be analyzed at the University of Maine Analytical Lab and Soil Testing Service at a cost of \$35/sample, or \$15,365 total.

Table 10. Estimated yearly costs for one field crew to implement data collection portion of the ERMN vegetation monitoring protocol.

	Estimated Yearly Costs
Salary (including fringe)	
Field Crew Members (2)	\$16,500.00
Field Crew Leader	\$9,500.00
Logistics	
Fleet Vehicle	\$4,000.00
Housing and Travel Expenses	\$6,000.00
Supplies	\$1,000.00
Total	\$37,000.00

References

- Aber, J. D., C. L. Goodale, S. V. Ollinger, M. Smith, A. H. Magill, M. E. Martin, R. A. Hallett, and J. L. Stoddard. Is nitrogen deposition altering the nitrogen status of Northeastern forests? *BioScience* 53(4):375–389.
- Abrams, M. 1998. The red maple paradox. *BioScience* 48(5):355–364.
- Anderson, R. C. 1994. Height of White-Flowered Trillium (*Trillium grandiflorum*) as an Index of Deer Browsing Intensity. *Ecological Applications* 4(1):104–109.
- Augustine, D. J., and L. E. Frelich. 1998. Effects of White-Tailed Deer on Populations of an Understory Forb in Fragmented Deciduous Forests. *Conservation Biology* 12(5):995–1004.
- Augustine, D. J., and D. deCalesta. 2003. Defining deer overabundance and threats to forest communities: From individual plants to landscape structure. *Ecoscience* 10(4):472–486.
- Beyer, H. L. 2004. Hawth's Analysis Tools for ArcGIS. Available at <http://www.spataleecology.com/htools>.
- Brand, G. J., M. D. Nelson, D. G. Wendt, and K. K. Nimerfro. 2000. The hexagon/panel system for selecting FIA plots under an annual inventory. In McRoberts, R. E., G. A. Reams, and P. C. Van Deusen (eds.). Proceedings of the first annual forest inventory and analysis symposium: 1999 November 2–3; San Antonio, TX. Gen. Tech. Rep. NC-213. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. Pages 8–13. Available at: <http://fia.fs.fed.us/symposium/proceedings/>.
- Coulston, J. W., M. J. Ambose, K. H. Ritters, B. L. Conkling, and W. D. Smith. 2005. Forest Health Monitoring: 2003 National Technical Report. Gen. Tech. Rep. SRS-85. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 97 pp.
- Czech, B. 2004. A chronological frame of reference for ecological integrity and natural conditions. *Natural Resources Journal* 44(4):1113–1136.
- De Leo, G. A., and S. Levin. 1997. The multifaceted aspects of ecosystem integrity. *Conservation Ecology* 1:3.
- Diefenbach, D. R., and C. Mahan. 2002. Setting Realistic Objectives: Vegetation Inventory and Monitoring at Shenandoah National Park. Technical Report NPS/PHSO/NRTR—2002/087. National Park Service. Philadelphia, PA.
- Diefenbach, D. R., and R. S. Fritsky. 2007. Developing and testing a rapid assessment protocol for monitoring vegetation changes on state forest lands. Final Report submitted to the Department of Conservation and Natural Resources, Pennsylvania. 45 pp.

- Driscoll, C. T., G. B. Lawrence, A. J. Bulger, T. J. Butler, C. S. Cronan, C. Eagar, K. F. Lambert, G. E. Likens, J. L. Stoddard, and K. C. Weathers. 2001. Acidic deposition in the northeastern United States: sources and inputs, ecosystem effects, and management strategies. *BioScience* 51(3):180–198.
- Drohan, J. R., and W. E. Sharpe. 1997. Long-term changes in forest soil acidity in Pennsylvania, USA. *Water, Air, and Soil Pollution* 95:299–311.
- Environmental Systems Research Institute, Inc. (ESRI). 1999–2005. ArcMap 9.1. Environmental Systems Research Institute, Inc., 380 New York St., Redlands, CA 92373.
- Fenneman, N. M. 1938. *Physiography of the eastern United States*. McGraw-Hill. New York, NY.
- Fletcher, J. D., W. J. McShea, L. A. Shipley, and D. Shumway. Use of common forbs to measure browsing pressure by white-tailed deer (*Odocoileus virginianus* Zimmerman) in Virginia, USA. *Natural Area Journal* 21(2):172–176.
- Hale, C. M., L. E. Frelich, and P. B. Reich. 2006. Changes in hardwood forest understory plant communities in response to European earthworm invasions. *Ecology* 87(8):1637–1649.
- Hendrix, P. F., and P. J. Bohlen. 2002. Exotic earthworm invasions in North America: ecological and policy implications. *BioScience* 52(9):801–811.
- Horsely, S. B., S. L. Stout, and D. S. DeCalesta. 2003. White-tailed deer impact on the vegetation dynamics of a northern hardwood forest. *Ecological Applications* 13(1):98–118.
- Iverson, L. R., A. M. Prasad, B. J. Hale, and E. K. Sutherland. 1999. Atlas of current and potential future distributions of the common trees of the eastern United States. US Forest Service Northeastern Research Station. General Technical Report NE-265. 245 pp.
- Irwin, R. J. 2008. Part B Lite QA/QC Review Checklist for Aquatic Vital Signs Monitoring Protocols and SOPs. National Park Service. Water Resources Division. Fort Collins, Colorado. Distributed on the Internet only.
http://www.nature.nps.gov/water/VitalSigns_index/VitalSignsdocuments.cfm/
- Karr, J. R. 1993. Defining and assessing ecological integrity - beyond water-quality. *Environmental Toxicology and Chemistry* 12(9):1521–1531.
- Karr, J. R., and D. R. Dudley. 1981. Ecological perspective on water-quality goals. *Environmental Management* 5(1):55–68.
- Keefer, J. S., M. R. Marshall, and B. R. Mitchell. 2009. Early Detection of Invasive Species—Surveillance and Rapid Response for the Eastern Rivers and Mountains and Northeast Temperate Networks. Natural Resource Report NPS/ERMN/NRR—2009/DRAFT. National Park Service. Fort Collins, Colorado.

- Kirschbaum, C. D., and B. L. Anacker. 2005. The utility of Trillium and Maianthemum as phyto-indicators of deer impact in northwestern Pennsylvania, USA. *Forest Ecology and Management* 217:54–66
- Kogelmann, W. J., and W. E. Sharpe. 2006. Soil acidity and manganese in declining and nondeclining sugar maples stands in Pennsylvania. *Journal of Environmental Quality* 35:433–441.
- Latham, R. E., J. Beyea, M. Benner, C. A. Dunn, M. A. Fajvan, R. R. Freed, M. Grund, S. B. Horsley, A. F. Rhoads, and B. P. Shissler. 2005. Managing White-tailed Deer in Forest Habitat from an Ecosystem Perspective: Pennsylvania Case Study. Report by the Deer Management Forum for Audubon Pennsylvania and Pennsylvania Habitat Alliance, Harrisburg. xix + 340 pp.
- Marshall, M. R., and N. B. Piekielek. 2007. Eastern Rivers and Mountains Network Ecological Monitoring Plan. Natural Resource Report NPS/ERMN/NRR—2007/017. National Park Service. Fort Collins, Colorado.
- Mack, R. N., D. Simberloff, W. M. Lonsdale, H. Evans, M. Clout, and F. A Bazzaz. 2000. Biotic invasions: causes, epidemiology, global consequences, and control. *Ecological Applications* 10(3):689–710.
- McDonald, T. L. 2004. GRTS for the Average Joe: A GRTS Sampler for Windows. http://www.west-inc.com/biometrics_reports.php.
- McWilliams, W. H., S. L. King, and C. T. Scott. 2001. Assessing regeneration adequacy in Pennsylvania's forests: a pilot study. *In* Reams, Gregory L., Ronald, E. McRoberts, and Paul C. Van Deusen, eds. Proceedings, 2d annual Forest Inventory and Analysis symposium. 2000 October 17–18. Salt Lake City, UT. Gen. Tech. Rep. SRS-47. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 119–122.
- McWilliams, W. H., T. W. Bowersox, P. H. Brose, D. A. Devlin, J. C. Finley, K. W. Gottschalk, S. Horsley, S. L. King, B. M. LaPoint, T. W. Lister, L. H. McCormick, G. W. Miller, C. T. Scott, H. Steele, K. C. Steiner, S. L. Stout, J. A. Westfall, and R. L. White. 2005. Measuring Tree Seedlings and Associated Understory Vegetation in Pennsylvania's Forests. *In* McRoberts, R. E., G. A. Reams, P. C. Van Deusen, and W. H. McWilliams. Cieszewski, Chris J., eds. 2005. Proceedings of the fourth annual Forest Inventory and Analysis symposium. 2002 November 19–21. New Orleans, LA. Gen. Tech. Rep. NC-252. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 257 pp.
- Nemec, A. F. L., and G. Davis. 2002. Efficiency of six line intersect sampling designs for estimating volume and density of coarse woody debris. Res. Sec., Van. For. Reg., B.C. Min. For., Nanaimo, B.C. Tec. Rep. TR-021/2002.

- Parrish, J. D., D. P. Braun, and R. S. Unnasch. 2003. Are we conserving what we say we are? Measuring ecological integrity within protected areas. *Bioscience* 53(9):851–860.
- Perles, S. J., G. S. Podniesinski, E. A. Zimmerman, W. A. Millinor, and L. A. Sneddon. 2006a. Vegetation classification and mapping at Fort Necessity National Battlefield. Technical Report NPS/NER/NRTR—2006/038. National Park Service. Philadelphia, PA.
- Perles, S. J., G. S. Podniesinski, E. A. Zimmerman, W. A. Millinor, and L. A. Sneddon. 2006b. Vegetation classification and mapping at Friendship Hill National Historic Site. Technical Report NPS/NER/NRTR—2006/041. National Park Service. Philadelphia, PA.
- Perles, S. J., G. S. Podneisinski, E. A. Zimmerman, W. A. Millinor, L. A. Sneddon. 2006c. Vegetation Classification and Mapping at Johnstown Flood National Memorial. Technical Report NPS/NER/NRTR—2006/034. National Park Service. Philadelphia, PA.
- Perles, S. J., G. S. Podneisinski, E. A. Zimmerman, E. Eastman, and L. A. Sneddon. 2007a. Vegetation Classification and Mapping at Allegheny Portage Railroad National Historic Site. Technical Report NPS/NER/NRTR—2007/079. National Park Service. Philadelphia, PA.
- Perles, S. J., G. S. Podniesinski, E. Eastman, L. A. Sneddon, and S. C. Gawler. 2007b. Classification and Mapping of Vegetation and Fire Fuel Models at Delaware Water Gap National Recreation Area: Volume 1 of 2. Technical Report NPS/NER/NRTR—2007/076. National Park Service. Philadelphia, PA.
- Pimentel, D., L. Lach, R. Zuniga, and D. Morrison. 2000. Environmental and economic costs of nonindigenous species in the United States. *BioScience* 50(1):53–65.
- Proulx, N. 2003. Ecological risk assessment of non-indigenous earthworm species. Minnesota Department of Natural Resources, Saint Paul, MN. 18 pp.
- Pickford, S. G. and J. W. Hazard. 1978. Simulation studies on line intersect sampling of forest residue. *Forest Science* 24(4):469–483.
- Rentch, J. S. 2006. Structure and functioning of Terrestrial Ecosystems in the Eastern Rivers and Mountains Network: Conceptual Models and Vital Signs Monitoring. Natural Resources Report NPS/NER/NRR—2006/007. National Park Service. Philadelphia, PA.
- Rooney, T. P., S. M. Wiegmann, D. A. Rogers, and D. M. Waller. 2004. Biotic impoverishment and homogenization in unfragmented forest understory communities. *Conservation Biology* 18(3):787–798.
- Rooney, T. P. 2007. Escaping herbivory: refuge effects on the morphology and shoot demography of the clonal forest herb *Maianthemum canadense*. *Journal of the Torrey Botanical Society* 124(4):280–285.

- Ruhren, S., and S. N. Handel. 2000. Considering herbivory, reproduction, and gender when monitoring plants: a case study of Jack-in-the-Pulpit (*Arisaema triphyllum* [L.] Schott). *Natural Areas Journal* 20(3):261–266.
- Ruhren, S., and S. N. Handel. 2003. Herbivory constrains survival, reproduction and mutualisms when restoring nine temperate forest herbs. *Journal of the Torrey Botanical Society* 130(1):34–42.
- Sanders, S., S. E. Johnson, and D. M. Waller. 2006. General vegetation monitoring protocol for the Great Lakes Network, Version 1.0. National Park Service, Great Lakes Network, Ashland, WI.
- Schmit, J. P., D. C. Chojnacky, and M. Milton. 2006. Forest Monitoring Protocol, Version 1.0. National Park Service. National Capital Region Network. Washington, DC.
- Stevens, D. L., and A. N. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal of American Statistical Association* 99(465):262–278.
- Tierney, G., and D. Faber-Langendoen. 2007a. NPS Northeast Temperate Network Long-term Forest Monitoring Protocol. Natural Resources Report NPS/NETN/NRR—XXXX/XXX. National Park Service. Fort Collins, Colorado.
- Tierney, G., and D. Faber-Langendoen. 2007b. Analyzing and Reporting Ecological Integrity. National Park Service. Northeast Temperate Network. Woodstock, VT.
- United States Forest Service (USFS). 2007. Forest Inventory and Analysis National Core Field Guide. Version 4.0. United States Forest Service. 224 pp.
- Urquhart, N. S., S. G. Paulsen, and D. P. Larsen. 1998. Monitoring for Policy-Relevant Regional Trends over Time. *Ecological Applications* 8(2):246–257.
- Urquhart, N. S., and T. M. Kincaid. 1999. Designs for detecting trend from repeated surveys of ecological resources. *Journal of Agricultural, Biological, and Environmental Statistics* 4(4):404–414.
- Van Wagner, C. E. 1964. The line-intersect method in forest fuel sampling. *Forest Science* 28:267–276.
- Vanderhorst, J. P., J. Jeuck, and S. C. Gawler. 2007. Vegetation Classification and Mapping of New River Gorge National River, West Virginia. Technical Report NPS/NER/NRTR-2007/092. National Park Service. Philadelphia, PA.
- Vanderhorst, J. P., B. P. Streets, J. Jeuk, and S. C. Gawler. 2008. Vegetation Classification and Mapping of Bluestone National Scenic River, West Virginia. Technical Report NPS/NER/NRTR—2008/106. National Park Service. Philadelphia, PA.

- Vitousek, P. M. 1990. Biological invasions and ecosystem processes: towards an integration of population biology and ecosystem studies. *Oikos* 57:7–13.
- Webster, C. R., and G. R. Parker. 2000. Evaluation of *Osmorhiza claytonia* (Michx.) C.B. Clarke, *Arisaema triphyllum* (L.) Scott, and *Actaea pachypoda* Ell. as potential indicators of white-tailed deer overabundance. *Natural Areas Journal* 20(2):176–188.
- Webster C. R., M. A. Jenkins, and J. H. Rock. 2005. Long-term response of spring flora to chronic herbivory and deer exclusion in Great Smoky Mountains National Park, USA. *Biological Conservation* 125:297–307.
- Woodall, C., and M. S. Williams. 2005. Sampling protocol, estimation, and analysis procedures for the down woody materials indicator of the FIA program. General Technical Report NC-256. USDA Forest Service. North Central Research Station. St. Paul, MN. 47 pp.
- Woodall, C., and V. J. Monleon. 2008. Sampling protocol, estimation, and analysis procedures for the down woody materials indicator of the FIA program. General Technical Report NRS-22. USDA Forest Service. Northern Research Station. Newtown Square, PA. 68 pp.
- Woodley, S. 1993. Monitoring and measuring ecosystem integrity in Canadian National Parks. Pp 155–176. *in* S. Woodley, J. Kay, and G. Francis (editors). *Ecological Integrity and Ecosystem Management*. St. Lucie Press.

Appendix A: Standard Operating Procedures.

ERMN Vegetation Vital Sign Protocol
Field Season Preparation
Version 3.0 (March 2009)

Overview

This SOP describes preparations for the summer field season and includes a list of necessary field equipment. Preparations should be completed by the start of the field season in early May.

Staff

This forest monitoring protocol involves the forest crew leader plus one or two crew members. Much of the vegetation monitoring protocol is most accurately and efficiently completed when working in pairs. One person on the crew (most likely the forest crew leader) should have good identification skills for woody, herbaceous, and graminoid plants in Pennsylvania and West Virginia and have some experience in forest sampling methods. Other crew members should have good woody plant identification skills and enjoy working outdoors. Between the crew leader and the two crew members, the crew should ideally have knowledge or expertise in the following areas: forest pests and pathogens; forest soils; and herbaceous and graminoid plant identification. The protocol will also require some knowledge of databases, as well as GIS mapping in ArcGIS or ArcView. The ERMN Data Manager can provide support for these tasks.

Locating skilled crew members takes time. Consider contacting universities and colleges in the ERMN area for qualified students. List the job announcements on websites such as the Society for Conservation biology job database (<http://www.conbio.org/jobs>) or listserves such as the Ecological Society of America's ecolog listserve (ecolog-l@listserv.umd.edu). Identify professors and professionals (such as those at the state Heritage Programs, the Morris Arboretum, etc) in the region who can refer potential seasonal staff.

Planning and Coordination

A current NPS research permit is required for each park scheduled for vegetation monitoring. The status of vegetation monitoring research permits and applications for new permits are available at the NPS Research Permit and Reporting System website (<http://science.nature.nps.gov/research>). ERMN personnel or the field crew leader should ensure that each ERMN park natural resource manager has the current Vegetation Monitoring Protocol including all SOPs, as well as an up-to-date map of sampling locations. A map clearly showing the locations of all plots must be provided to the cultural resource specialist in each park at least one month prior to any soil sampling. The cultural resource manager will assess the presence of cultural artifacts potentially compromised by soil sampling. All plot markers and tree scribing procedures must be cleared with each park natural resource manager prior to plot establishment. These procedures may vary by park.

ERMN should 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, including the Analytical Lab at the University of Maine (<http://anlab.umesci.maine.edu>, contact Sue Ehrich erich@maine.edu).

Maps

Prior to each field season, prepare maps showing the year's sampling locations at each park. One map should show the plot locations overlaid on the USGS topographical maps, with roads, trails, and park boundaries included. A second map should show the 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. If necessary, 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 using a color LaserJet printer (inkjet printing does not adhere well to Rite-in-Rain paper).

Supply the crew with Gazetteers for Pennsylvania and West Virginia, as well as the Emergency Response map for the Gauley River (available at the Cathedral Café, 134 S. Court Street, Fayetteville, WV, 25840, 304-574-0202), and the National Geographic map of New River Gorge National River (also includes Gauley and Bluestone Rivers).

Download plot coordinates into the ERMN GPS unit (see the Using the Global Positioning System SOP). Immediately after downloading the plot coordinates, it is critical to check the GPS map page to ensure that the plot locations are shown correctly on the GPS, ensuring that the coordinates were downloaded in the correct projection.

Schedule

Begin field crew training in May as soon as all crew members are available. Training will last one week and is discussed in more detail below.

To reduce seasonal variation between sampling visits, the following order must remain consistent from year to year. The growing season is longer in West Virginia, therefore, sample the West Virginia parks at the beginning and the end of the field season. Although this schedule may be altered by unforeseen events, strive to sample the parks according to the following schedule:

Late May–Early June: NERI
June–Early July: DEWA
July: ALPO, JOFL, FONE and FRHI
August: GARI and BLUE

The field crew leader should carefully consider logistics and the crew's capabilities and motivation levels when setting a weekly work schedule. Flex-time (e.g. four 10-hour days/week, and/or eight days working 10-hour days followed by six days off) may be more efficient to accommodate long travel times to parks and plot locations.

Logistics

ERMN personnel or the field crew leader should reserve or acquire a field vehicle for transport to and within parks. Depending on employees and projects contracts, a Pennsylvania State University fleet vehicle can be rented (contact Fleet Operations, 814-865-7571). Vehicles are also available from rental companies (e.g. Enterprise, National, etc). For all Pennsylvania parks, most plots can be accessed via a regular car and reasonable hiking. In DEWA, a few plots may

require a four wheel drive vehicle or a canoe. Resource managers at DEWA may provide a 4WD vehicle and/or canoe to the field crew on a day-by-day basis during the field season. In BLUE, a regular car should be sufficient. Since the Bluestone River is shallow enough to wade at most riffles, a canoe should not be necessary. In GARI and NERI, a four wheel drive vehicle with high clearance and a scrape plate is necessary to access several large sections of the parks. Wading across the Gauley and New Rivers is impossible and dangerous in almost all river stretches in the parks. Guided raft access may be necessary in NERI.

