

**GREAT SMOKY MOUNTAINS NATIONAL PARK:
VEGETATION MONITORING PROTOCOL**

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I. Background and Objectives

Great Smoky Mountains National Park (GRSM) is internationally renowned as a center of biological diversity within North America. Complex ecological gradients combine to create a diverse mosaic of plant communities comprised of over 1,300 native species. The biological importance of GRSM led to its designation as an International Biosphere Reserve in 1976.

Despite its large size (>200,000 ha) and protected status, numerous biotic and abiotic factors have altered and continue to threaten plant communities within GRSM. Among biotic factors, exotic species have been the most destructive. During the 1930s, chestnut blight virtually eliminated the American chestnut (*Castanea dentata*) from the forest landscape of eastern North America. Since it was first discovered in 1954 (Speers 1958), the balsam woolly adelgid (*Adelges piceae*) has decimated Fraser fir (*Abies fraseri*) populations in high-elevation spruce-fir forests within GRSM (Smith and Nicholas 1998, Jenkins 2003), and hemlock adelgid (*Adelges tsugae*) may greatly impact hemlock (*Tsuga canadensis*) in the Park during the next decade (Taylor 2002). Since the late 1980s, dogwood anthracnose (*Discula destructiva*), a pathogenic fungus, has killed dogwood trees throughout the Park and mortality has been as high as 90% in some forest types (Jenkins and White 2002). Over the past decade, beech bark disease, an insect/fungus complex, has decimated American beech (*Fagus grandifolia*) trees in high-elevation hardwood forests (Vandermaast 2005). Although the population has been reduced, the European wild boar (*Sus scrofa*) continues to alter understory vegetation within GRSM. Deposition of sulfur dioxide, nitrogen oxides, and particulate matter may acidify soils in susceptible areas, resulting in greater aluminum toxicity (Cronan and Schofield 1990). In addition, high ozone levels continue to stress plant populations at high elevations (Somers et al. 1998).

Native ungulates also exert considerable influence on the composition and structure of native vegetation. In the woodlots in and around Cades Cove, white-tailed deer (*Odocoileus virginianus*) have altered the cover, diversity, and population demographics of forest herbs (Griggs et al. 2006, Webster et al. 2005a). In 2001, the NPS reintroduced elk (*Cervus elaphus*) to GRSM. If this species is successfully reestablished, it may have considerable effects on a wide range of vegetation communities throughout the Park.

In addition to these factors, alterations in the Park's disturbance regimes have impacted vegetation communities. Throughout the Park, plant communities continue to recover from past unregulated logging and agricultural use (Pyle 1988, Webster et al. 2005b). Fire suppression has allowed the succession of numerous pine stands to hardwood dominance. In the absence of fire, succession towards hardwoods is accelerated by mortality caused by the southern pine beetle (Coulson et al. 1999). Within hardwood stands, oak species are not regenerating under closed canopies on mesic sites. The recently implemented prescribed burning program within the Park is counteracting many of these successional changes, but the full effect of fire on species composition and stand structure must be evaluated.

This long history of major impacts to plant communities within GRSM clearly shows the need for a vegetation monitoring program. Once in place, a network of permanent plots will serve as an early warning system of potential changes in plant communities and will provide park managers with information needed to devise strategies to respond to new threats. Since the long-

term monitoring program at GRSM is considered a prototype, implementation of a vegetation monitoring component will allow the development and testing of methodologies for use in other parks. In addition, ecological information gathered from these plots will be of interest to scientists and managers throughout the world facing similar community and landscape level threats.

Program Objectives

1. Establish a network of plots in a statistically valid fashion that allows inferences to be made about vegetation communities throughout the Park.
2. Develop a schedule for the remeasurement of plots within the network that tracks ecological trends through time.
3. Analyze and summarize data in management reports that allow review and decision making by park managers.
4. Share results with others in the scientific and management communities by publishing in peer-reviewed journals and presenting at professional meetings.