ERMN personnel or the field crew leader should contact the natural resource manager and/or research coordinator at each park to discuss the timing of field visits and reserve park lodging, if available. If no park lodging is available, make alternative lodging reservations. Wherever possible, lodging should include kitchen facilities and the internet.

Training

Prior to commencing each field season, ERMN must ensure all field personnel fully understand the field protocols by conducting in-situ training sessions. Field crew preparation should involve careful review and discussion of all SOPs, as well as field sessions using training plots. Crew members must read the entire protocol and all SOPs thoroughly. 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 should cover:

- job hazards and safety procedures;
- introduction to ERMN forest ecosystems;
- review common tree and shrub species of Pennsylvania and West Virginia;
- proper use of all equipment, including GPS, field computer, compass, clinometer, measuring tape, dbh tape, digital camera, laser hypsometer, and NPS radio;
- declination settings on compasses;
- using a clinometer to measure slope as percent and in degrees;
- reading plot locations maps;
- plot layout and installation;
- rules for rejecting or shifting pre-selected plot locations;
- measuring horizontal vs. slope distance;
- estimating slope distance using slope conversion table;
- determining terrain position, stand structure, stand disturbance, and crown closure;
- proper tree scribing technique;
- accurate diameter-at-breast-height measurement;
- determining of tree crown class;
- identifying specific tree conditions and foliage problems;
- identifying high priority exotic pests and pathogens for the ERMN;
- assessing snag and coarse woody debris decay classes;
- measuring seedling height;
- estimating percent cover classes;
- inspecting the forest floor for earthworm casts and burrows;
- collecting soil samples and separating by soil horizon;

- labeling, drying and storing soil samples;
- labeling unknown plant specimens;
- procedures for careful data collection and quality control;
- minimizing plot trampling;
- how the data are used and what information is gained from each type of data collected (i.e. why each type of data is important);
- expectations of field crew behavior;
- use of PSU fleet vehicles and NPS field vehicles;
- completing and submitting timesheets and expenses reports.

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, which will inhibit ERMN's ability to detect long-term trends. 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, 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 and within the microplots and quadrats. Extra-care must be taken to avoid trampling the regeneration microplots, the herb quadrats, and any coarse woody debris on or near a transect.

During training, designate one crew member as the field computer lead, and another as the GPS lead. The field computer lead should receive extra training in all aspects of the use and care of the field computer and the use of the ERMN vegetation monitoring database. Likewise, the GPS lead should receive extra training in the use of the GPS unit, and should carefully study the Using the Global Positioning System SOP, and the Garmin manual.

The ERMN Plant Ecologist should spend at least the first week of data collection after training in the field with the crew, to answer additional questions about the protocols and assure that the protocols are being implemented correctly.

Communication and Crew Oversight

The crew should carry a National Park Service radio at all times. Program the radio to the appropriate frequencies in each park. Crew members should know which frequencies work in which sections of each park, how to contact park radio dispatch, and be familiar with proper radio etiquette. In parks with cell phone coverage, crew members should carry a cell phone in the field for safety and to call their supervisor concerning protocol questions.

It is essential for the crew to maintain regular contact with ERMN staff throughout the field season. Establish a regular weekly telephone call time between crew leader and supervisors to

review the week's work. The update should cover questions or problems related to plots, protocol, logistics, and scheduling.

Division of labor for the crew must allow the crew leader to remain aware of crew activity on the plot during the regular course of data collection.

ERMN coordinators and any other supervisors should endeavor to join the crew in the field at least twice during the field season to directly observe data collection procedures.

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 repaired 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.

Handle the field computer carefully and protect the screen from injury at all times. During hard rain, store the field computer in a waterproof bag and use datasheets. Protect all electronic equipment, including the GPS unit, the digital camera, the laser, and the Sonin distance measures from water damage.

ERMN Vegetation Monitoring Equipment List:

General:

Park topo and aerial photo maps showing plot locations in protective plastic folders

Road maps for park region

Binder containing protocol and all Standard Operating Procedures

Slope conversion table

Park permits

Flagging

Pencils (sharpened or with extra lead)

Black Industrial Sharpies

Daypacks (3)

First aid kit

Insect repellent

Poison ivy soap

Snake chaps (3 pair)

Water and food

Field vests – optional

Raingear

Plot Establishment:

GPS unit and spare AA batteries

GPS antennae and spare battery

Compass (3)

30-m tape (3)

Chaining pins (3) – also called surveyor's steel arrows

18" long $\frac{3}{4}$ " diameter rebar (1 per plot)

Aluminum cap with plastic insert (for Pennsylvania parks, 1 per plot)
Brass cap with plastic insert (for West Virginia parks, 1 per plot)
Metal-plastic putty to attach caps to rebar
Rubber mallet
Small metal sledge hammer
Galvanized metal spikes, 10" or 12" long (10 per plot)

Plot Measurement:

Field computer
Harness table for field computer
Data sheets (on regular and Rite-in-Rain paper)
Enclosed clipboard (2)
Clinometer
Laser hypsometer
Sonin Electronic Distance Measures Combo Pro
10 m DBH tape
2 m DBH tape
Loggers Tape, retractable with distance and DBH measurements (2)
Finley pole (broom handle 1.5m long, with 1m, scribe height, and DBH marked)
Finley wedge for measuring sapling DBH
Steiner stick, marked at sapling height cut-offs
Non-stretch rope, with loop with in one end and a knot marking 2 m in length (2)
Tree scribe with guard, sharpened (2)
Peterson's Eastern Trees field guide
Compact, waterproof binoculars (8x)
Ruler (24", sturdy)
Ruler (10", clear plastic)
Reusable Signage System (for plot identification photograph)
Paper printed with park code and date fields for photo point sign (or extra paper to create sign)
PVC Quadrat frame - 1 x 1 m, w/ purple 10cm sections spray painted on to aid % cover estimates
10x hand lens (2)
Plastic bags for plant samples
Newcombs Wildflower Guide
PVC soil sampling quadrat – 10 cm x 10 cm
Sturdy trowel
Bunny soil knife or keyhole saw
Clippers
Sealable gallon-sized plastic bags for soil samples (6 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
Flora of Pennsylvania - Rhoads and Block

Flora of West Virginia - Strausbaugh and Core
The Shrub Identification Book - Symonds
The Tree Identification Book – Symonds
Peterson Field Guide to the Ferns of NE & Central N. America – Cobb, Farnsworth, and Lowe
Full-size plant press
Newspaper for pressing plant samples
AA Battery recharger
Replacement reels for loggers tape
Connector cables for GPS unit and digital camera
Power cords for Field computer and GPS antennae batteries

**ERMN Vegetation Vital Sign Protocol
Using the Global Positioning System (GPS)
Version 3.0 (March 2009)**

Overview

This SOP delineates the proper use of the ERMN Garmin GPSmap 60CSx unit.

Getting Started

Install two fully charged AA rechargeable batteries in the back of the unit. Always carry two additional fully charged AA batteries as back up.

Turn on the Garmin GPS by depressing the small power button near the antennae 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) to following menus:

System: GPS = Battery Saver
 WAAS / EGNOS = Enabled
Units: Position Format = UTM UPS
 Map Datum = WGS 84
 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.

Use the PAGE button to page through Satellite, Map, Compass, Altimeter, and Trip screens. Press the MENU button once to get a local menu, or twice to view the main menu showing setup and other options. Use the center ROCKER keypad to scroll up, down, left, or right through selections. Use the QUIT button to cancel a selection, or backup one step. When scrolling through fields in a menu, press the ENTER button to view all available options in a field. Also press ENTER to make a selection. To access the list of waypoints or navigate to a waypoint, press the FIND button.

To turn off the Garmin GPS unit, press and hold the small power button near the antennae 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 and the coordinate system is Universal Transverse Mercator (UTM). The zone is 17 for BLUE, NERI, GARI, FONE, FRHI, ALPO, and JOFL. The zone is 18 for DEWA and UPDE.

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.

Additional Antenna

In BLUE, GARI, and NERI, connect an external antenna to the GPS unit to capture sufficient signals. The external antenna requires its own battery, which also powers the GPS unit when connected to the antenna. Charge the antenna battery overnight, and carry a charged backup battery in the field. During plot work, disconnect the antenna from the battery to prolong battery life.

The antenna connects to the back of the GPS unit via two cables: a power cable and a “signal” cable. Place a rubber band around the GPS unit and cable connections to secure the cables in place. Do not connect the signal cable to the GPS unit when the power cable is not connected. Doing so will draw on and quickly deplete the GPS’s AA batteries.

Navigating

Check the Satellite page. When sufficient satellites (4 for 3D navigation, 3 for 2D navigation) have been located, the satellite page will display your location coordinates and the estimated accuracy. If 3D navigation is active, “3D” will appear in the satellite on the top of the screen. The GPS is most accurate when it has at least four satellites and a 3D position. Satellite reception will vary with interference from trees, topography, structures, weather, and satellite positions. The antenna should point skyward when navigating or collecting points.

You can navigate using the Map or Compass screens. Select a location (waypoint) to navigate toward by pressing the FIND button, and select WAYPOINTS. Select the Waypoint you would like to navigate to by Name or by Location. Now the Map or Compass screens will show the direction to travel.

When navigating using the GPS, remember that directional signals you receive from the GPS are only valid while you are moving. 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 may 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

- 1) To record a new location (waypoint), press the MARK button from any of the main screens.
- 2) On this screen, scroll to the waypoint name adjacent to the blue flag. Hit ENTER and type the name of the plot using the rocker bar and ENTER to select letters and numbers.
- 3) Name the plot using the four letter park code, three digit unique number, plus the capital letter F to represent that this point was taken in the field. (e.g. NERI.031F) To find the “.” and the numbers, highlight the “↑” and hit ENTER. A number pad will appear on the right side of the screen. After entering the name, Highlight OK, and hit ENTER.
- 4) Scroll to AVE at the bottom right of the screen. Hit ENTER. Let the Measurement Count reach at least 100–150 points. Watch the Estimated Accuracy—good estimated accuracy is under 10 m; excellent estimated accuracy is under 5 m.

- 5) When the desired number of points or estimated accuracy has been reached, hit ENTER to save the location. Note the estimated accuracy displayed before you hit ENTER. Record this on the datasheet.
- 6) Make sure that the name of the plot now shows at the top of the screen. Record the coordinates shown on the screen onto the datasheet. Scroll to OK and hit 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 with a descriptive name and date (e.g. DEWA_field_plot_locations_20070715.shp)

Suggested Reading

Garmin GPSMAP 60CSx Owner's Manual
Garmin GPSMAP 60CSx Quick Start Guide

**ERMN Vegetation Vital Sign Protocol
Site Selection and Plot Establishment
Version 3.0 (March 2009)**

Overview

This SOP provides instruction for establishing plots and collecting site information. Prior to the field season, select plot locations using GIS and the GRTS sampling algorithm to obtain a random, spatially balanced sample. Prior to implementing the GRTS selection process, remove plots that fall on private land, non-vegetated land uses, and steep slopes (i.e., >30 degrees) from the grid of potential points. Locations with safety hazards or difficult access may be discarded in the field using the procedures described below.

ERMN must ensure that plot marking procedures have been approved by the natural 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 relative to your position. This contrasts with magnetic north—the direction a compass needle points when in the northern hemisphere. Magnetic north varies across the landscape and over time. To locate true north, it is necessary to adjust a compass to account for the differences 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 2009, the declination for ERMN parks is as follows:

Park	Declination	Compass Adjustment
BLUE	7° 45' West	8° West
NERI	7° 42' West	8° West
GARI	7° 56' West	8° West
FRHI	8° 58' West	9° West
FONE	9° 13' West	9° West
ALPO	10° 8' West	10° West
JOFL	9° 56' West	10° West
DEWA	12° 37' West	13° West

Establishing Plot Center

Examine park maps, topographic maps, and aerial photography to determine the best route to a preselected plot location. Using GPS and compass, travel to the plot location. Remember that the GPS unit may affect compass readings—keep them sufficiently far apart. Do not take safety risks while traveling to plots. If off-trail topography becomes too steep or difficult, find an alternative route. If a safe route does not exist, discard the location and record the reason for abandoning the location.

To avoid plot location bias, it is very important to establish plot center as close to the pre-defined coordinates as possible. Doing otherwise can lead to serious data bias. As you near the pre-selected location, use the following protocol to locate plot center. The GPS unit will likely not have sufficient precision to navigate exactly to the pre-selected location. Thus, as soon as the GPS indicates you are within 15 m of the pre-selected location, continue exactly 10 paces (20 steps) in the direction of the pre-selected location and stop. Do not veer off course to avoid obstacles. This is plot center.

At plot center, ensure that the area is not a managed grassland (i.e., mowed periodically), cropland, or developed land, and that plot center is ≥ 15 m from the park boundary, agricultural fields, roads, developed land, or large perennial streams (without canopy closure over the stream). Small trails, ephemeral streams, or streams under closed canopy can be included in the plot. If the plot center is < 15 m from any of the features listed above, move the plot center 20 m horizontal distance perpendicular to the feature. This is the new plot center. If multiple features (roads, fields, streams) are present and there is insufficient space (< 40 m between features) to establish a plot, discard the plot and record the reason. Proceed to the next location on the list of plot locations.

If the plot presents a safety hazard such as steep slopes or unstable snags, discard the plot and record the reason. Proceed to the next location on the list of plot locations.

At plot center, set the 18 inch piece of rebar with appropriately labeled survey cap into the ground as close as possible to that location. If the rebar cannot be set exactly where you are standing, locate a place in the general vicinity (~ 2 m radius) where the rebar can be set. The survey cap should be flush with ground. The rebar marks the plot center from which all plot measurements are taken.

Establishing Transects

From the rebar, establish six (6) transects at 0, 60, 120, 180, 240, 300 degrees using a compass and measuring tape. The length of each transect is 15 m, **slope distance**. Be exact about sighting each transect since the transect will be relocated on the next sampling visit. Measure distances within 0.1 m error, and sight bearings within 4 degrees error.

When sighting compass bearings, crew members must take care that metal objects do not affect the compass needle, and that the compass is held level (flat) at all times. The compass needle will not show small shifts in azimuth when the compass is tilted. When sighting up or down slope, remember to hold the compass level—do not tilt it relative to the slope.

To measure slope distance, pull the tape taught parallel to the ground surface, ensuring that it is not caught on vegetation. Both ends of the tape must be held at the same height above the ground to keep it parallel to the ground.

At the end of each transect, set a galvanized 12 inch spike flush to the ground. If the spike cannot be placed exactly at the end of the transect due to rocks or trees, place the spike along the transect as close to the end as possible. It is important that the spike is on the same azimuth as the transect, even if the spike is not exactly 15 m from the plot center. Note the location of the spike in Plot Notes on the datasheet (e.g., spike for 180 transect placed 10 cm closer to plot center from the end of the transect). The transect is always 15 m in length even if the spike had to be placed at a distance shorter or longer than 15 m. On subsequent revisits, measure exactly 15 m slope distance as the transect length, using the spike as a reference point for the true end of the transect.

At the ends of three transects, attach the claw of the measuring tape to the spike to keep the tape in place during plot work. At the ends of the other three transects, place the handle of the measuring tape over the spike and wind the tape tight, locking the winding handle in place to keep the tape taut.

Establishing Microplots

Establish four (4) microplots at 30, 150, 210, and 330 degrees using a compass and measuring tape. The center of the microplot should be 7.5 m **slope distance** from plot center. Be exact about sighting and distance measurements since the plots are permanent. Distances should be measured to within 0.1 m error, and bearings should be sighted to within 4 degrees error.

To measure slope distance, pull the tape taught parallel to the ground surface, ensuring that it is not caught on vegetation. Both ends of the tape must be held at the same height above the ground to keep it parallel to the ground.

When sighting compass bearings, crew members must take care that metal objects do not affect the compass needle, and that the compass is held level (flat) at all times. The compass needle will not show small shifts in azimuth when the compass is tilted. When sighting up or down slope, remember to hold the compass level—do not tilt it relative to the slope.

At the center of the microplot, set a galvanized 12 inch spike flush to the ground. If the spike cannot be placed exactly at the center of the microplot due to rocks or trees, place the spike along the same azimuth as close as possible to 7.5 m from plot center. It is important that the spike is on the correct azimuth, even if the spike is not exactly 7.5 m from the plot center. Note the location of the spike in Plot Notes on the datasheet (e.g., spike marking the center of Microplot 150 was placed 10 cm closer to plot center on the correct azimuth). The location of the spike marks the center point of the microplot, the point from which the 2-m radius is measured, even if the spike is not exactly 7.5 m from plot center. On subsequent visits to the microplot, the spike should be used as the center point of the microplot. If a spike cannot be placed within 0.5 m of the actual microplot center (7.5 m from plot center) due to large rocks or trees, mark the center temporarily with a rock, flagging, or chaining pin while data is recorded. Record in the plot notes why the microplot center was not marked with a spike.

Data Collection

PARK. 4-letter park code (BLUE, NERI, GARI, FRHI, FONE, ALPO, JOFL, DEWA, or UPDE).

PLOT. Plot identification number, unique within each park.

GRTS ORDER. Order that this plot fell in the GRTS-determined sampling order.

OBSERVERS. First initial and last name of each crew member present.

DATE: Month/day/year that data was collected (e.g., 08/17/2007)

UTME. East Universal Transverse Mercator value of the plot center from the GPS unit once the location of plot center has been determined using the average position function.

UTMN. North Universal Transverse Mercator value of the plot center from the GPS unit once the location of plot center has been determined using the average position function.

DATUM. Use UTM NAD 83. For ALPO, JOFL, FONE, FRHI, BLUE, NERI, and GARI, the zone will be 17. For UPDE and DEWA, the zone will be 18.

GPS ACCURACY. Positional accuracy of the UTMN and UTME coordinates, in meters, as determined by the GPS unit when the average position function stopped.

DIRECTIONS. Directions for driving and walking to the plot, including trails, landmarks, distances, and bearings from identifiable landmarks or reference points. Include parking recommendations where applicable. Be very specific, so that future crews can successfully follow your directions.

ELEVATION. Elevation above mean sea level of the plot center, in meters, as determined by the GPS unit.

SLOPE. The predominant down slope angle across plot to the nearest percent. Occasionally, there will be multiple aspects within a plot (in a valley or on a narrow ridge), choose the predominant slope to measure by considering what direction water would eventually flow if poured onto the plot. Slope is determined with a clinometer by sighting parallel to the average incline or decline of the plot. To measure average slope, Observer 1 stands at the upper plot boundary and sights Observer 2 standing at the lower plot boundary. Observer 1 must sight Observer 2 at a height equivalent to the eye-level of Observer 1. Read slope directly as percent (not degrees) from the clinometer.

ASPECT. The direction the ground surface of the plot faces. Aspect is measured downslope using a compass. Record aspect to the nearest 1°. If the plot is flat and has no aspect, record “Flat”.

PLOT NOTES. Record any unusual plot features or problems encountered during plot setup, including reasons for discarding any pre-selected plot locations. Note any problems or irregularities inserting plot markers. Note any features which indicate plot history, including

evidence of past agricultural, silvicultural, or recreational use regardless of how long ago it may have been.

Revision History

From Version 1.0 to Version 2.0

December 2007 – distance to microplot centers from plot center should be measured as slope distance instead of horizontal distance.

ERMN Vegetation Vital Sign Protocol
Photopoint
Version 3.0 (March 2009)

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. Take photographs shortly after plot setup to record plot conditions before trampling occurs.

Data Collection

Photograph the plot from the end of one of the plot's transects, facing in towards plot center. The default location is the end of the 180° transect (shown as black square in figure below).

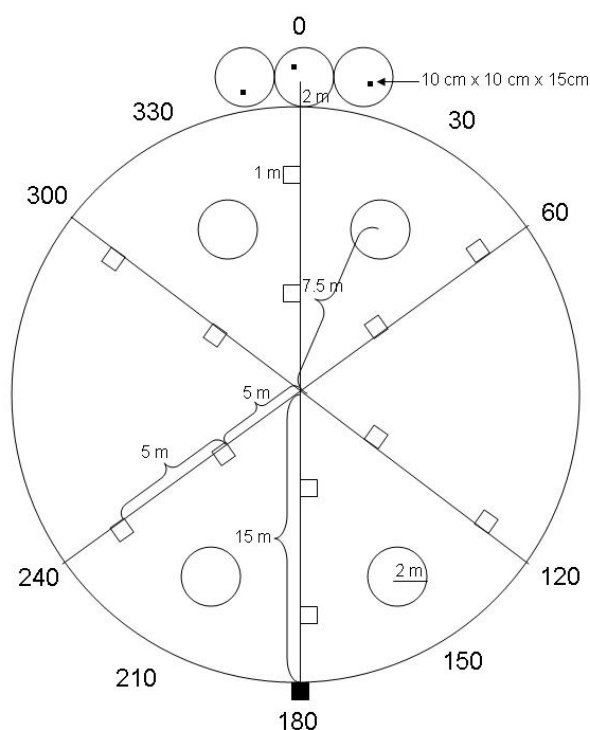
Select the end of the transect that will provide the best representative and unobstructed view of the plot. Choose a location where the view of the plot is not blocked by a large tree, dense vegetation or other obstructions. Note the photo location on the data sheet.

The photo should be taken from the end of a transect facing towards plot center. If necessary (in very thick vegetation), the plot photo can also be taken from plot center facing the direction of one of the transects. In this case, clearly explain on the data sheet where the photo was taken and which direction the camera was facing.

An identification sign must be visible in each photograph. Insert a sheet of paper printed with the park, plot number, and date in large black letters into the portable sign. Place the portable sign 2–5 m in front of the camera location where it is easily seen in the photograph but does not obstruct the view of the plot.

Capture one digital photograph of the plot. Use the landscape mode 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. If the camera has a date stamp function, make sure the date and time are set correctly and turn this function on.

For the Canon PowerShot S3IS camera, set the picture size to M2 Normal to achieve a good balance between quality picture resolution and manageable file size.



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

At the end of each week, the plot photos taken that week should be downloaded from the camera onto the field computer and backed up on an external thumb drive. Download the photos into clearly labeled folders on the field computer.

Data Collection

LOCATION FROM WHICH PHOTOGRAPH WAS TAKEN. Record the location in the plot from which the photograph was taken. This location will typically be from the end of the 180° transect.

PHOTO NUMBER. Record the photo number assigned to the photograph by the camera

PHOTO NOTES. Record any other important information about the photograph or its location.

Revision History

From Version 2.0 to Version 3.0

April 2009 – Changed the photo location to the end of the transect that will provide the best representative and unobstructed view of the plot. Previously, the photo location was the end of the 180 degree transect, or the best transect to the counter-clockwise position from 180 transect.

**ERMN Forest Vital Sign Protocol
Stand Measurements
Version 3.0 (March 2009)**

Overview

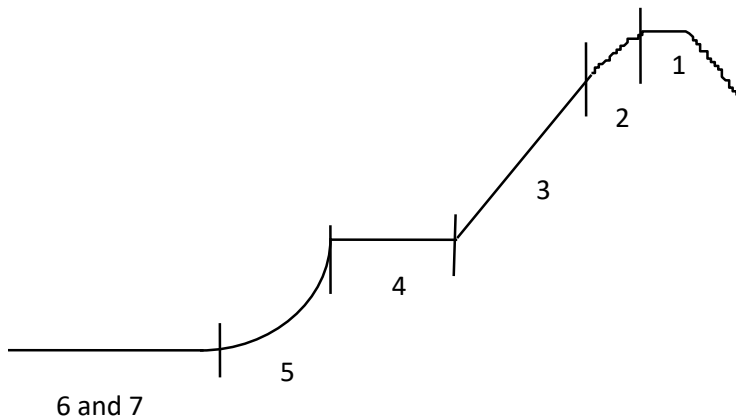
This SOP collects stand-level measurements within the plot to allow interpretation of other measures, and to assess stand structure and disturbance. This SOP is designed for use only during the summer leaf-on period (approximately May 15 to September 15).

Canopy closure and cover classes do not contain exact breakpoints (e.g., 25%). Classes are either above or below each breakpoint. This encourages the crew to assess and recorded cover classes rapidly, without compromising accuracy.

Data Collection

TERRAIN POSITION. Record the terrain position of the plot, using following codes:

- 1 Top of slope - convex region
- 2 Upper slope - convex region near top of slope
- 3 Mid-slope - uniform, fairly straight region
- 4 Bench - level land with slopes above and below
- 5 Lower slope - concave region near bottom of slope
- 6 Bottomland - flat and low-lying; may be associated with drainage and flooding
- 7 Flatland - unrelated to drainage and flooding; may have minimal elevation change



STAND STRUCTURE. Record the basic stand structure in the plot using the following codes:

- 1 Even-sized: A succeeding stand dominated by a single cohort of closely competing trees of relatively uniform size and height with a closed tree canopy ($\geq 60\%$ tree canopy cover). Smaller trees are typically stressed or overtopped and have fallen behind their associates. Regeneration and/or tall relics from a previous stand may be present. However, at least 66% of the trees in the plot have similar diameter and height.
- 3 Multi-sized: A later-successional or mature stand characterized by a distinct canopy with typical regeneration below including trees of many sizes and heights. Canopy trees vary in age and diameter such that $<66\%$ of the trees have similar diameter and height. Typically has a closed tree canopy ($\geq 60\%$ tree canopy) but gap dynamics may be evident.
- 4 Mosaic: Plot contains at least two distinct structural classes or size classes of trees, each covering at least 25% of the stand.
- 5 Early-successional: A succeeding stand without a closed tree canopy ($<60\%$ canopy cover). May be dominated by a mix of trees, saplings, shrubs and herbaceous vegetation.
- 6 Woodland: A stand with at least 25% but less than 60% canopy tree cover, giving the area an open appearance. Trees are open-grown, or growing in small groups interspersed with shrub or herbaceous cover or bare rock. Do not use this code for early-successional plots apparently succeeding to forest, or a forested plot that currently has $< 60\%$ canopy cover due to gap dynamics.

CROWN CLOSURE. Estimate the percentage of plot area covered by live tree crowns directly overhead and record appropriate code. If foliage is not present due to seasonal variation or temporary defoliation, visualize the amount of live crown normally present. Do not visualize foliage that formerly existed on dead branches.

- | | |
|---|-------------|
| 1 | 0 to 10 % |
| 2 | 10 to 25 % |
| 3 | 25 to 50 % |
| 4 | 50 to 75 % |
| 5 | 75 to 100 % |

DEER IMPACT. Visually inspect the plot and record the level of deer impact observed (adapted from Brose et al 2008). The browse preference of many common tree and shrub species is listed in Table 1. The browse preference of some common herbaceous species is listed in Table 2.

Record the deer impact level using the following codes and criteria:

- 1 Very low impact. No browse observed. Found only inside well maintained, woven-wire, deer-exclosure fences.
- 2 Low impact. Browse is absent or scarce. Browse-preferred regeneration is abundant and of varying heights. Browse-preferred plants are present and able to flower and fruit. Stump sprouts are present and have minimal evidence of browse.
- 3 Moderate impact. Browse evidence is observed but not common. Browse-preferred regeneration is present but with little variability in height. There are no stump sprouts, or stump sprouts are browsed. Nonpreferred browse and browse-resistant species are common and widespread.

- 4 High impact. Browse evidence is common, or browse-preferred regeneration is rare to absent. Nonpreferred and browse-resilient vegetation is limited in height growth by deer browsing.
- 5 Very high impact. Browse evidence is omnipresent, or browse-preferred regeneration is absent. The abundance of nonpreferred vegetation is reduced by browsing. Browse-resilient plants show signs of heavy repeated browsing and a browse line is evident.

Table 1. Browse preferences for tree regeneration and shrubs (adapted from Latham et al 2005).

Browse Preference	Scientific Name	Common Name
High – Moderate Preference	<i>Acer rubrum</i>	red maple
	<i>Cornus</i> spp.	dogwoods
	<i>Fraxinus</i> spp.	ashs
	<i>Liriodendron tulipifera</i>	Tulip poplar
	<i>Nyssa sylvatica</i>	Blackgum
	<i>Prunus pensylvanica</i>	pin cherry
	<i>Quercus</i> spp.	oaks
	<i>Sassafras albidum</i>	sassafras
	<i>Tilia americana</i>	basswood
	<i>Viburnum</i> spp.	viburnums
High Preference in Autumn and Winter	<i>Betula</i> spp. (<i>lenta</i> , <i>alleghaniensis</i>)	birches
	<i>Fagus grandifolia</i>	American beech
	<i>Tsuga canadensis</i>	Eastern hemlock
Low Preference	<i>Acer pensylvanicum</i>	striped maple
	<i>Carya</i> spp.	hickories
	<i>Liquidambar styraciflua</i>	sweetgum
	<i>Hamamelis virginiana</i>	witch hazel
	<i>Ostrya virginiana</i>	eastern hophornbeam
	<i>Populus</i> spp.	aspen
	<i>Prunus serotina</i>	Black cherry
	<i>Robinia pseudoacacia</i>	black locust

Table 2. Browse preference for herbaceous species.

Scientific Name	Common Name
Preferred Browse Species	
<i>Actaea</i> spp. (<i>A. pachypoda</i> , <i>A. podocarpa</i> , <i>A. racemosa</i> , <i>A. rubra</i>)	banberries
<i>Arisaema triphyllum</i>	Jack in the Pulpit
<i>Maianthemum canadense</i>	Canada mayflower
<i>Maianthemum</i> spp. (<i>M. racemosum</i> , <i>M. stellatum</i>)	false lily of the valleys
<i>Medeola virginiana</i>	Indian cucumber root
<i>Osmorhiza</i> spp. (<i>O. claytonia</i> , <i>O. longistylis</i>)	sweetroot
<i>Polygonatum</i> spp. (<i>P. biflorum</i> , <i>P. pubescens</i>)	Solomon's seal
<i>Prosartes</i> spp. (<i>P. lanuginosa</i> , <i>P. maculata</i>)	yellow fairy bells, mandarin
<i>Smilax</i> spp. (<i>S. rotundifolia</i> , <i>S. glauca</i> , <i>S. taminoides</i>)	catbriers
<i>Trillium</i> spp. (numerous)	trilliums
<i>Uvularia</i> spp. (<i>U. grandiflora</i> , <i>U. perfoliata</i> , <i>U. puberula</i> , <i>U. sessilifolia</i>)	bellworts
Browse Preference is Debated	
<i>Podophyllum peltatum</i>	mayapple
Species that are Avoided	
<i>Ageratina altissima</i>	white snake root
<i>Dennstedtia punctilobula</i>	hay-scented fern
<i>Thelypteris noveboracensis</i>	New York fern

MICROTOPOGRAPHY. Microtopography is small-scale variation in the land surface caused by tree tip-ups that create a pit and mound undulation. Microtopography is eliminated when a site is plowed, and recovers over time once an area is reforested. Record presence (1) or absence (0) of pit and mound microtopography on the plot. If pit and mound topography is suggested but not clear, record 9.

% COVER BY LAYER. Estimate the total cover of vascular plant foliage by strata within the plot. A rapid cover estimate is made, ignoring overlap among species. It may help to visualize cover by collapsing each layer into a 2-dimensional space, ignoring normal spaces occurring between leaves. Estimate total cover for each strata listed below. Use the following cover classes: <1%, 1–2%, 2–5%, 5–10%, 10–25%, 25–50%, 50–75%, 75–95%, 95–100%

Groundstory: <0.5 m above ground

Mid-understory: 0.5–2 m above ground

High-understory: 2–5 m above ground.

Subcanopy: Height defined for each plot. Must be >5 m.

Canopy: Height defined for each plot.

SUBCANOPY HEIGHT. Within the plot, select three intermediate trees with crowns visible from the ground that have heights typical of most intermediate trees in the subcanopy of the stand. To measure the height of each tree, move to a position as far from the base of the tree as possible along minimal slope while still allowing sufficient view of the tree crown. Determine height to the top of the intermediate tree either using the laser hypsometer or an analog clinometer. Record the height in meters.

To use the laser hypsometer:

- Set the laser to Height Routine, so that “HT” is visible in the bottom of the viewfinder.
- Hold the laser horizontal and sight the bole of the target tree through the viewfinder. Press the fire button.
- Then, sight the base of the target tree through the viewfinder. Press the fire button.
- Next, sight the top of the target tree through the viewfinder. Press the fire button. Note: It is not necessary that the laser actually hit the foliage at the top of the target tree. When measuring the base and the top of the tree, the laser hypsometer is actually measuring angle from horizontal, not distance. Therefore, your line of sight to the top of the tree does not need to be unobstructed as when measuring distance.
- The height of the tree should appear in the viewfinder.

To use an analog clinometer and simple triangulation:

- Use the clinometer to read the angles to the top of the tree and to its base. Grasp the clinometer with the right hand and sight through the optics with the right eye, keeping the left eye open and looking at the tree top. A movable scale with angle measurements in percent should be visible and should rotate as the clinometer is tilted. An optical illusion extends the hair-line crosshair outside of the clinometer frame. Aim the clinometer so that the extended hair-line coincides with the top of the tree. Hold the clinometer steady, close your left eye and read the percent on the right side of the rotating scale. This is Percent 1; include whether the percent is positive or negative.
- Repeat the previous step, this time aiming the extended hair-line at the base of the trunk. This is Percent 2; include whether the percent is positive or negative.
- Next, aim the extended hair-line of the clinometer above the base of the trunk to the point where the angle measurement is 0 degrees. This point on the trunk represents eye level of the observer. Run a measuring tape from the level of the observer’s eye to this point on the trunk. Check to make sure that your tape is measuring horizontal distance. Note this distance measurement in meters.
- Convert the percentages to decimals and complete the following equation:
$$\text{Calculate tree height} = (\text{Percent 1} - \text{Percent 2}) \times \text{Distance}$$

CANOPY HEIGHT. Repeat the instructions above to measure the height of three co-dominant trees. Within the plot, select three co-dominant trees with crowns visible from the ground that have heights typical of most co-dominant trees in the canopy of the stand. Record the height in meters.

DOMINANT VEG. For each of the strata listed above, record the type of vegetation dominant in that stratum. The type of vegetation with the most percent cover is the dominant vegetation. The possible types of vegetation are: Fern, Graminoid, Herb, Deciduous Shrub, Evergreen Shrub, Deciduous Tree, Evergreen Tree, and Vine.

SECONDARY VEG. If there is a second type of vegetation which covers greater than 25% of the plot, record that type of vegetation in the secondary vegetation column. Do this for each stratum that has a second type of vegetation covering greater than 25% of the plot. Not every stratum will have a secondary vegetation type. The types of vegetation are: Fern, Graminoid, Herb, Deciduous Shrub, Evergreen Shrub, Deciduous Tree, Evergreen Tree, and Vine.

DISTURBANCE CODE. Record up to three (3) disturbance codes from most to least important based on visual inspection of the plot. A disturbance must cause “significant threshold” damage, equivalent to either: 1) 25% of all trees in a plot, 2) 50% of the individual trees of a species (must include at least two trees in or near the plot), or 3) disturbance to at least 25% of the soil surface, understory vegetation, and canopy. Only record disturbances which appear to have occurred since the previous inventory or within the last four (4) years. If you record an unknown disturbance, attempt to capture a picture illustrating the disturbance.

- 00 None - no observable disturbance
- 10 Insect damage
 - 11 insect damage to understory vegetation
 - 12 insect damage to trees, including seedlings and saplings
- 20 Disease damage
 - 21 disease damage to understory vegetation
 - 22 disease damage to trees, including seedlings and saplings
- 30 Fire - prescribed or natural
- 40 Animal damage
 - 41 beaver damage to vegetation
 - 42 porcupine
 - 43 deer/ungulate
 - 44 bear
 - 45 rabbit
 - 46 domestic animal/livestock including grazing
 - 47 flooding caused by beaver
- 50 Weather damage
 - 51 ice/snow
 - 52 wind including hurricane, tornado
 - 53 flooding caused by weather
 - 54 drought
 - 55 earth movement/avalanches
- 60 Vegetation - suppression, competition, or vines
- 70 Unknown/not sure/other. Describe in Notes and take photo.
- 80 Human-caused damage - other than described in these codes. Describe in Notes and take a photograph.
- 90 Silvicultural treatment
 - 91 Overstory removal - removal of all or most of the canopy trees
 - 92 Selective cutting - removal of one or more trees from a stand (but see 91)
 - 93 Site preparation - clearing, slash burning, chopping, disking, bedding, or other practice to prepare site for regeneration.
 - 94 Artificial regeneration
 - 95 Other silvicultural treatment - use of fertilizers, herbicides, girdling, pruning, or other activities to improve the commercial value of the stand. Describe in Notes and take a photograph.

DISTURBANCE THRESHOLD. For each disturbance recorded above, record which threshold was triggered: 1) damage to 25% of all trees in a plot, 2) damage to 50% of the individual trees of a species (must include at least 2 trees in or near the plot), or 3) disturbance to at least 25% of the plot's soil surface, understory vegetation, or canopy.

DISTURBANCE % COVER. For each disturbance recorded above, record an approximate disturbance percentage to the nearest 10%. If the recorded disturbance was triggered by Threshold 1, record the approximate percentage of all trees in the plot damaged by that disturbance. If triggered by Threshold 2, record the approximate percentage of the individual trees of that species damaged by that disturbance. If triggered by Threshold 3, record the percentage of the soil surface, understory, or canopy affected by that disturbance.

FOREST FLOOR: Examine the ground within the plot and estimate the percent cover of each of the categories listed below. Use the following cover classes: <1, 1–2, 2–5, 5–25, 25–50, 50–75, 75–95, or 95–100 %. For reference, a 2.6 m by 2.6 m square is equal to 1% cover of the plot area.

BARE SOIL. Record the percentage of the plot covered by bare soil (mineral or organic). Do not include soil covered by leaf litter.

ROCK. Record the percentage of the plot covered by exposed bedrock or surface rocks (>10 cm).

WATER. Record the percentage of the plot covered by water.

OTHER. Record the percentage of other things that have significant cover in the plot (e.g. trash, etc).

TRAMPLED. Record the percentage of the plot showing evidence of trampling by humans, wildlife, or livestock. Trampling is assessed relative to the conditions of adjacent undisturbed soil. Include area occupied by established or unofficial trails traversing the plot, and record type of trail in plot notes.

Literature Cited

- Brose, P. H., K.W. Gottschalk, S. B. Horsley, P.D. Knopp, J.N. Kochenderfer, B.J. McGuinness, G.W. Miller, T.E. Ristau, S.H. Stoleson, and S.L. Stout. 2008. Prescribing regeneration treatments for mixed-oak forests in the Mid-Atlantic region. General Technical Report NRS-33. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 100 p.
- Latham, R. E., J. Beyea, M. Benner, C. A. Dunn, M. A. Fajvan, R. R. Freed, M. Grund, S. B. Horsley, A. F. Rhoads and B. P. Shissler. 2005. Managing White-tailed Deer in Forest Habitat From an Ecosystem Perspective: Pennsylvania Case Study. Report by the Deer Management Forum for Audubon Pennsylvania and Pennsylvania Habitat Alliance, Harrisburg. xix + 340 pp.

Revision History

From Version 2.0 to Version 3.0

February 2009 – Replaced Deer Browse Line which recorded presence/absence/unclear with Deer Impact from Brose et al 2008. The 5 levels of deer impact have clearer definitions for each level and will provide a more sensitive and repeatable measure. Added tables of browse preferred/avoided species for reference.

- Changed protocol for Subcanopy Height and Canopy Height from measuring the height of one tree in the subcanopy and canopy to measuring three trees in each layer. Using the average of three measurements will hopefully reduce the large variation in measurements between observers and years.

- Changed Disturbance threshold #3 to read: “3) disturbance to at least 25% of the soil surface, understory vegetation, and **canopy**.” so that the creation of large canopy gaps can be recorded. For example, if a few of the largest trees in the plot fall or were harvested (but they were <25% of the trees and, <50% of any species), resulting in a third of the canopy is opening, this disturbance can now be recorded.

April 2009 – For Stand Structure, changed “Even-aged” to “Even-sized” and “Multi-aged” to “Multi-sized” in response to reviewer comments that we were collecting no information on tree age. Also added more definite, quantitative definitions of those categories in response to field crew confusion over the distinction between the two categories.