Measurable Objectives

Vegetation monitoring at GRSM is designed to detect and describe changes in the composition and structure of vegetation communities throughout the Park. Because of the complexity of the Park's vegetation (over 1300 species of native plants distributed across 79 vegetation associations), it is impossible to identify a few measurable parameters that can be tracked through time as a summation of change. Therefore, our measurable objectives are fairly broad examinations of temporal changes, spatial variability, and the influence of environmental factors.

1. Describe the contemporary species composition, structure, diversity, and edaphic characteristics of vegetation communities.
2. Quantify temporal changes in the species composition, structure, diversity, and edaphic characteristics of vegetation communities.
3. Determine the influence of environmental variables on temporal changes and spatial variability.

II. Sampling Design

Spatial Design

A stratification of GRSM was developed in cooperation with the University of North Carolina. According to Jobe and McKnight (2003), this stratification was based upon three factors: elevation (5 levels), hillshade (3 levels), and topographic convergence index (3 levels). This "environmental zipcode" design was originally developed by Dean Urban (Duke University), Julia Kintsch (Duke University), and Peter White (University of North Carolina at Chapel Hill) for use in the southern Appalachians. An additional factor, accessibility, was added to optimize

sampling effort. Because much of the effort and time expended to establish plots in backcountry areas is spent getting to the plot location, a clustering technique was used to maximize the number of plots that can be sampled around a given point. At each point, plots were located within unique zipcodes within a 1000 m radius.

The stratification offers three levels of plot density (135, 210, and 270 plots) that incorporate a full representation of all zipcodes (Figure 1). Initially, the long-term vegetation monitoring plot network will consist of 150 plots. The full 135 plot array will be used with an additional 15 plots selected from the 210 plot array to improve sampling of under-represented zipcodes and under-sampled parts of the Park. A full description of how the stratification was conducted (Jobe and McKnight 2003) is included as Appendix B.

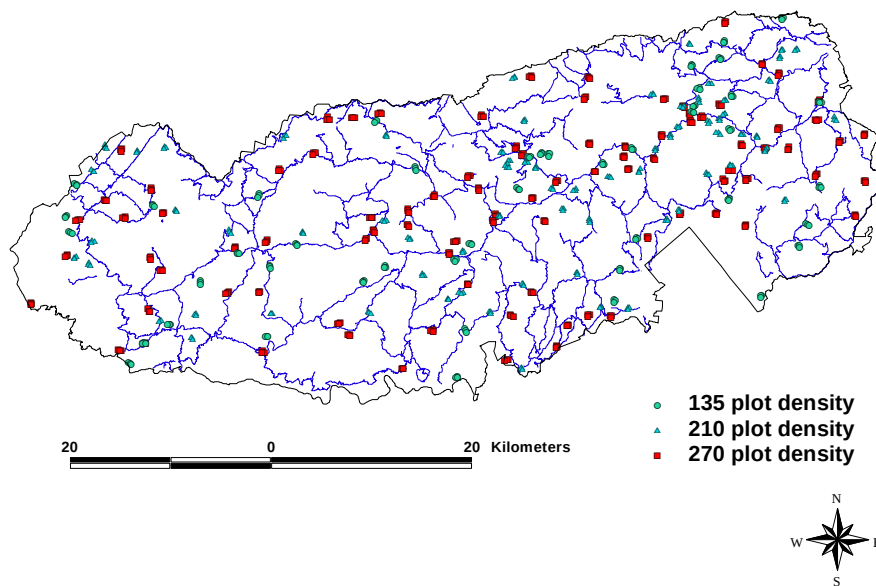


Figure 1. Plot stratification based upon environmental variation and accessibility shown in relationship to trails in GRSM. Environmental variation was defined based upon three factors: elevation (5 levels), hillshade (3 levels), and topographic convergence index (3 levels). Plot distributions for three sampling intensities are shown: 135, 210, and 270 plots.