ERMN Vegetation Vital Sign Protocol
Coarse Woody Debris
Version 3.0 (March 2009)

Overview

This SOP quantifies coarse woody debris using line intercept transect sampling along six 15-m transects at each plot. These data yield information on forest structural diversity and habitat for wildlife and fungi.

Definitions

Coarse woody debris (CWD) includes down, dead tree and shrub boles, large limbs, and other woody pieces. To be tallied in this protocol, the CWD piece must be ≥ 7.5 cm diameter and ≥ 1 m long. CWD includes dead trees leaning >45 degrees from vertical, measured along the bole.

CWD does not include:

- a. Woody pieces <7.5 cm in diameter at the point of transect intersection.
- b. Woody pieces <1 m in length.
- c. Dead trees leaning 0 to 45 degrees from vertical.
- 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

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.

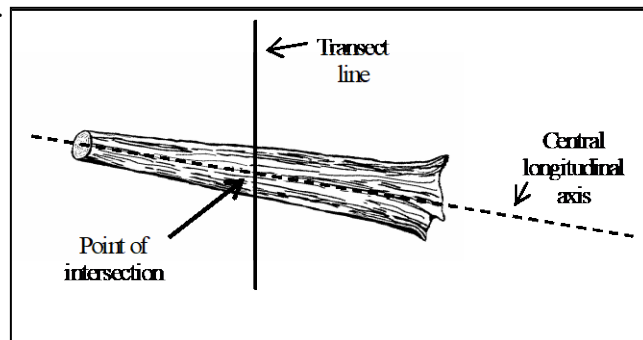
Transect Set Up

The six CWD transects extend 15 m slope distance from plot center in the following directions: 0° , 60° , 120° , 180° , 240° , and 300° . Transects are laid out along a straight line to avoid biasing piece selection. Detailed directions for establishing these transects are provided in the Site Selection and Plot Establishment SOP.

Tally Rules for CWD

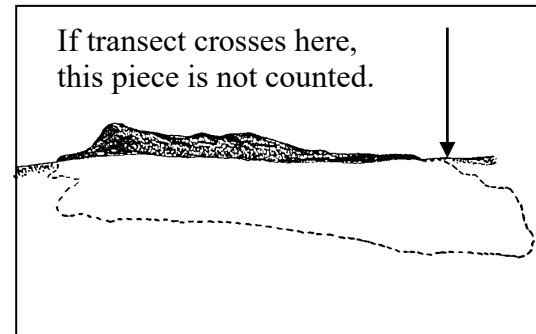
Most CWD will be lying on the ground. To be tallied by this protocol, the transect must intersect the central longitudinal axis of the piece of CWD (see diagram below left). The point of intersection between the transect and the central longitudinal axis of the piece must occur above the ground (see diagram below right). The CWD piece must meet the minimum diameter criteria (≥ 7.5 cm) at the point of intersection, as well as the minimum length criteria (≥ 1 m).

VIEW FROM ABOVE



(adapted from USFS 2005)

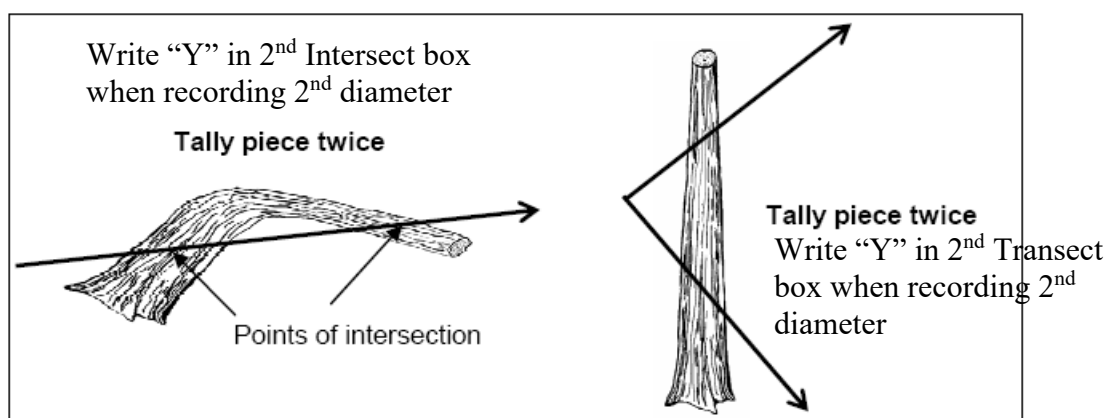
VIEW FROM SIDE



(adapted from Jenkins et al. 2004)

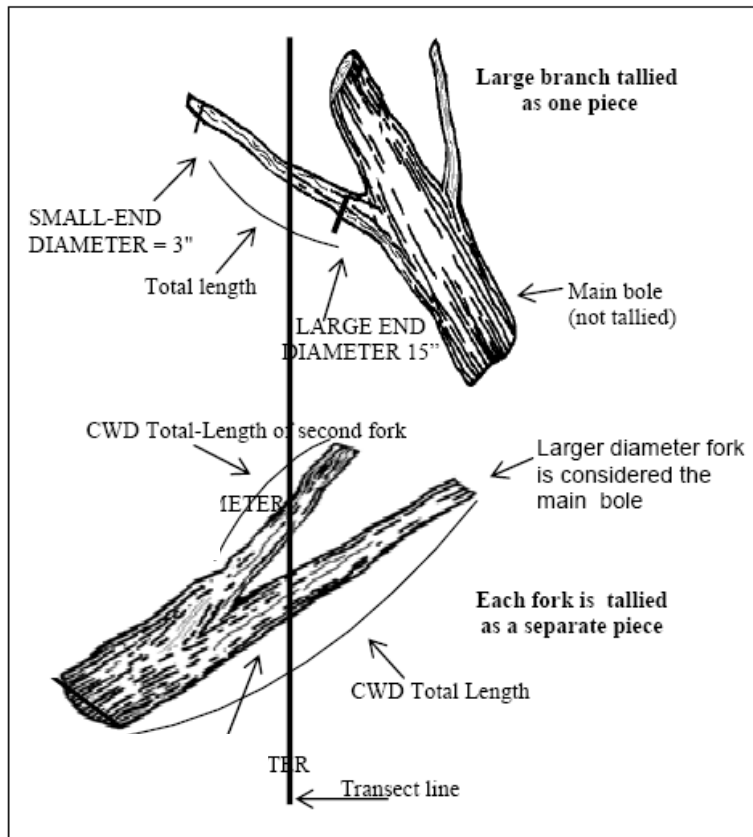
All snags leaning $>45^\circ$ from vertical should be tallied regardless of height off the ground. If a snag is too high to reach, record this fact in the Notes and estimate its diameter.

If a piece intersects a transect line more than once or intersects more than one transect, measure and record the diameter of the piece each time it intersects (see diagram below). When recording the diameter of a CWD piece the second time it intersects on a single transect, put a "Y" in "2nd Intersect" box on the data sheet. When recording the diameter of a CWD piece on a second or third transect, put a "Y" in "2nd Transect" box or "3rd Transect" box on the data sheet. If the plot center falls directly on a CWD piece, tally that piece only once on the 0° transect. This case will be uncommon.



(adapted from USFS 2005)

When the transect crosses a forked downed tree bole or large branch connected to a downed tree, tally each qualifying piece separately (see diagram below). To be tallied, each individual piece must meet the minimum diameter and length requirements. Write “Y” in the 2nd Intersect box when recording to second diameter of the forked piece.



(adapted from USFS 2005)

If a piece is fractured across its diameter or length, and would pull apart at the fracture when pulled from either end or sides, treat it as two separate pieces. If judged that it would not pull apart, tally as one piece. Tally only the piece intersected by the transect line.

Do not tally a piece if it intersects the transect on the root side of the root collar. Do not tally roots.

Data Collection

TRANSECT SLOPE. Measure and record the average slope of the transect to the nearest 1% using a clinometer. The observer with a clinometer should stand over the plot center at transect origin and sight a known height on a second person located at the transect end. The known height is the approximate height of the observer's eye on the second person.

TRANSECT. Record the number indicating the azimuth of the transect: 0°, 60°, 120°, 180°, 240°, or 300°. Sample the 0° transect first and work clockwise around the plot. If no pieces of

CWD cross the transect, record the transect azimuth and put a horizontal line through the Diameter and Decay Class boxes. All transects must be recorded for each plot.

For each piece of CWD tallied, record the following:

DIAMETER AT INTERSECTION. Record the diameter of the CWD piece, to the nearest 0.5 cm, at the point where the transect intersects the central longitudinal axis of the piece of CWD. Take care to measure diameter perpendicular to the piece's central axis (not perpendicular to the transect) as shown below. Diameter of CWD is typically measured by holding a metal tape or ruler above the log. To avoid parallax error, position your eyes directly over each end of the ruler in sequence. First position your eyes above one side of the CWD piece. Align the 0 end of the ruler with that side of the CWD piece. Then, without moving the ruler, position your eyes above the other side of the CWD piece. Read the diameter at the distance that appears aligned with that side of the CWD piece.



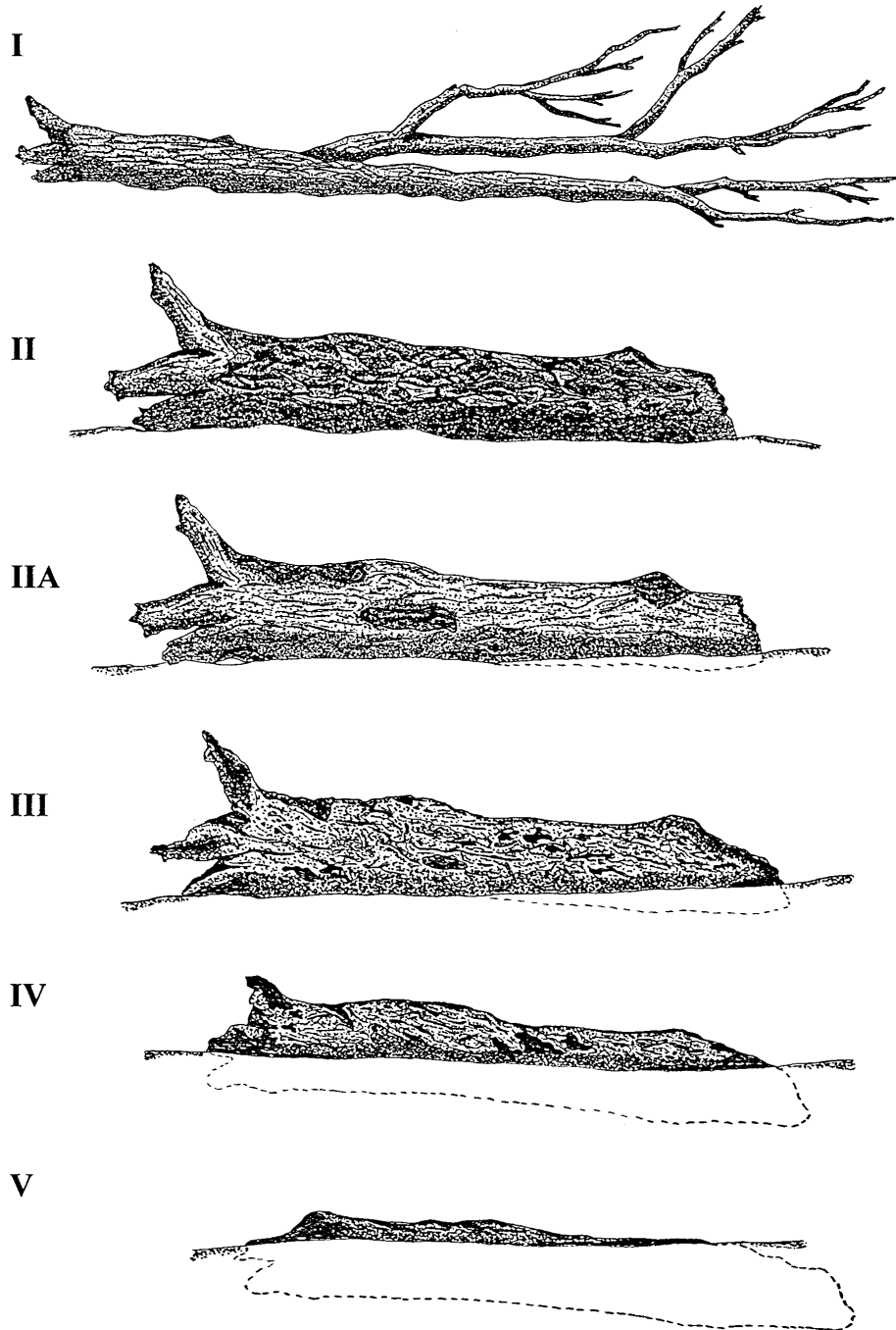
(from Coulston 2003)

DECAY CLASS. Record the code indicating the predominant decay class (>50% of the piece) along the length of the entire CWD piece. If no single class dominates, average the decay classes present. See the figure and tables on the following pages for illustrations and descriptions of decay classes.

HOLLOW. Record whether piece is hollow (Y) or not (N). A piece is considered hollow if a cavity extends at least 0.5 m along the central longitudinal axis of the piece, and the cavity entrance is at least 1/4 the diameter of the piece.

2ND INTERSECT. If a piece of CWD intersects the same transect more than once or two pieces of CWD are connected, record an “Y” in the “2nd Intersect” box on the lines that record the second, third, etc diameters recorded from the same piece of CWD. Indicate in the Notes which pieces are connected, as shown in the example below.

2ND TRANSECT. If a piece of CWD intersects with a second transect, record an “Y” in the “2nd Transect” box on the line that records the second diameter measured from the same piece of CWD. Indicate in the Notes which diameters were measured from the same piece of CWD, as shown in the example below.



Decay stages of down deadwood in eastern deciduous forests. Classes are based upon Pyle and Brown (1998). Figure is adapted from Jenkins et al. (2004). We will not use Decay Class IIA.

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 Betula and Prunus	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 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

(adapted from Pyle and Brown 1998 and USFS 2005)

3RD TRANSECT. If a piece of CWD intersects with a third transect, record an “Y” in the “3rd Transect” box on the line that records the third diameter measured from the same piece of CWD. Indicate in the Notes which diameters were measured from the same piece of CWD.

NOTES. Record anything unusual about the transect placement or the pieces of CWD. If the 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, as shown in the example below.

Example of Completed CWD Transect Data Sheet

Transect	Diameter	Decay Class	Hollow	2 nd Intersect	2 nd Transect	3 rd Transect	Notes
0	-----	-----					
60	8.5	2	N	N	N	N	#1
60	10.0	2	N	Y	N	N	Forked piece, connected to #1
120	-----	-----					
180	26.5	3	N	N	N	N	#2
180	13.5	4	Y	N	N	N	
240	19.0	3	N	N	Y	N	Same piece as #2
300	8.0	1	N	N	N	N	Pinus strobus

References

- Coulston, John W. et. al. 2003. Forest Health Monitoring 2003 National Technical Report. U.S. Department of Agriculture, Forest Service, Southern Research Station.
- Jenkins, M. A., Webster, C.R., Parker, G.R., and M.A. Spetich. 2004. Coarse woody debris in managed Central Hardwood forests of Indiana, USA. *Forest Science* 50:781–792.
- Pyle, C., and M. M. Brown. 1998. A rapid system of decay classification for hardwood logs of the eastern deciduous forest floor. *Journal of the Torrey Botanical Society* 125:237–245.
- United States Forest Service. 2005. Forest Inventory and Analysis National Core Field Guide Phase 3 – Downed Woody Materials. Version 3.0. United States Forest Service. 38 pp.

ERMN Vegetation Vital Sign Protocol
Groundstory Diversity
Version 3.0 (March 2009)

Overview

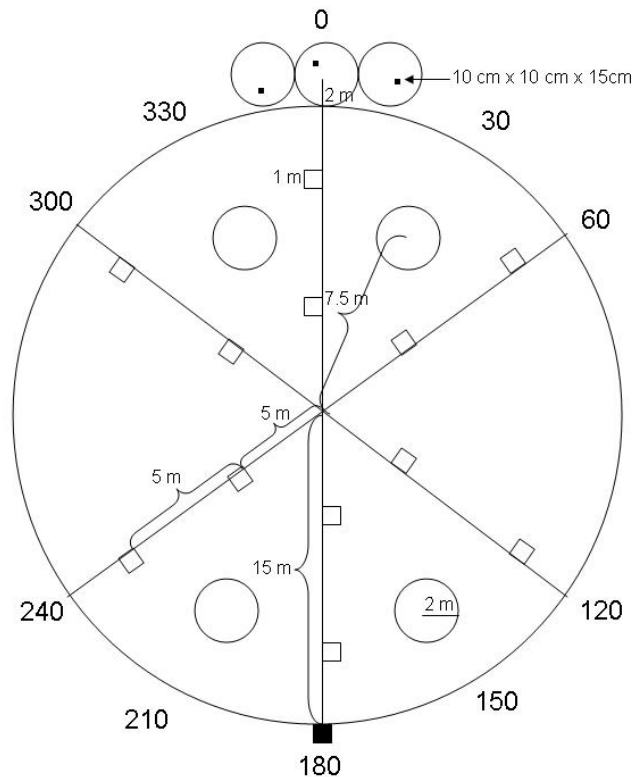
This SOP measures the composition and abundance of groundstory vascular plants. Species percent cover data are collected in twelve 1-m² quadrats nested within each 15-m radius plot. This SOP should be conducted by a person (botanist or vegetation crew leader) familiar with flora of the region, especially herbaceous, graminoid, and fern species. This protocol should be conducted only during the summer months (approximately May 15 to September 15).

Quadrat Set Up

The quadrat frame is made from ½ inch PVC pipe, with four pieces cut to be 1 m long when inserted into right angle corner pipe joints. One side of each corner joints should be detachable to improve maneuverability. The quadrat poles should be painted with 10-cm lengths of purple PVC primer, alternating with 10-cm lengths of unpainted white area. Thus, when the quadrat is assembled, each 10-cm x 10-cm purple or white square section illustrates 1% of the quadrat, facilitating accurate estimation of percent cover.

The location of the twelve quadrats is determined by the six transects used to measure coarse woody debris. These six transects extend 15 m slope distance from plot center in the following directions: 0°, 60°, 120°, 180°, 240°, and 300°. Transects are laid out along a straight line to avoid biasing the data collection. Two quadrats are placed along each transect. Quadrats are always placed to the LEFT of the transect meter tape, as one looks down the transect from plot center (i.e., the quadrats are placed on the counter clockwise side of the transect tape, as shown in the adjacent figure). The lower corners of the quadrats are placed at 5 and 10 meters from plot center, respectively, such that the quadrats cover 5–6 m from plot center and 10–11 m from plot center. The quadrats are placed so that the outer edge of the quadrat frame touches the outside edge of the meter tape. The quadrats are laid on the ground so that it is measuring 1 m slope distance along the transect. Do not prop up the edges to make the quadrat level.

When a quadrat is located on a steep slope the observer should be positioned next to or downhill from the quadrat to prevent sliding or falling into the quadrat. In areas of thick vegetation, the quadrat poles should be slid through the vegetation.



To avoid trampling the vegetation in the quadrats, all crew members must be aware of quadrat locations and avoid these areas. Always walk on the RIGHT side of the transect when heading away from plot center, and walk on the LEFT side of the transect when heading towards plot center. In other words, stay on the clockwise side of the transects and avoid the area on the counterclockwise side of the transects.

Data Collection

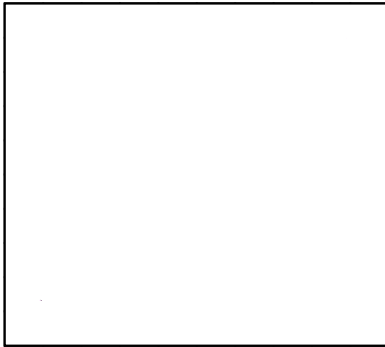
Percent cover class: Within a quadrat, percent cover will be recorded using the following cover classes:

Percent Cover Range	Cover Class	Class Midpoint
Absent	0	0
0–1%	1	0.5
1–2%	2	1.5
2–5%	3	3.5
5–10%	4	7.5
10–25%	5	17.5
25–50%	6	37.5
50–75%	7	62.5
75–95%	8	85.0
95–100%	9	97.5

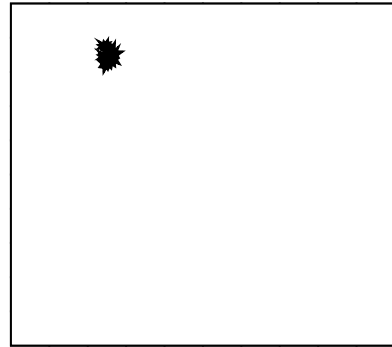
(from Peet et al. 1998)

Graphic representations of these cover classes and their midpoints are provided on the following page. Use the 10×10-cm purple and white square sections painted on the quadrat poles to help determine percent cover. Each purple or white square illustrates 1% of the quadrat.