Detectable Level of Change

Numerous studies of vegetation involving plot sampling have been conducted in GRSM since the 1930s. However, most of these plots are not suitable for long-term monitoring due to a lack of precise information about plot locations, small plot size, or limited sampling (White and Busing 1993). During the late 1970s and early 1980s a series of plots were established, mostly in the west end of the Park, by the Uplands Research Lab of the NPS. The locations of these 0.1 ha plots were generally well documented and permanently marked. These plots were subjectively located to capture a broad range of site conditions and disturbance histories and include areas of mature forest, abandoned farmland, limestone windows, and past burning. Sampling within these plots was quite intensive and includes data from all vegetation strata. Because these plots are not distributed across the entire Park and plot locations were selected through several unrelated projects, this network of plots does not meet the needs of a park-wide long-term monitoring program. However, data collected from the resampling of these plots have answered important questions about long-term vegetation change and allowed the examination of minimum sample size and power analysis.

Over the last decade, the use of power analysis in designing monitoring programs has increased. Power analysis can provide useful insight into the minimum sample size needed to have a predetermined probability of identifying a particular effect or difference as significant (at a preset α level). However, since a vegetation monitoring program is concerned with changes in multiple measurements and indices (basal area, density, importance value, percent cover, volume, species richness, Shannon-Weiner diversity, etc.) describing multiple species and forest stand components, it is not possible to base the number of plots sampled on the analysis of a few variables. Therefore, this protocol uses power analysis as a broad guide in determining sample size. Power analysis was used to determine the sample sizes needed to detect a 20% change in the importance of three species representing overstory, understory, and herbaceous vegetation with 80% power ($\alpha = 0.05$). Eastern hemlock (*Tsuga canadensis*) basal area was used to represent overstory vegetation, flowering dogwood (*Cornus florida*) density was used to represent understory vegetation, and Christmas fern (*Polystichum acrostichoides*) percent cover was used to represent herbaceous vegetation. For these analyses, we used data collected from a series of plots established in western GRSM in the late 1970s and early 1980s (White and Busing 1993) and resampled during the late 1990s-2000. While by no means representative of the nearly infinite number of variables that may change in forest communities, these three analyses do provide a reasonably good assessment of sample sizes needed to detect impacts to common species. The estimated sample sizes needed to detect the desired level of change ranged from 11 to 20 (Table 1). While these three species are not found on all plots, the likelihood of finding each of them on at least 20 out of the 135 plots included in the proposed array is excellent. Therefore, it appears that the proposed sampling intensity is sufficient to detect a 20% change in the importance of common species.

Table 1. Results of minimum sample size analysis for three common species (80% power, $\alpha = 0.05$).

Species	Change to detect	No. of plots in dataset	Mean	Standard deviation	No. of plots needed
<i>Tsuga canadensis</i>	20% change in basal area	84	1.31	1.95	20
<i>Cornus florida</i>	20% change in density	87	85.77	97.54	13
<i>Polystichum acrostichoides</i>	40% change in percent cover	40	1.74	1.81	11

Plot Design

Generally, plot sampling will follow the methodologies of the Carolina Vegetation Survey (CVS). According to Peet et al. (1998), this system is appropriate for diverse applications, incorporates multiple scales, yields data compatible with those from other common methods, and may be applied across a broad range of vegetation types. The standard unit of observation in this system is a 10 X 10 m module. This modular design allows flexibility in sampling intensity, time commitment, and plot layout. Depending upon the homogeneity of vegetation, multiple modules are used to form larger sample units that better represent plant communities. A standard 2 X 5 module configuration (20 X 50 m, total area = 0.1 ha, Figure 2) is most often used, but the number and/or arrangement of modules may be altered to better capture the complexity of a vegetation community. For example, a series of five 10 X 10 m modules have been used to sample vegetation of cliff tops. Plots will be positioned to ensure that sampled vegetation is as homogeneous as possible. Typically, new plots will be placed along contours perpendicular to the slope or lengthwise on ridges or along drainages. Typical plot layout will follow that shown in Figure 2. In this design, the plot is the primary sample unit.

A wide range of data are collected from each plot (see Table 2 for a full summary). On each forested plot, species composition and structure of vascular plant communities are assessed for three strata: the canopy, subcanopy, and herbaceous layers. Nested plots allow the examination of relationships between area and species accumulation. Other ecological components are examined, including down deadwood volume, stand age, and soil chemistry. The data collected in the long-term monitoring program are beyond the scope outlined by Peet et al. (1998), but this expanded effort is necessary to effectively track long-term change.