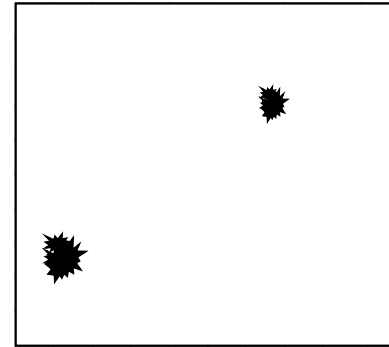
Notice the exact breakpoints (e.g., 25%) are not included in any class. Classes are either above or below each breakpoint. This is not a mistake. The most suitable class should be assessed and recorded as rapidly as possible while maintaining accuracy.



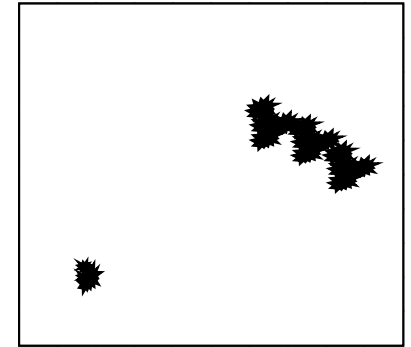
Class 0: Absent



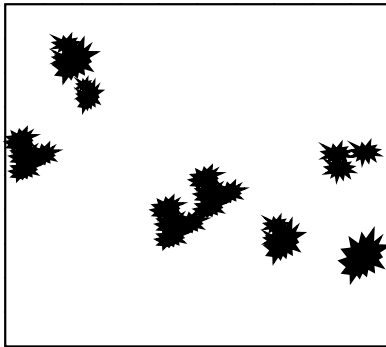
Class 1: 0 – 1 %



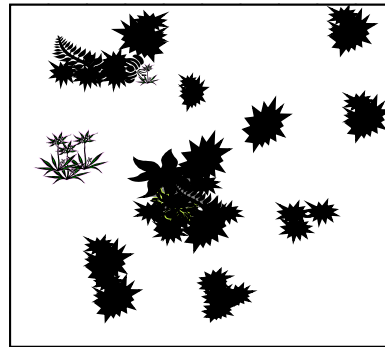
Class 2: 1 – 2 %



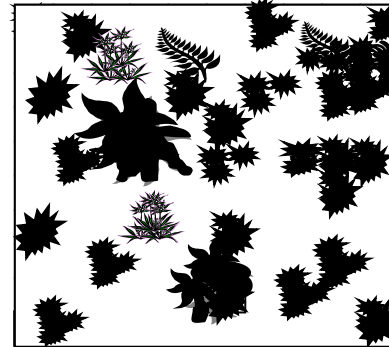
Class 3: 2 – 5 %



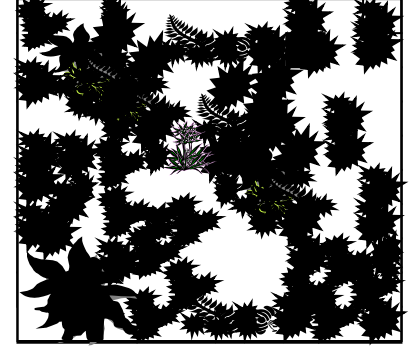
Class 4: 5 – 10 %



Class 5: 10 – 25 %



Class 6: 25 – 50 %



Class 7: 50 – 75 %

(modified from Peet et al. 1998)



Class 8: 75 – 95 %



Class 9: 95 – 100 %

Quadrat Characterization

Quadrat Substrate Characterization: Examine the quadrat. If the vascular and nonvascular plants were removed (or it was winter), what does the surface of the quadrat look like? Record the appropriate percent cover class for each of the following categories within the quadrat. The first four categories (Rock, Wood, Trunk, Trash) provide information on how much space in the quadrat is unavailable for plant growth. The second three categories (Soil, Litter, Water) provide information on the conditions available for plant growth. The total cover of these seven categories should add up to approximately 100% (the total will not be exact due to the range of values included in the larger percent cover classes).

% ROCK. Record the cover class of exposed rock and moss- or lichen-covered rocks. Include all rocks greater than 1 cm in length by 1 cm in width.

% WOOD. Record the cover class of downed coarse and fine woody debris >1 cm in diameter. Moss- or lichen-covered wood is counted as wood cover. Woody debris that is not touching the ground is not included in the percent cover.

% TRUNK. Record the cover class that best represents the basal area of live woody trunks and stems > 1 cm in diameter at the root collar.

% TRASH. Record the cover class of human-discarded objects (tires, bottles, metal, etc) visible on the ground. Lightweight items (plastic bags/wrappers) that have blown into the quadrat and will likely blow or roll out of the quadrat should not be included in the percent cover. The cover of trash buried below the soil surface should not be included.

% SOIL. Record the cover class of exposed bare dirt or sand. Large areas of moss that are not on rock or wood are counted as dirt percent cover.

% LITTER. Record the cover class of leaf and other vegetative litter.

% WATER. Record the cover class of standing, ponded, or flowing water on the surface of the quadrat.

Quadrat Vegetation Characterization: Examine the vegetation < 2m in height in the quadrat. Record the appropriate percent cover class for each of the following within the quadrat. The total of these five categories can be less than 100%, if portions of the quadrat are unvegetated. The total can exceed 100% if vegetation is dense and overlapping. Refer to the Master Plant List to determine which species are woody, herbaceous, graminoid, fern, or vine.

% NONVAS. Record the cover class of all nonvascular plants, including moss and lichens.

% WOODY. Record the cover class of all woody species (i.e., trees seedlings, saplings, and shrubs). Refer to the Master Plant List to determine which species are trees and shrubs.

% VINE. Record the cover class of all woody and herbaceous vine species. Refer to the Master Plant List to determine which species are vines.

% GRAM. Record the cover class for all graminoid species, including grasses, rushes, and sedges.

% FERN. Record the cover class for all fern species and fern allies such as *Lycopodium* spp..

% HERB. Record the cover class for all herbaceous species (i.e., vascular plants that are not woody, vines, graminoid, or fern).

Species Data

SPECIES. Each quadrat is examined by an observer (vegetation crew leader or contract botanist) familiar with flora of that park. Record the list of all vascular plant species that are rooted in or overhanging the quadrat within 2 m of the ground. Species names follow the Integrated Taxonomic Information System (ITIS). Refer to the Master Plant List for proper nomenclature.

CONFIDENCE. 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 = Orchidacea; Confidence = 1) 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 = 3) for obscure, small, or un-collectable individuals. Use the following codes:

- 1 = confident
- 2 = somewhat confident
- 3 = not very confident

PERCENT COVER CLASS. The percent cover class for each species is estimated and recorded, using the cover classes discussed above. For each species, cover is based on a vertically projected polygon described by the outline of the foliage, ignoring any normal spaces occurring between leaves. Estimate only foliar cover on plants or portions of plants that fall inside the quadrat frame and are less than 2 m above the ground. Base percent cover estimates on the current years' growth, by including living, damaged, and dead material only from the current year. Record the percent cover present at the time of the plot visit. Do not adjust the percent for the time of year during which the visit was made (i.e., for immature or wilted plants). Overlap of plants of the same species is ignored. There will often be overlap of plants of different species. Therefore, the total cover for a quadrat may exceed 100%.

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. Follow these guidelines to determine whether and how to collect a specimen for subsequent identification:

- Do not collect any plants represented by 5 or fewer individuals (i.e., locally sparse) in the general vicinity of the plot. If an unknown plant is not locally sparse, it can be collected from the plot, outside the quadrats.

- 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, collect a photograph. 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.

Deer Browse Indicators

QUADRAT. Record the code corresponding to each quadrat. Use the transect azimuth and the distance from plot center. Appropriate codes are: 0-5, 0-10, 60-5, 60-10, 120-5, 120-10, 180-5, 180-10, 240-5, 240-10, 300-5 and 300-10.

If any of the target species listed in the table below occur in the quadrat, the data described below will be recorded.

Scientific Name	Common Name
Actaea spp. (A. pachypoda, A. podocarpa, A. rubra, A. racemosa - formerly Cimicifuga racemosa])	baneberries
Arisaema triphyllum	Jack in the pulpit
Maianthemum canadense	Canada mayflower
Maianthemum spp. (M. racemosum, M. stellatum)	false lily of the valleys
Medeola virginiana	Indian cucumber root
Osmorhiza spp. (O. claytonia, O. longistylis)	sweetroot
Podophyllum peltatum	mayapple
Polygonatum spp. (P. biflorum, P. pubescens)	solomon's seals
Prosartes spp. (P. lanuginosa, P. maculata)	yellow fairy bells, mandarin
Trillium spp. (numerous)	trilliums
Uvularia spp. (U. grandiflora, U. perfoliata, U. puberula, U. sessilifolia)	bellworts

SPECIES. Record the species name only if the species is rooted in the quadrat. Plants that are overhanging into the quadrat but that are not rooted inside are not counted in this section of the protocol.

NUMBER OF UNBROWSED REPRODUCING PLANTS. For each target species, tally number of plants with evidence of flowering or fruiting and no evidence of browse using the dot tally system.

NUMBER OF BROWSED REPRODUCING PLANTS. For each target species, tally number of plants with evidence of flowering or fruiting and with evidence of browse using the dot tally system.

NUMBER OF UNBROWSED NON-REPRODUCTIVE PLANTS. For each target species, tally number of non-flowering, non-fruiting plants with no evidence of browse using the dot tally system.

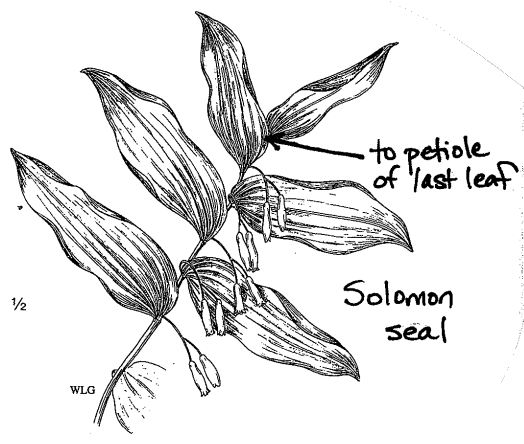
NUMBER OF BROWSED NON-REPRODUCTIVE PLANTS. For each target species, tally number of non-flowering, non-fruiting plants with evidence of browse using the dot tally system.

HEIGHT. For each target species, measure the height of the tallest 3 plants in each quadrat. Height is measured in centimeters, to the nearest 1 cm. Start with the plant that appears the tallest and work towards smaller plants until 3 plants have been measured (if 3 are present). To measure height, gently align the plant along a ruler. Realign the ruler along any curves present to account for additional height masked by a curved stem. See the drawings on the following pages that illustrate the point for each species at which height should be measured.

Record the height of the tallest plant under HEIGHT 1. Record the height of the second tallest plant under HEIGHT 2. Record the height of the third tallest plant under HEIGHT 3.

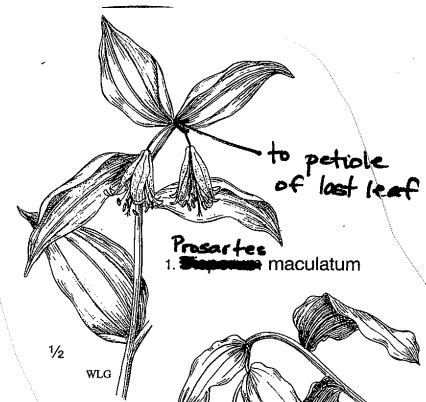
Plot Species

A time-constrained search for additional plant species is conducted on the whole 707 m² plot by an observer (vegetation crew leader or contract botanist) familiar with vegetation at the park. Record all additional vascular species that occur within 2 meters of the ground within the plot, searching for no more than 15 minutes. If portions of the plot are wet, only emergent plants are recorded. Record the list of additional species found in the plot on the Quadrat Species datasheet under the heading "Plot Species". Record the level of confidence in species identifications using the confidence codes listed above.

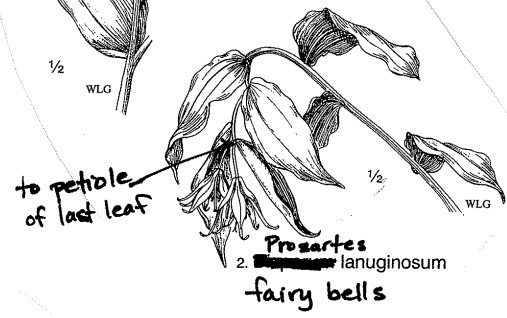


Solomon seal

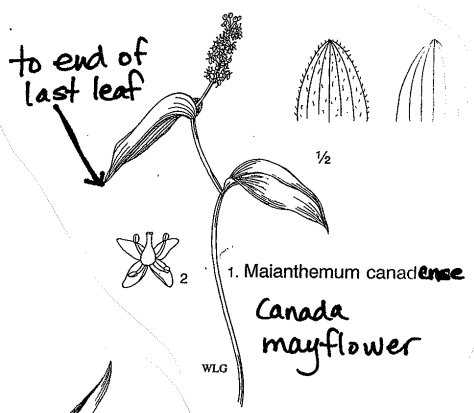
2. *Polygonatum biflorum* and
Polygonatum pubescens



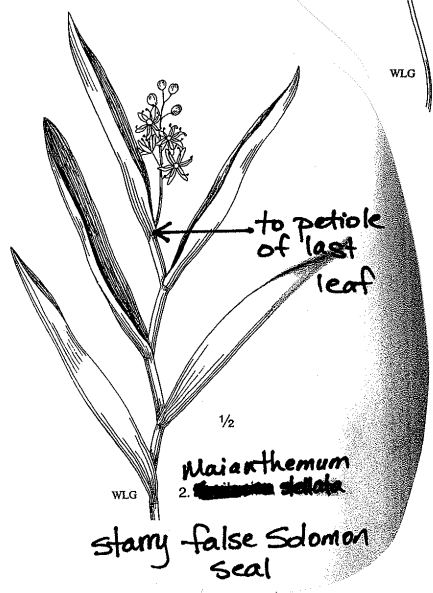
1. *Proserpinaca maculatum*



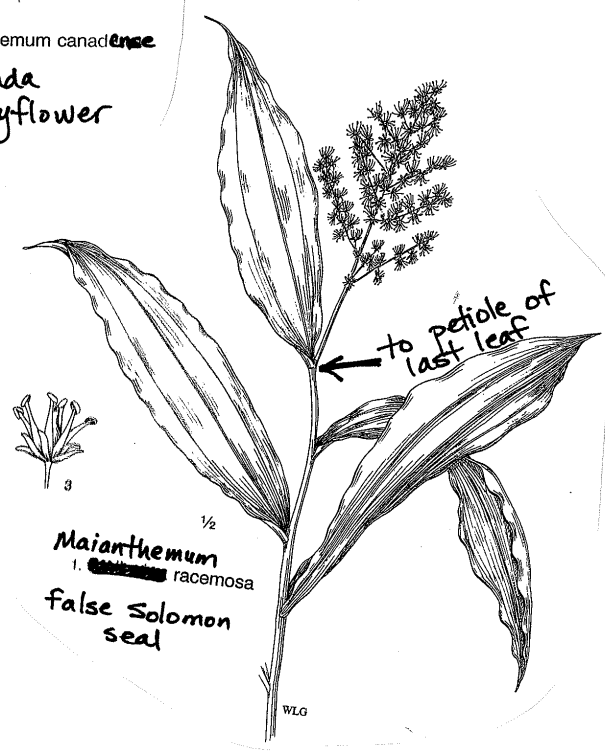
2. *Proserpinaca lanuginosum*
fairy bells



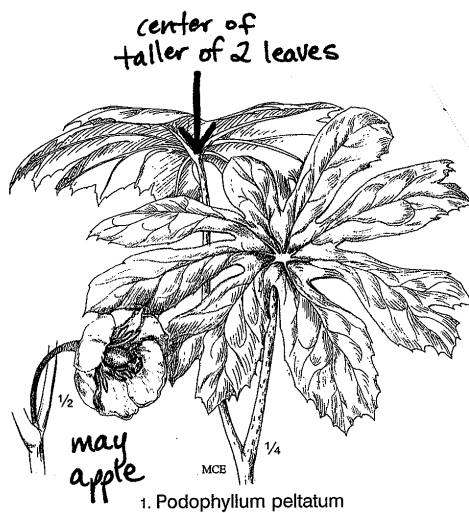
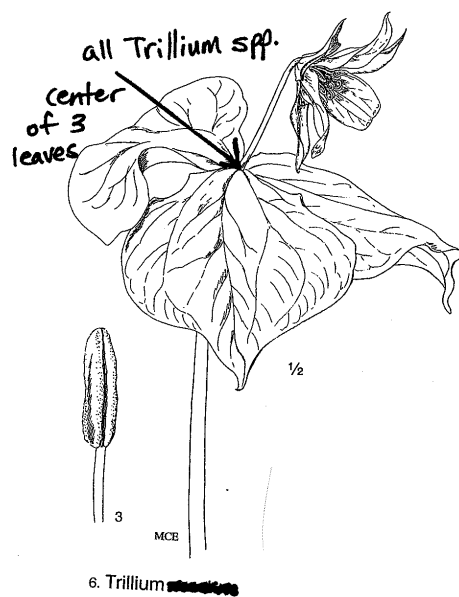
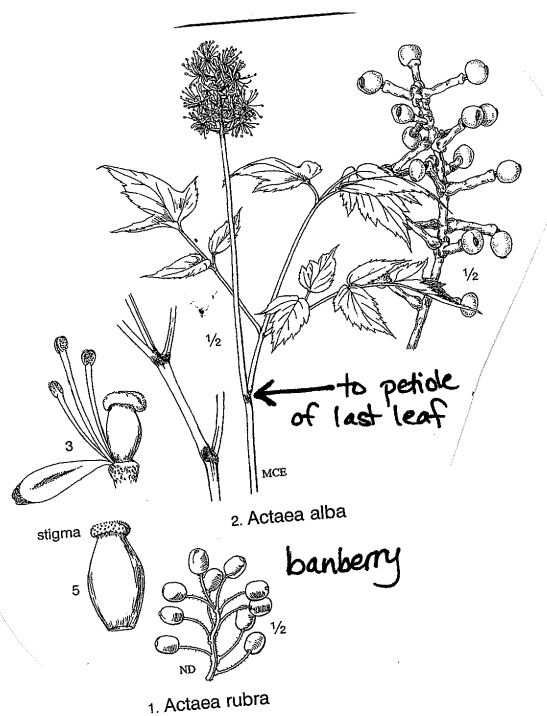
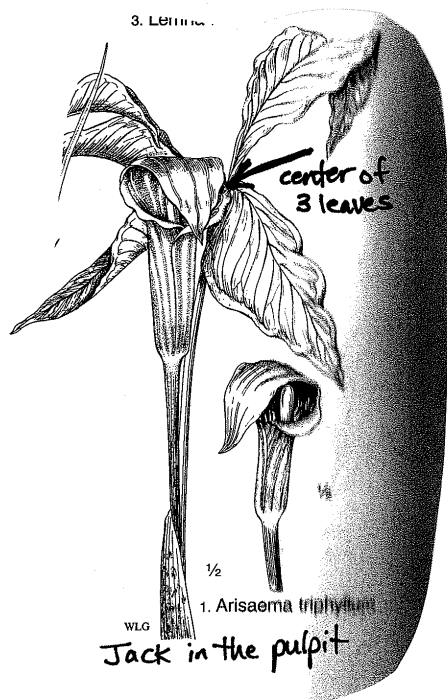
1. *Maianthemum canadense*
Canada mayflower

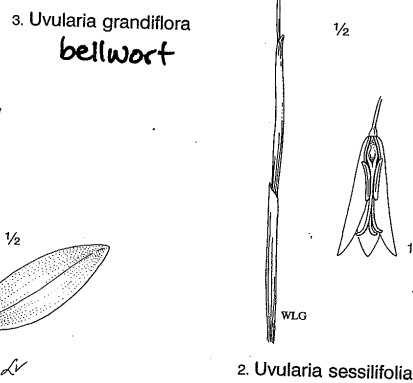
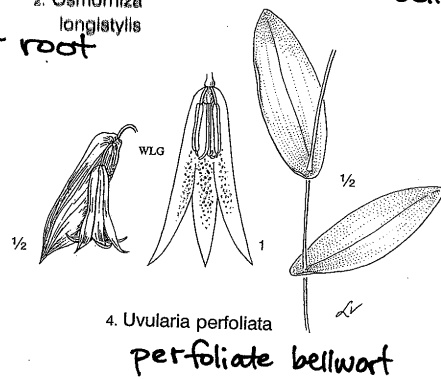
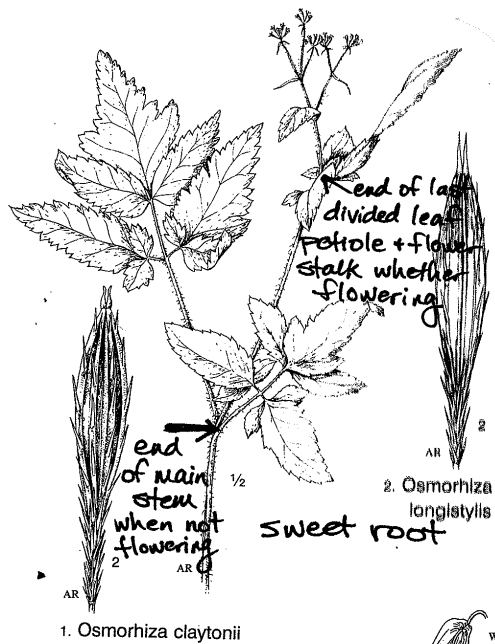
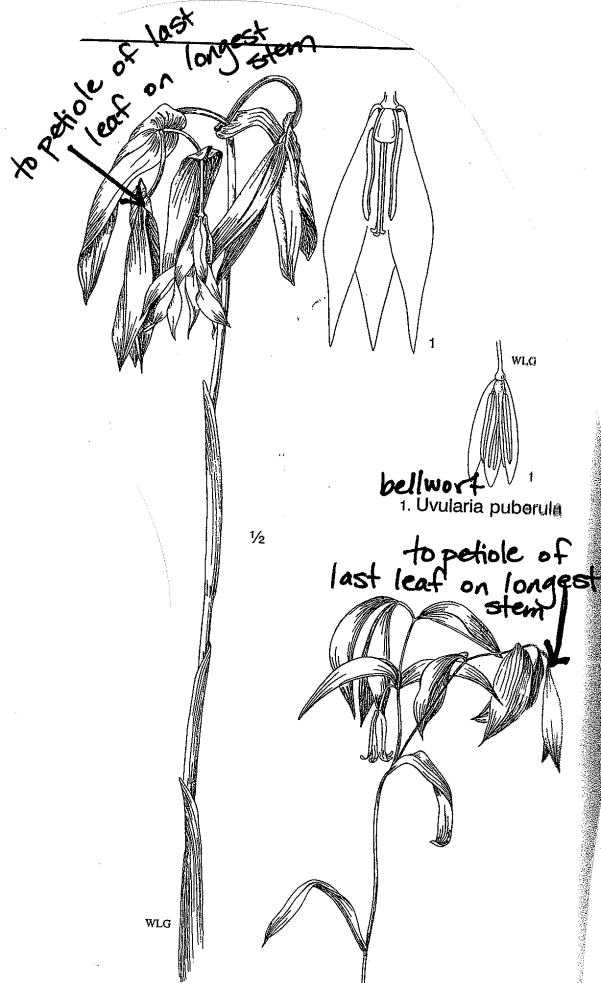
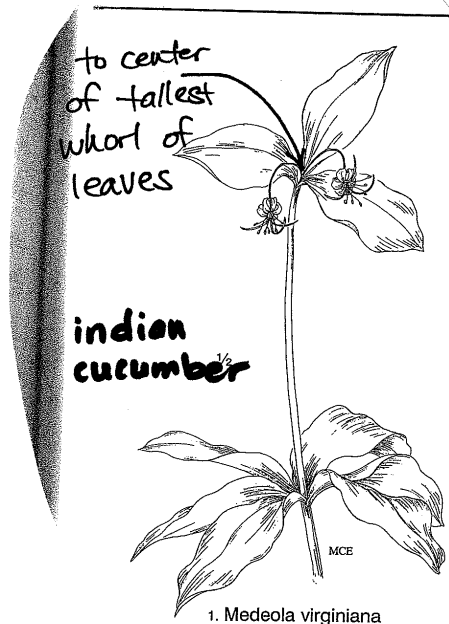


2. *Maianthemum stellatum*
starry false Solomon seal



1. *Maianthemum racemosum*
false Solomon seal





2. *Uvularia sessilifolia*

References

- Braun-Blanquet, J. 1965. Plant sociology: the study of plant communities (Transl. by G.D. Fuller and H.S. Conard) Transl. of 1st edition of Pflanzensoziologie (1928). McGraw-Hill, New York and London. 438p.
- Daubenmire, R.F. 1968. Plant communities: A textbook of plant synecology. Harper & Row. New York. 300p.
- Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley & Sons. New York. 547 p.
- Peet, R. K., Wentworth, T. R., and P. S. White. 1998. A flexible multipurpose method for recording vegetation composition and structure. *Castanea* 63: 262–274.

Revision History

From Version 1.0 to Version 2.0

December 2007 – Added browsed vs. unbrowsed to number of reproducing and non-reproducing deer browse indicator plants.

February 2008 – Removed seedlings counts by species from quadrats. Seedling data will be collected in the microplots.

April 2008 – Changed the type of species being recorded in the quadrats to all vascular plants (added woody species). Previous, only herbaceous, graminoid, fern or vine species were recorded in the quadrats and woody species were not recorded.

-- Added a time-constrained search of the plot to record species found in the plot, but not in the quadrats. This was added based on the recommendations of Johnston et al (2008) reporting the experiences of the Great Lakes Network. The Northeast Temperate Network also collects these data.

-- Added Confidence column to each quadrat and plot species record to indicate the observer's level of confidence in their identification.

ERMN Vegetation Vital Sign Protocol
Tree Regeneration and Shrubs
Version 3.0 (March 2009)

Overview

This SOP quantifies live saplings, established seedlings, and shrubs by species on four 2-m radius circular microplots. Seedlings are also quantified by size class. These data yield information on advance regeneration, future cover, and the effects of deer browse.

Definitions

Height of a seedling is the distance from the ground to the top of the terminal bud. 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.

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.

Seedlings are live juvenile trees with at least two true leaves, and that have less than 1.0 cm DBH. Any juvenile tree shorter than breast height (<1.37 m tall) is a seedling. A seedling is counted only if it is rooted in the microplot. Seedlings <5 cm in height are not counted in the tally. Refer to the Master Plant List to determine which species are considered trees.

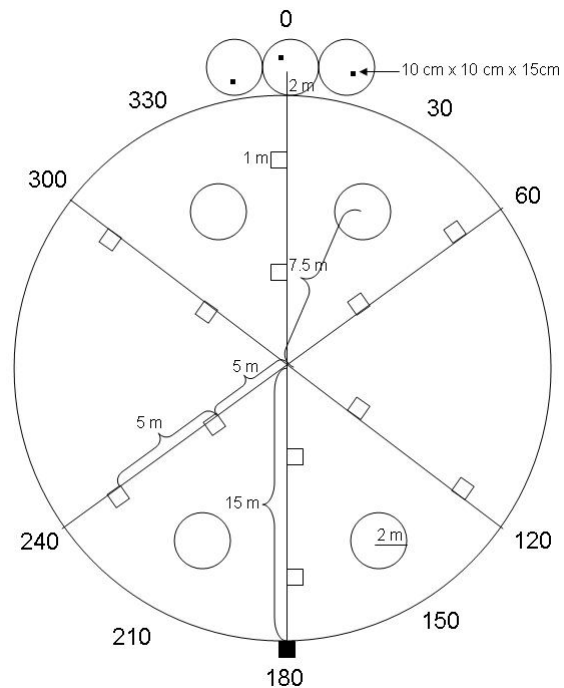
Saplings are live juvenile trees with diameter-at-breast-height (DBH) ≥ 1.0 cm but <10.0 cm. Saplings are alive if there are any living parts (i.e., leaves, buds, cambium) at or above DBH. Saplings that have been temporarily defoliated are considered alive. A sapling is counted only if it is rooted in the microplot. Refer to the Master Plant List to determine which species are considered trees.

Shrubs are woody species that will not reach the canopy. Refer to the Master Plant List to determine which species are considered shrubs. To be counted in this protocol, a shrub must have at least two true leaves. Shrubs are alive if there are any living parts (i.e., leaves, buds, cambium) in the above ground portion of the plant. Shrubs that have been temporarily defoliated are considered alive. Many shrubs have multiple stems originating from a common base - these are counted as a single shrub. Shrub stems are counted only if they are rooted in the microplot. However, the percent cover of shrubs overhanging into the microplot but not rooted in it, are recorded.

Microplot Set Up

From plot center, measure 7.5 m slope distance in each of the following directions: 30°, 150°, 210°, and 330°, to find the center of each microplot (see figure below). Mark the microplot center with a spike set flush to the ground. Detailed directions for establishing the microplots are provided in the Site Selection and Plot Establishment SOP.

The microplot is a circular plot of 2-m radius slope distance. The boundary of the microplot is determined by using two 2-m long ropes with loops at one end. To collect the microplot data, loop the end of each 2-m rope around the center spike. Stretch one rope out to the north from the center spike, marking the location of the end of the rope with the metal mallet used to set the center spike. Stretch the other rope towards 30° or 60°, creating a triangular section between the two ropes. Make sure the ropes are lying flat and are not caught on the vegetation. One crew member will search for saplings, seedlings, and shrubs in the roped-section, and will call out the species, tallies, and heights. The other crew member will record the data and assist with moving the ropes. Once all data has been recorded from the first section, the rope pointing north is moved clockwise passed the second rope to create a new section. Follow this procedure until the metal mallet marking the first rope's location is reached and the entire microplot has been searched.



Data Collection

Microplot Characterization: Examine the vegetation <2 m in height in the microplot. Record the appropriate percent cover class for each of the following categories within the microplot. The total of these four categories can be less than 100% if portions of the microplot are unvegetated or woody cover is dense. The total can exceed 100% if vegetation is dense and overlapping. Use the following percent cover categories: 0=0%; 1=<1%; 2=1–2%; 3=2–5%; 4=5–10%; 5=10–25%; 6=25–50%; 7=50–75%; 8=75–95%; 9=95–100%. For reference, a 35 cm by 35 cm square is equal to 1% cover of the microplot area.

% NONVAS. Record the percent cover class of all nonvascular plants, including moss and lichens.

% VINE. Record the percent cover class of all woody and herbaceous vine species. Refer to the Master Plant List to determine which species are vines.

% GRAM. Record the percent cover class for all graminoid species, including grasses, rushes, and sedges.

% FERN. Record the percent cover class for all fern species and fern allies such as *Lycopodium* spp..

% HERB. Record the total cover class for all herbaceous species (i.e., vascular plants that are not woody, graminoid, or fern). Refer to the Master Plant List to determine which species are herbaceous.

SAPLING SPECIES. Record the USDA PLANTS code for the genus and species of each sapling. Species names follow the Integrated Taxonomic Information System (ITIS). If 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 microplot from similar specimens and make a note to correct the species code later. Record genus or family if it is known, and “sp01”, “sp02” etc for each unknown species. For saplings that cannot be identified to family, use “UNKCON” for Unknown Conifer and “UNKHDW” for Unknown Hardwood.

SAPLING DIAMETER. Measure the diameter at 1.37 m above the ground on the uphill side of each sapling. Use the Finley pole marked at 1.37 m to find the correct height at which to measure the diameter. See instructions for measuring diameter in unusual situations in the Tree Measurements SOP. For saplings 1–8 cm in diameter, use the Finley sapling gauge to measure diameter to the nearest 0.5 cm. For saplings 8.1–9.9cm, use the 2-m DBH tape to measure diameter to the nearest 0.5 cm.

SEEDLING SPECIES. Record the USDA PLANTS code for the genus and species. Species names follow the Integrated Taxonomic Information System (ITIS). If 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. Samples should not be taken if the entire plant will be killed or entirely removed from the microplot. If possible, collect samples outside the microplot from similar specimens and make a note to correct the species code later. Record genus or family if it is known, and “sp01”, “sp02” etc for each unknown species. For seedlings that cannot be identified to family, use “UNKCON” for Unknown Conifer and “UNKHDW” for Unknown Hardwood.

SEEDLING COUNT. Within each microplot, count the number of live tree seedlings by species in the following height classes: 5–15 cm, 15.1–30 cm, 30.1–100 cm, 1.01–1.5 m, >1.5 m. Record the tally of seedlings on the datasheet using the dot tally system. Use the Steiner stick and the Finley pole to measure seedling height, following the height measuring guidelines described above. Juvenile trees >1.5 m in height and with a DBH $\geq$ 1 cm are not included in the seedling count because they are saplings. Seedlings <5 cm in height are not counted or recorded.

Tree seedlings that originate at a common root collar (i.e., branch under the leaf litter) are independent seedlings. Tally the height of each seedling separately.

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 DBH.

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 DBH.

SHRUB SPECIES. Record the USDA PLANTS code for the genus and species. Species names follow the Integrated Taxonomic Information System (ITIS). If species cannot be determined in the field, collect a twig sample with foliage, buds, fruit, or flowers, and/or a photograph to make a positive identification later. If possible, collect samples outside the microplot and make a note to correct the species code later. Record genus or family if it is known, and “sp01”, “sp02” etc for each unknown species. For shrubs that cannot be identified to family, use “UNK” for Unknown.

SHRUB COUNT. Record the number of live shrubs in each microplot by species. Multiple stems originating from a common base are counted as a single shrub. Shrub stems are counted only if they are rooted in the microplot.

SHRUB COVER. Record the percent cover class for each shrub species using the cover classes listed below. Imagine the percent cover of each shrub as its shadow on the ground if the sun were directly overhead. Consider the entire shrub, including portions of the shrub that are >2 meters in height, in the percent cover estimate. The cover contributed by shrubs overhanging the microplot but not rooted in it are included in the total percent cover for that species. Likewise, for species which are overhanging, but do not have individuals rooted in the microplot, only percent cover will be recorded for those species. Use the following percent cover categories: 0=0%; 1=<1%; 2=1–2%; 3=2–5%; 4=5–10%; 5=10–25%; 6=25–50%; 7=50–75%; 8=75–95%; 9=95–100%. Notice the exact breakpoints (e.g., 25%) are not included in any class. Classes are either above or below each breakpoint. This is not a mistake - it is to encourage the crew not to waste time trying to decide if the correct value is exactly 25%.

Revision History

From Version 1.0 to Version 2.0

December 2007 – Distance to microplot centers from plot center should be measured as slope distance instead of horizontal distance.

February 2008 – Seedlings that are < 5 cm in height are no longer counted because: 1) seedlings <5 cm are not used in the USFS FIA Stocking Index calculations; 2) they experience high mortality; 3) between year variation will be very high depending on mast, weather, and cyclic predation; 4) this reduces the number of seedlings that the crew has to count by 30–40%, saving valuable field time.

From Version 2.0 to Version 3.0

May 2009 – Clarified the measurement of shrub cover to: “Consider the entire shrub, including portions of the shrub that are >2 meters in height, in the percent cover estimate.”

ERMN Forest Vital Sign Protocol
Tree Measurements
Version 3.0 (March 2009)

Overview

This SOP records species, diameter, and condition of all live and standing dead trees ≥ 10 cm diameter-at-breast-height on 15-m radius plots. These data provide information on tree growth, mortality, condition, and stand structure and composition.

Caution

Dead trees can be a safety hazard. Crews must exercise caution. Trees deemed unsafe to measure should be estimated but not touched.

Definitions

Diameter-at-breast-height (DBH) is measured at 1.37 m above the ground line on the uphill side of the tree.

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.

Dead standing trees lack any living parts (i.e., leaves, buds, cambium) at or above DBH, and lean < 45 degrees from vertical, as measured along the bole. They 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, cambium) at or above DBH. 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 (live or dead) with a diameter greater than or equal to 10 cm at DBH and capable of attaining heights > 7 m. Refer to the Master Plant List to determine which species are considered trees.

Procedure

According to the Site Selection and Plot Establishment SOP, six transects are established within the plot. Begin tallying trees from the 0 degree (north) transect and continue clockwise around the plot.

A tree on the plot boundary will be included only if the center of the stump lies directly on or within the plot boundary. To determine if the center of the stump falls in the plot, measure the horizontal distance from plot center to the front of a crew member standing adjacent to the stump's center. If this distance is greater than 15 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.

For each tree, measure and record the horizontal distance to the front edge of the trunk from plot center using the laser. The front end of the laser (not your eye) should be over plot center while taking the distance measurement. Make sure that “HD” is visible in the laser viewfinder while all distance measurements are taken. If a tree bole is leaning significantly into or out of the plot, do not shoot the tree bole with the laser unless you can see the base of the tree in the viewfinder. Instead, have a crew member stand adjacent to and level with the front of the tree base. Measure the distance to the front of the crew member with the laser.

In plots with tall dense shrubs or saplings, the laser may not work. In these circumstances, the Sonin distance measure can be used. However, the Sonin device measures slope distance, not horizontal distance. Therefore, the two parts of the Sonin device must be held at the same horizontal level when measuring distance. When this is not possible, the distance measurement must be converted from slope distance to horizontal distance using the slope conversions table provided on the end of this SOP.

Measure and record tree azimuth from plot center using a compass. If a tree leans significantly to the right or the left, measure the azimuth from plot center to the center of the stump, not the bole.

Measure the diameter at breast height, using the white DBH mark on the Finley pole to identify the correct DBH height. Unusual DBH situations are discussed below. Use the blue mark on the Finley pole to identify the location of the scribe mark (5 cm below DBH), and create a horizontal mark on the bark of the tree, using the tree scribe. Scribes cut through the corky layer of bark to enter the phloem, but do not reach the cambium. Thus, a scribe permanently marks the tree bole without wounding the tree. Scribes are 5–7 cm in length and are perpendicular to the tree axis. The scribe mark should always be located 5 cm below where the diameter was measured. If the diameter was measured in an unusual place, the scribe mark must be placed 5 cm below the location of the diameter measurement. This will allow accurate remeasurement of DBH during return visits. The scribe mark should face plot center. At FONE, FRHI, ALPO, and JOFL, if there is a trail close to the plot, scribe marks should be placed on the far side of the tree, away from the trail, so that the marks are not seen from the trail. If the scribe mark is not facing plot center, or is unusual in any way, write a description of the irregularity in the Tree Notes section. Scribe snags unless they are unstable. Do not scribe snags that sway when touched to ensure no snags are knocked down. Note in Tree Notes that snag was not scribed, and proceed to record data as usual.

Data Collection

TREE NUMBER. Assign each live or dead tree >10 cm DBH a sequential number, starting with 1, 2, 3, etc, on the 15-m radius plot. The tree closest to the 0 degree transect is labeled 1 and tree numbers are assigned proceeding clockwise around the plot.

SPECIES. Record the USDA PLANTS code for the genus and species of each tree. Species names follow USDA PLANTS and the Integrated Taxonomic Information System (ITIS). If 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. Record genus or family if known, and “sp01”, “sp02”, etc for each unknown species. For standing dead trees that cannot be identified to family, use “UNKCON” for Unknown Conifer and “UNKHDW” for Unknown Hardwood.

DISTANCE. Measure the horizontal distance to the front edge of the trunk from the plot center using the laser. Record the distance to the nearest 0.1 meter. When measuring distance with the laser, the front edge of the laser should be directly over plot center, not your eye. The laser measures distance from the front edge of the instrument, not the eye piece. Remember that horizontal distance is the distance that determines if a tree is in the plot, not slope distance.

AZIMUTH. Measure the azimuth from the plot center to each tree, sighting the center of the base of each tree with a compass. Record the true north azimuth to the nearest degree (see Site Selection and Plot Establishment SOP for compass declination instructions).

Note: If the same distance and azimuth are recorded for two or more adjacent trees (the trees are clumped), record some identifying feature of each tree in the Notes section. For example, “left”, “middle”, and “right” in the Notes section for three adjacent trees would signify that from plot center, the trees were measured from left to right. In general, all clumped trees should be measured clockwise, from left to right. Recording some manner of identifying individual trees within a clump is important so that the remeasurement of DBH is recorded with the correct tree during the next sampling visit.

DBH. Measure tree diameter at breast height (1.37 m) above the ground on uphill side of tree (see figures below). Do not measure from a pit or atop a mound or emergent rock. Use the white DBH mark on the Finley pole to consistently find breast height. Round diameter measurement to the nearest 0.1 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 and pulled perpendicular to the axis of the trunk (see figures below). Tapes that are not run straight will overestimate the trunk diameter. Wrap the tape tightly around the tree and 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). Always scribe the tree 5 cm below where DBH is taken, even if DBH is taken in an unconventional place on the trunk. Note the location of the DBH measurement in Tree Notes, using distances and unique tree characteristics. When re-measuring the diameter of a tree tallied in a previous survey, always take the measurement 5 cm above the scribe mark unless it is physically impossible (e.g., tree buried by mudslide) or there is an abnormality at the previous diameter measurement point. Always note deviations from previous measurements in the Tree Notes section.

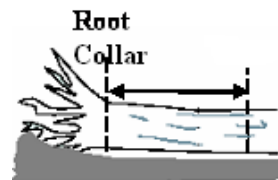
Irregularities at DBH: If there is an abnormality (e.g., swelling, bump, depression, or branch) at DBH, take the measurement just below the abnormality if possible. If the abnormality extends far below DBH, then take the measurement just above DBH. Describe the location of the measurement in Tree Notes.

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 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 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, as shown in picture at right.



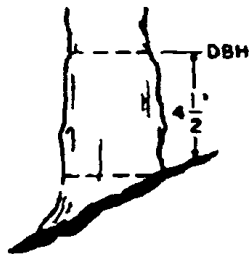
Swollen bases: Trees with swollen bases rising higher than 1.0 m are measured 0.5 m above the top of the swelling. Trees with swelling below 1 m are measured at standard DBH.

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.

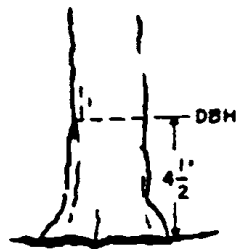
Forked tree: Trees which fork at or above breast height (1.37 m) are tallied and measured as one tree. Diameter should be measured below the point at which forking affects DBH (see Picture 4 below). Scribe the trunk with a horizontal mark 5 cm below where DBH was measured. This point should be recorded in Tree Notes.

For trees that fork below breast height (1.37 m), each trunk ≥ 10 cm is tallied as a separate tree. If the fork is less than 0.5 m above the ground, measure DBH of each trunk at standard breast height (1.37 m). If the fork is greater than 0.5 m above the ground, measure the diameter of each trunk at 1 m above the fork (see Picture 5 below). Scribe each trunk with a horizontal mark 5 cm below where DBH was measured. 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.

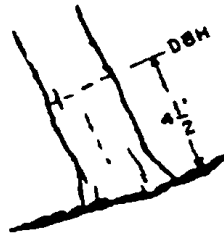
DIAMETER BREAST HIGH MEASUREMENT IN A VARIETY OF SITUATIONS



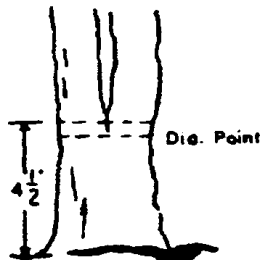
1. Tree on slope



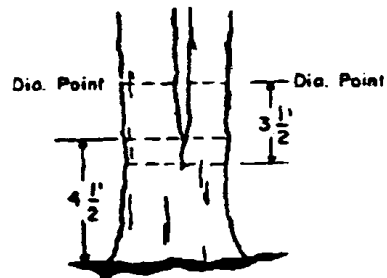
2. Tree on level ground



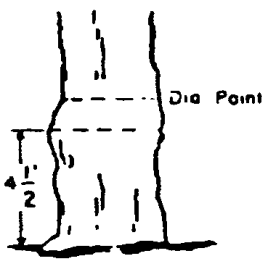
3. Leaning tree



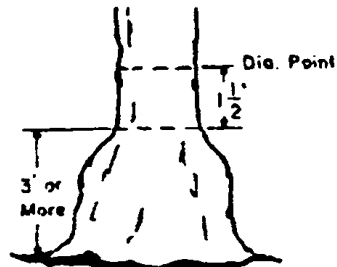
4. Tree forking at or above 4 1/2 feet



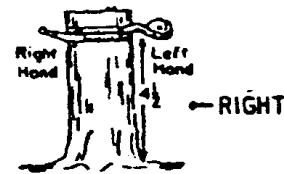
5. Tree forking below 4 1/2 feet



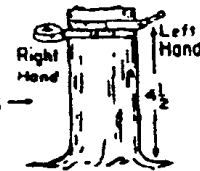
6. Tree deformed at 4 1/2



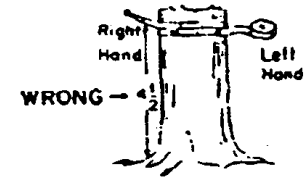
7. Bottleneck tree



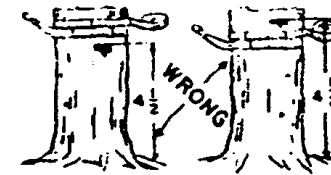
LEFT HANDED - Right hand crossed under.



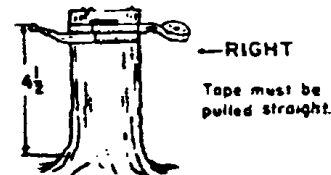
RIGHT HANDED - Left hand crossed over.



LEFT HANDED - Right hand cross



Always assume that the 4 1/2 ft D.B.H. point is at the top of lower tape at this point

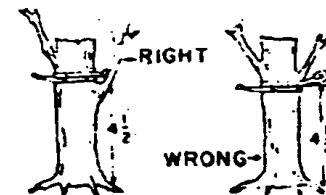


Tape must be pulled straight.

The tape must be at right angles to the lean of the tree.



Don't place tape at abnormal place on the bole

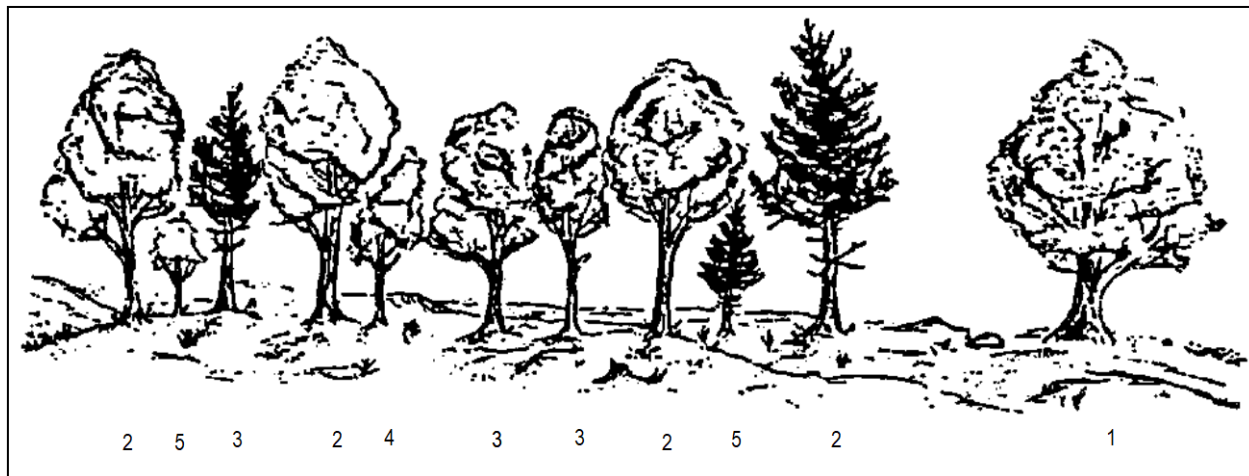


TREE STATUS. Record a status code for each tree.

- 0 No status. Previously tallied tree is no longer in sample because the tree: a) shrunk below 10.0 cm DBH, b) moved outside the plot boundaries, c) was incorrectly tallied last time, or d) a change in procedure now excludes this tree. Record 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.
- 2 Standing dead tree.
- 3 Removed. Previously tallied tree has been cut and removed by humans during harvest, silviculture treatment, or land clearing.
- 4 Fallen dead tree. Previously tallied tree has fallen and will no longer be tracked as a live tree.

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. 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 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?

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.

Record the general overall health of the tree using the codes below. Estimate vigor before estimating dieback or recording tree or foliage conditions.

- 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.

DIEBACK. Twig dieback is defined as branch mortality that begins at the terminal portion of a limb and progresses downward. Dieback is assumed to be the result of stress on the tree. Short-term stresses such as excessive seed production, weather extremes, or insect defoliation may cause temporary dieback, but when the stress is removed the trees may recover. Prolonged stresses may, however, result in an increase in dieback, and eventual decline and death of the tree.

Dieback is assessed only on twigs that are 2.5 cm in diameter or smaller at the point of attachment. Twigs with prematurely dead terminals are considered to have dieback down to the next lower fork of equal sized branch.

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.

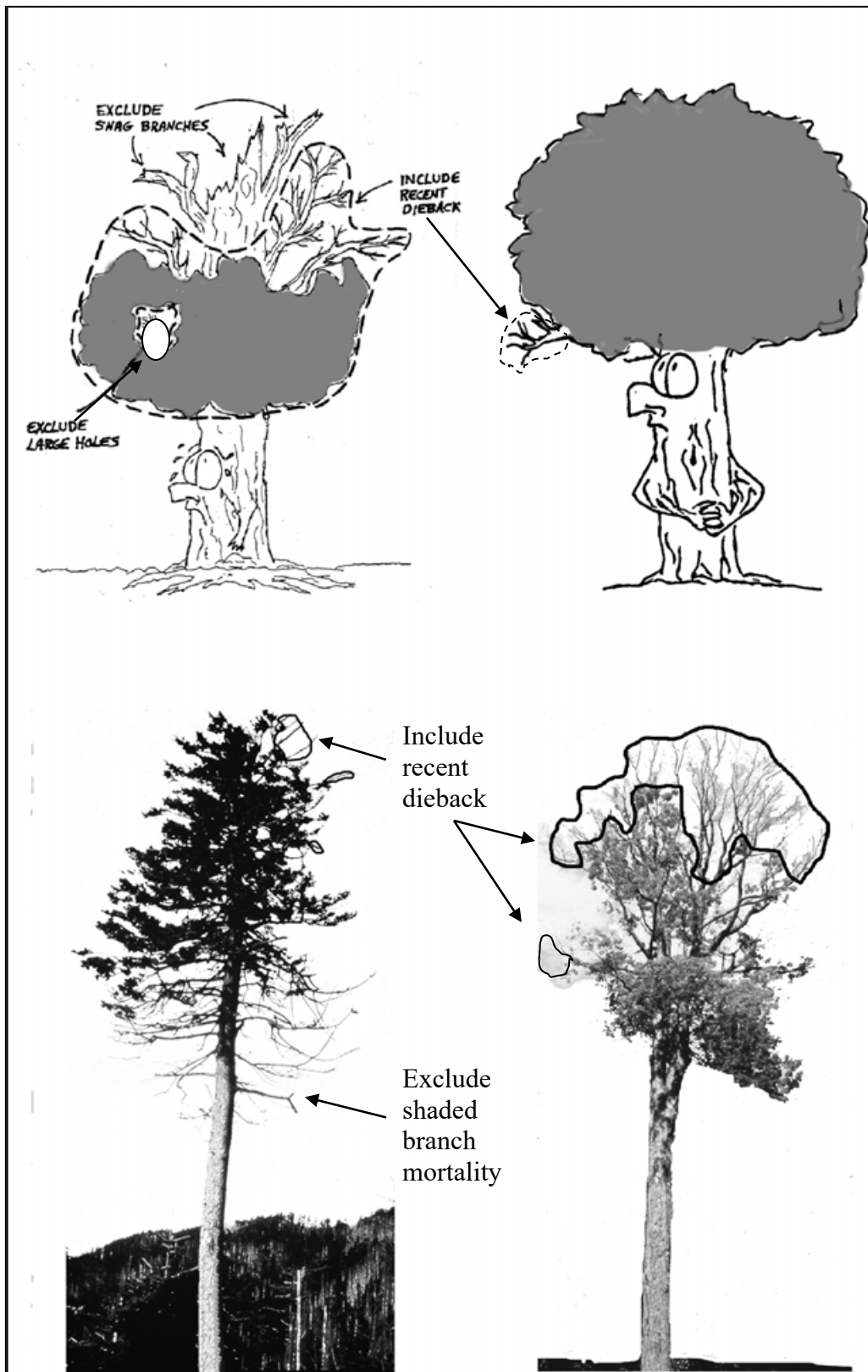
Then examine all twigs 2.5 cm in diameter or smaller in the crown, looking for twigs with dieback. Estimate the amount of the outline that includes dieback. The following should be **excluded** from the dieback percentage:

- 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.
- Twigs or branches that are larger than 2.5 cm in diameter at the point of attachment.
- 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.

Estimate the proportion of the crown with twig dieback using the following categories:

Dieback Class Code	Dieback Class Range (percent of twigs with dieback)
0	0 %
5	1–5 %
10	6–15 %
20	16–25 %
30	26–35 %
40	36–45 %
50	46–55 %
60	56–65 %
70	66–75 %
80	76–85 %
90	86–95 %
99	96–100 %

Dieback should be estimated when leaves are mature, but before the appearance of fall color. Two crew members are 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. When the two estimates disagree, the percentage class nearest the average of the two is recorded. The diagrams on the following page illustrate what to include and exclude when assessing dieback.



(adapted from USFS 2005a)

TREE CONDITIONS. Record the presence of any of the following pests, pathogens, or damages. If none of these conditions exist, record a horizontal line in the Tree Condition box.

Pests and Pathogens

ALB - Asian Longhorned Beetle

BBD - Beech Bark Disease

BTC - Butternut Canker

DWA - Dogwood Anthracnose

EAB - Emerald Ash Borer

EHS - Elongate Hemlock Scale

ETC - Eastern Tent Caterpillar

FTC - Forest Tent Caterpillar

GPM - Gypsy Moth

HWA - Hemlock Woolly Adelgid

SOD - Sudden Oak Death

FOLIAGE CONDITIONS. Visually assess canopy foliage and record up to three (3) problems as chlorosis (C), necrosis (N), holes (H), small leaves (S), wilting (W), leaf loss (L), or other (O – describe in Tree Notes). 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: 1–10, 10–25, 25–50, 50–75, 75–100%.

TREE NOTES: 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 clumped trees that have the same distance and azimuth. Record the species of vine present.

Damage Code	Description of Damage
ABGR	Abnormal growth pattern for the species of concern. This category would include a range of physical deformities not included in the remainder of the damage codes.
BIRD	Bird damage such as woodpecker or sapsucker holes.
BLIG	Blight 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	Broken top of the tree.
BROM	Witches' broom 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	Crooked or twisted bole for species in which this is uncharacteristic.
DECY	Advanced decay of bole and limbs.
DTOP	Dead top.
EPIC	Epicormic sprouting, adventitious shoots arising from suppressed buds on the stem; often found on trees following thinning or partial girdling.
FIRE	Fire scar or cambial damage due to fire.
FORK	Forked 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	Frost crack or other frost damage.
GALL	Galls 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	Hollowed-out 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 insects in the tree bole or the canopy, or their sign, such as frass, pitch tubes or bark beetle galleries.
LEAN	Tree is leaning significantly. If on a slope, tree deviates considerably from plumb.
LIGT	Lightning scar or other damage to the tree caused by lightning.
MAMM	Damage caused by mammals, such as bear claw marks, porcupine or beaver chewings, and deer or elk rubbings.
OZON	Ozone 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 roots.
ROTT	A rot of fungus other than a conk, often associated with a wound or crack in a tree.
SPAR	Unusually sparse foliage for that species and size of tree.
SPRT	Basal sprouting; new shoots arising from the root collar or burl.
UMAN	Human-caused damage such as axe marks, embedded nails or fence wire, or vandalism.
VINE	Vines 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 wound to a tree that cannot be identified by one of the other damage codes, including wounds or cracks of unknown cause.

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

(adapted from Pyle and Brown 1998 and USFS 2005b)

References

- Miller, I., D. Lachance, W.G. Burkman, and D.C. Allen. 1991. North American Sugar Maple Decline Project: organization and field methods. General Technical Report NE-154. Radnor, PA: US Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 26 pp.
- Pyle, C., and M. M. Brown. 1998. A rapid system of decay classification for hardwood logs of the eastern deciduous forest floor. *Journal of the Torrey Botanical Society* 125: 237–245.
- United States Forest Service. 2005a. Forest Inventory and Analysis National Core Field Guide Phase 3 – Crowns: Measurements and Sampling. Version 3.0. United States Forest Service. 20 pp.
- United States Forest Service. 2005b. Forest Inventory and Analysis National Core Field Guide Phase 3 – Downed Woody Materials. Version 3.0. United States Forest Service. 38 pp.

Revision History

From Version 1.0 to Version 2.0

December 2007 – Added notes about identifying clumped trees with same distance and azimuth.

February 2008 – Clarified distance and azimuth measures for leaning trees. Add notes on the importance of proper scribe location.

From Version 2.0 to Version 3.0

February 2009 – Added assessment of tree vigor, using 5 classes ranging from healthy to functionally dead, as defined by NAMP (Miller et al 1991). This was recommended by Long during protocol review and hopefully will add useful information on forest health (% healthy trees, % severe decline, etc).

-- Added assessment of dieback, using percentage class categories recommended by Long that are consistent with our existing foliage conditions percentage class. Definitions and field methods for dieback adapted from NAMP (Miller et al 1991) and USFS FIA (USFS 2005).

Slope Conversion Table

Slope		HORIZONTAL DISTANCE = SLOPE DISTANCE * X	SLOPE DISTANCE = HORIZONTAL DISTANCE * X
Degrees	Percent	Multiplier X	Multiplier X
0	0	1.0000	1.0000
1	2	0.9998	1.0002
2	3	0.9994	1.0006
3	5	0.9986	1.0014
4	7	0.9976	1.0024
5	9	0.9962	1.0038
6	11	0.9945	1.0055
7	12	0.9925	1.0075
8	14	0.9903	1.0098
9	16	0.9877	1.0125
10	18	0.9848	1.0154
11	19	0.9816	1.0187
12	21	0.9781	1.0223
13	23	0.9744	1.0263
14	25	0.9703	1.0306
15	27	0.9659	1.0353
16	29	0.9613	1.0403
17	31	0.9563	1.0457
18	32	0.9511	1.0515
19	34	0.9455	1.0576
20	36	0.9397	1.0642
21	38	0.9336	1.0711
22	40	0.9272	1.0785
23	42	0.9205	1.0864
24	45	0.9135	1.0946
25	47	0.9063	1.1034
26	49	0.8988	1.1126
27	51	0.8910	1.1223
28	53	0.8829	1.1326
29	55	0.8746	1.1434
30	58	0.8660	1.1547

ERMN Vegetation Vital Sign Protocol
Data Quality Assurance and Quality Control
Version 3.0 (March 2009)

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.

Training

The crew leader is responsible to ensure that all crew members:

- 1) can correctly identify plant species,
- 2) understand all field protocols,
- 3) 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:

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

Data Collection

Field data are collected in two ways. First, field crews may enter data directly into a field copy of the Vegetation Monitoring Database on the tablet computer. Alternatively, field crews may record data on paper field forms and later enter the data into the project database.

Regardless of the data collection method, all data values shall be called out and repeated 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.

Field computer

When weather and technology permit, the field crew will record data directly into the ERMN Vegetation Monitoring Database on the tablet computer. This eliminates potential errors in transferring data from paper field forms to the database. The database incorporates many functions and utilities to help reduce data entry errors such as look-up fields and appropriate upper and lower bounds for fields.

At the end of every plot, before the crew leaves the site, crew members must review all sections of the field database to ensure that all fields are completed and no obvious errors exist.

The computer database is backed up daily, using an external hard disk provided by the Network Data Manager. The field computer and the hard disk shall be stored separately. For example, when the computer is in the field, the hard disk shall be stored in another location (i.e., a hotel room, or in a vehicle). Furthermore, the database should be uploaded to another ERMN computer at least monthly during the field season as directed by the Network Data Manager.

Do not use the field computer in rain more than a light sprinkle. In case of steady rain the computer should be packed away and Rite-in-Rain datasheets used as directed below.

Datasheets

The crew must always bring paper datasheets on plain and Rite-in-Rain paper as a backup for data collection in case of rain or computer malfunction. 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 data sheets 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:

- Subcanopy and Canopy Heights in the Stand section
- 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 the 300 Transect
- Microplot Vegetation Characterizations (% cover of nonvascular, vine, graminoid, etc)

Produce a photo-copy of the original paper data sheets on acid-free paper within one week of data collection, and check to ensure all original data is present and legible. Deliver these copies to the Network Data Manager to store them in a building separate from the original data sheets.

Data Entry

If paper data sheets are used, data must be entered into the Vegetation Monitoring Database. The database incorporates 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 is illegible or is 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 reconcile these Post-it Note questions before data verification.

Data Verification

Following data entry, the crew leader or a supervisor shall review all entered data to ensure values present on paper field forms are accurately and completely entered into the database. This process is time consuming, but is critical to ensuring data quality. 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.

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

Each year, ERMN will resample at least 5% of sampled plots to determine the reliability of field data collection. Field staff for the remeasurement should not include field crew members who originally measured the plot; or, crew members should trade roles so that the measurer and recorder are different from when the plot was originally measured. 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 four times in three cycles (e.g., no more than four times in 12 years).

Revision History

From Version 2.0 to Version 3.0

January 2009 – Added DATA QC box to the upper right hand corner of each data sheet. New for the 2009 field season: Before the crew leaves each plot, a crew member other than the person who recorded on that data sheet must review that the data has been completely and correctly entered, and then sign their initials in the DATA QC box.

ERMN Vital Sign Protocol
Soil Measurements and Sampling
Version 3.0 (March 2009)

Overview

This SOP serves to characterize forest soil chemistry and provide information on the effects of atmospheric deposition upon the ability of soils to support forested ecosystems. Soil samples are shipped to designated facilities for soil chemistry analysis. This SOP includes a rapid assessment of earthworm presence, to characterize their spatial extent across the network.

Three soil samples approximately 10×10×10 cm in size are collected. One sample is collected from each of three 2-m radius circles along the northern edge of the 15-m plot. Soil 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. 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

Earthworm burrows are temporary or permanent soil channels made by earthworms. Burrows appear as circular openings on the soil surface. Sometimes burrows are covered by, or surrounded by, casts, litter or organic matter.

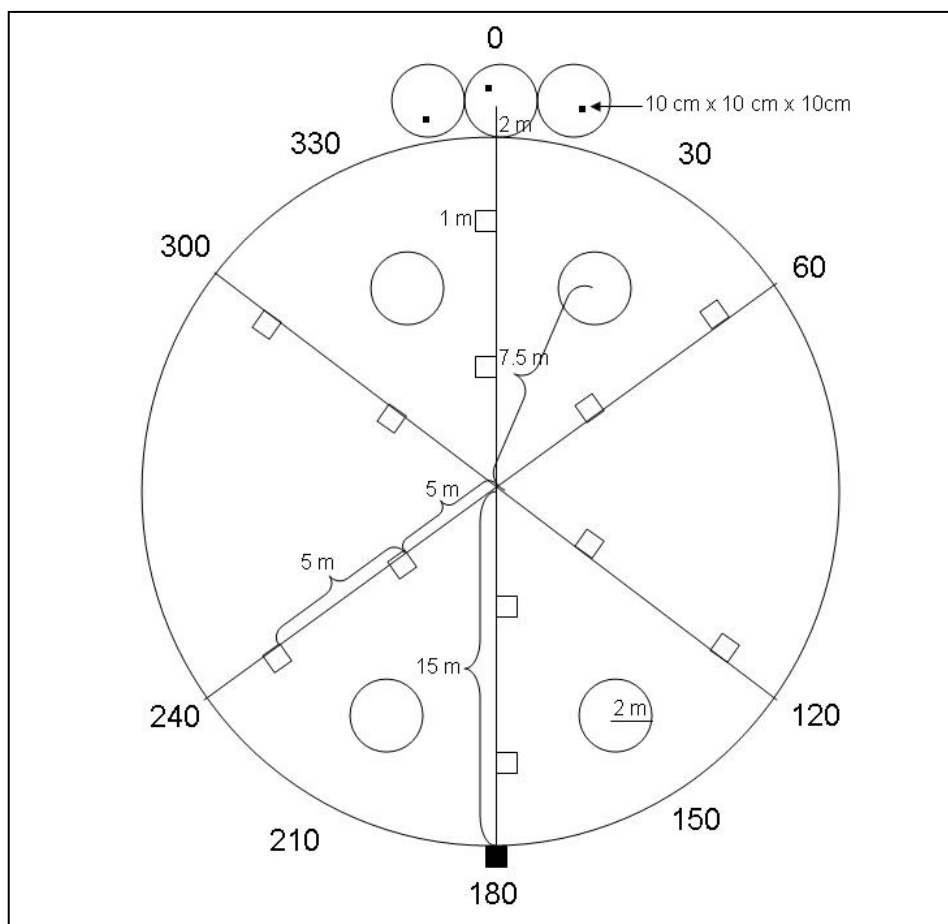
Earthworm casts are earthworm excrement comprised of soil mixed with digested plant residues. Casts appear as distinctive, moist aggregates of rich soil. In areas with established earthworm populations, casts may be visible throughout the summer. Cast production is highest during moist spring and fall seasons.

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.

O horizon is defined, for this protocol, as the consolidated organic material in between the unconsolidated litter and the top of the mineral soil. The O horizon in this protocol includes the Oa and Oi horizons, but not the Oe horizon. In other nomenclature, the O horizon in this protocol includes the F and H horizons, but not the L horizon.



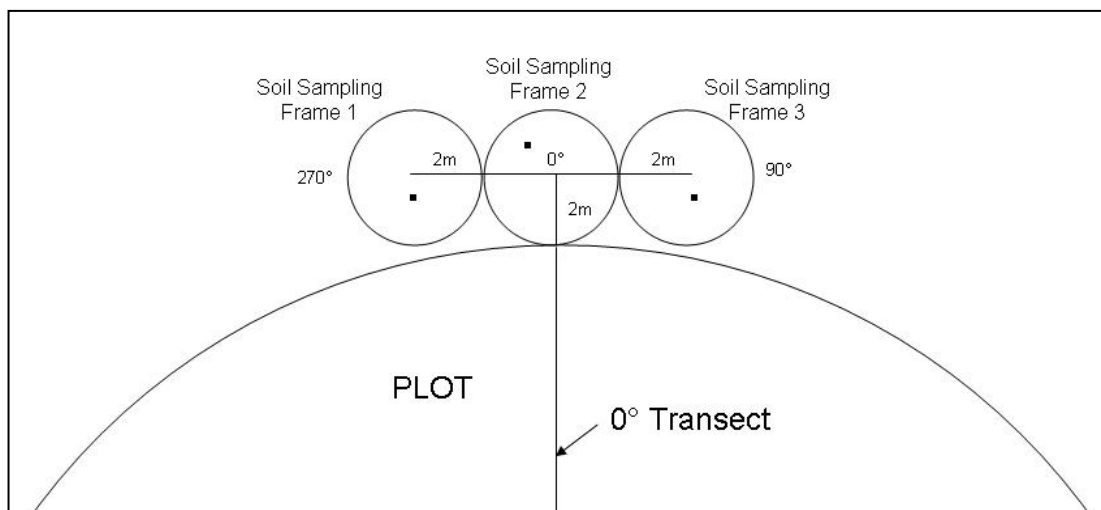
Sampling Location

Locate the soil sampling frames along the plot's northern edge (see figure above). To locate the middle soil sampling frame, measure 2 m slope distance along the 0° azimuth from metal spike that marks the end of that transect. This point is also 17 m slope distance from the plot center along the 0° azimuth. Place a chaining pin at this point. This is the center of Soil Sampling Frame 2 (see figure below).

From the first chaining pin, measure 4 m slope distance along the 270° azimuth. Place a chaining pin at this point. This is the center of Soil Sampling Frame 1 (see figure below).

From the chaining pin in the center of Soil Sampling Frame 1, measure 8 m slope distance along the 90° azimuth. Place a chaining pin at this point. This is the center of Soil Sampling Frame 3 (see figure below). 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 the end of the 0° transect due to obstructions or site



anomalies, establish the sampling frames on the end of the 60° transect. If soil cannot be sampled there, move clockwise around the plot to subsequent transects, until a suitable location is found. In these cases, note the location of the sampling frames in Frame Location field on the datasheet.

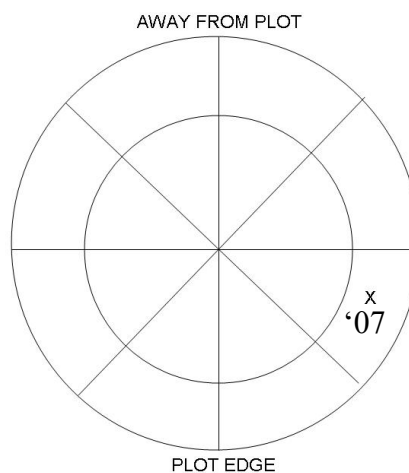
Soil Sampling Procedure

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.

For each vegetation monitoring plot, take one soil sample in each soil sampling frame (i.e., in each 2-m radius circle).

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. Avoid placing the quadrat on top of very decayed logs, animal burrows, trash, charcoal, or other anomalies that would influence the soil sample. 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 and in the adjacent figure. 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. “’07”) 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.



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 (MM/DD/YY), Park (Four letters), Vegetation Monitoring Plot Number, Soil Sampling Frame Number (1, 2, or 3), and Litter, as shown in the following example: NERI.052, Frame 1, Litter, 06/02/08. Do not remove consolidated litter which has begun to compress and decompose. Do not include any animal scat in the litter sample. Deer pellets 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, and enter a brief note explaining why in Soil Notes.

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 (MM/DD/YY), Park (Four letters), Vegetation Monitoring Plot Number, Soil Sampling Frame Number (1, 2, or 3), and Horizon (O), as shown in the following example: NERI.052, Frame 1, O Horizon, 06/02/08. 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 (MM/DD/YY), Park (Four letters), Vegetation Monitoring Plot Number, Soil Sampling Frame Number (1, 2, or 3), and Horizon (A), as shown in the following example: NERI.052, Frame 1, A Horizon, 06/02/08. 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 (MM/DD/YY), Park (Four letters), Vegetation Monitoring Plot Number, Soil Sampling Frame Number (1, 2, or 3), and Horizon (B), as shown in the following example: NERI.052, Frame 1, B Horizon, 06/02/08. 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.

Next, repeat this entire procedure in the remaining two soil sample plots.

Soil Sampling Procedure on Remeasurement Plots

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 end of the transect specified in Frame Location.

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. "'07") 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.

Data Collection

FRAME LOCATION. Record the location (distance and azimuth) of the center point of soil sampling Frame 2 in relation to the end of a transect. (e.g. "2 meters north of the end of the 0° transect").

SAMPLE LOCATION. Place an X in the appropriate sector to show the soil sample location in the sampling frame. Write the last two digits of the current year (e.g. "'07") 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.

LITTER THICKNESS UP-SLOPE and DOWN-SLOPE SIDES. At the approximate midpoints of the up-slope and down-slope edges of the soil quadrat, measure the depth of the litter to the nearest 0.5 cm as described above. If the ground is level, select two opposite sides of the quadrat on which to measure litter depth.

LITTER SAMPLE COLLECTED. Circle Y if a litter sample was collected. Circle N if a litter sample was not collected. If a sample was not collected, record the reason in the Soil Notes field.

EARTHWORMS. Record the presence (1) or absence (0) of earthworm casts and burrows at the soil sampling location for the current year. If examination is inconclusive, record 9, and record a brief note explaining why in Soil Notes.

O HORIZON THICKNESS. After excavating the O horizon, record the thickness of the O horizon as the distance from the top of the consolidated litter to the top of the mineral soil. Measure the thickness to the nearest 0.5 cm.

O HORIZON COLOR. Record the color of the O horizon, such as "dark brown", "grayish brown".

O HORIZON COLLECTED. Circle Y if any O horizon soil was collected. Circle N if O horizon soil was not collected. If a sample was not collected, record the reason in the Soil Notes field.

A HORIZON THICKNESS. Measure and record to the nearest 0.5 cm the thickness of the A horizon as observed in the soil profile. If the lower boundary of the A horizon is not observed, 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 and the lower boundary of the A horizon was not observed.

A HORIZON COLOR. Record the color of the A horizon, such as “medium brown”, “grayish brown”.

A HORIZON COLLECTED. Circle Y if any A horizon soil was collected. Circle N if A horizon soil was not collected. If a sample was not collected, record the reason in the Soil Notes field.

OBSERVED THE BOTTOM OF A HORIZON. Circle Y if the lower boundary of the A Horizon was observed. Circle N if the lower boundary of the A Horizon was not observed.

B HORIZON THICKNESS. Measure and record to the nearest 0.5 cm the exposed depth of B horizon as observed in the soil profile. In most cases, the lower boundary of the B horizon will not be observed. If these cases, write a “>” symbol before the observed thickness. For example, record “>5.0 cm” if the observed depth of exposed B horizon soil was 5.0 cm and the lower boundary of the B horizon was not observed.

B HORIZON COLOR. Record the color of the B horizon, such as “light brown”.

COLLECTED B HORIZON. Circle Y if any B horizon soil was collected. Circle N if B horizon soil was not collected.

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 features.

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. 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 labeled newspaper or metal pans to dry completely before being returned to plastic bags.

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 ERMN, and include a copy with the samples when shipped or delivered to the testing lab.

Sample Analysis

Send dried samples to the designated soil chemistry lab experienced in analyzing forest soils. Several soil laboratories have sufficient capabilities, including the Analytical Lab at the University of Maine (<http://anlab.umesci.maine.edu>, contact Sue Ehrich erich@maine.edu).

The lab should prepare samples by passing each through a 2 mm sieve to remove larger particles. Analysis must include:

- Total carbon and total nitrogen by dry combustion
- NH_4Cl extractable ions including Ca and Al

Sample Archives

When samples are sent to the laboratory, coordinate with the 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.

Revision History

From Version 1.0 to Version 2.0

February 2008 – Added the collection of leaf litter samples in order to weigh them, since litter weight may be a more consistent variable for long-term monitoring than litter depth.

Appendix B: Field Data Sheets.

QUADRATS

6 = 25-50%, 7 = 50-75%, 8 = 75-95%, 9 = 95-100%

Quadrat Characterization

[illegible]

Deer Browse Indicators: *Actaea* spp., *Arisaema triphyllum*, *Maianthemum* spp., *Medeola virginiana*, *Osmorhiza* spp., *Podophyllum peltatum*, *Polygonatum* spp., *Prosartes* spp., *Trillium* spp., *Uvularia* spp.

[illegible]

Park: _____ Plot: _____ Date: _____ Observers: _____ DATA QC ☐

REGENERATION AND SHRUBS

MICROPLOT 30						
%Nonvas		% Vine		%Gram	%Fern	%Herb
Sapling Species	DBH	Sapling Species	DBH	Shrub Species	# Stems	% Cover

Seedling Species	5-15 cm	15-30 cm	30-100cm	1-1.5m	>1.5m

MICROPLOT 150						
%Nonvas		% Vine		%Gram	%Fern	%Herb
Sapling Species	DBH	Sapling Species	DBH	Shrub Species	# Stems	% Cover

Seedling Species	5-15 cm	15-30 cm	30-100cm	1-1.5m	>1.5m

Percent Cover Categories: 0 = 0%, 1 = <1%, 2 = 1-2%, 3 = 2-5%, 4 = 5-10%, 5 = 10-25, 6 = 25-50%,
7 = 50-75%, 8 = 75-95%, 9 = 95-100%

Park: _____ Plot: _____ Date: _____ Observers: _____ DATA QC ☐

REGENERATION AND SHRUBS (continued)

MICROPLOT 210		%Nonvas	% Vine	%Gram	%Fern	%Herb
Sapling Species	DBH	Sapling Species	DBH	Shrub Species	# Stems	% Cover

Seedling Species	5-15 cm	15-30 cm	30-100cm	1-1.5m	>1.5m

MICROPLOT 330		%Nonvas	% Vine	%Gram	%Fern	%Herb
Sapling Species	DBH	Sapling Species	DBH	Shrub Species	# Stems	% Cover

Seedling Species	5-15 cm	15-30 cm	30-100cm	1-1.5m	>1.5m

Percent Cover Categories: 0 = 0%, 1 = <1%, 2 = 1 - 2%, 3 = 2-5%, 4 = 5-10%, 5 = 10-25 6 = 25-50%,
7 = 50-75%, 8 = 75-95%, 9 = 95-100%

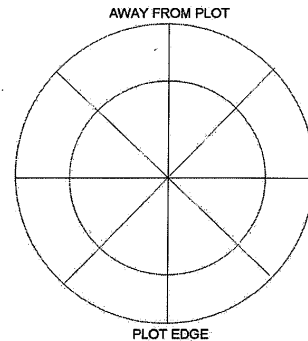
Park: _____ Plot: _____ Date: _____ Observers: _____ DATA QC ☐

SOIL

Frame Location: _____

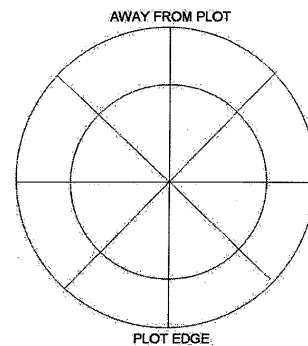
SAMPLE FRAME 1

Litter Thickness Up-slope Side: _____ cm
Litter Thickness Down-slope Side: _____ cm
Litter Sample Collected: Y N
Earthworms: 0 1 9
O Horizon Thickness: _____ cm, O Horizon Color: _____
O Horizon Collected: Y N
A Horizon Thickness: _____ cm, A Horizon Color: _____
A Horizon Collected: Y N
Observed Bottom of A Horizon: Y N
B Horizon Thickness: _____ cm, B Horizon Color: _____
B Horizon Collected: Y N
Soil Notes: _____



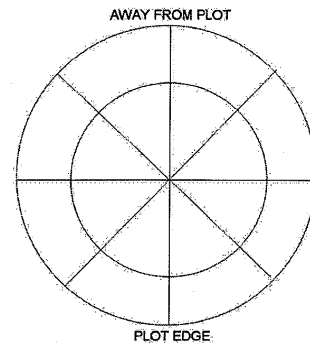
SAMPLE FRAME 2

Litter Thickness Up-slope Side: _____ cm
Litter Thickness Down-slope Side: _____ cm
Litter Sample Collected: Y N
Earthworms: 0 1 9
O Horizon Thickness: _____ cm, O Horizon Color: _____
O Horizon Collected: Y N
A Horizon Thickness: _____ cm, A Horizon Color: _____
A Horizon Collected: Y N
Observed Bottom of A Horizon: Y N
B Horizon Thickness: _____ cm, B Horizon Color: _____
B Horizon Collected: Y N
Soil Notes: _____



SAMPLE FRAME 3

Litter Thickness Up-slope Side: _____ cm
Litter Thickness Down-slope Side: _____ cm
Litter Sample Collected: Y N
Earthworms: 0 1 9
O Horizon Thickness: _____ cm, O Horizon Color: _____
O Horizon Collected: Y N
A Horizon Thickness: _____ cm, A Horizon Color: _____
A Horizon Collected: Y N
Observed Bottom of A Horizon: Y N
B Horizon Thickness: _____ cm, B Horizon Color: _____
B Horizon Collected: Y N
Soil Notes: _____



1509

[illegible]

Percent Cover Categories: 0 = 0%, 1 = <1%, 2 = 1-2%, 3 = 2-5%, 4 = 5-10%, 5 = 10-25, 6 = 25-50%, 7 = 50-75%, 8 = 75-95%, 9 = 95-100%

1508 J. Neurosci., July 26, 2006 • 26(30):1503–1511

[illegible]

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

NPS D-XXX, Month Year

National Park Service
U.S. Department of the Interior



Natural Resource Program Center
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA™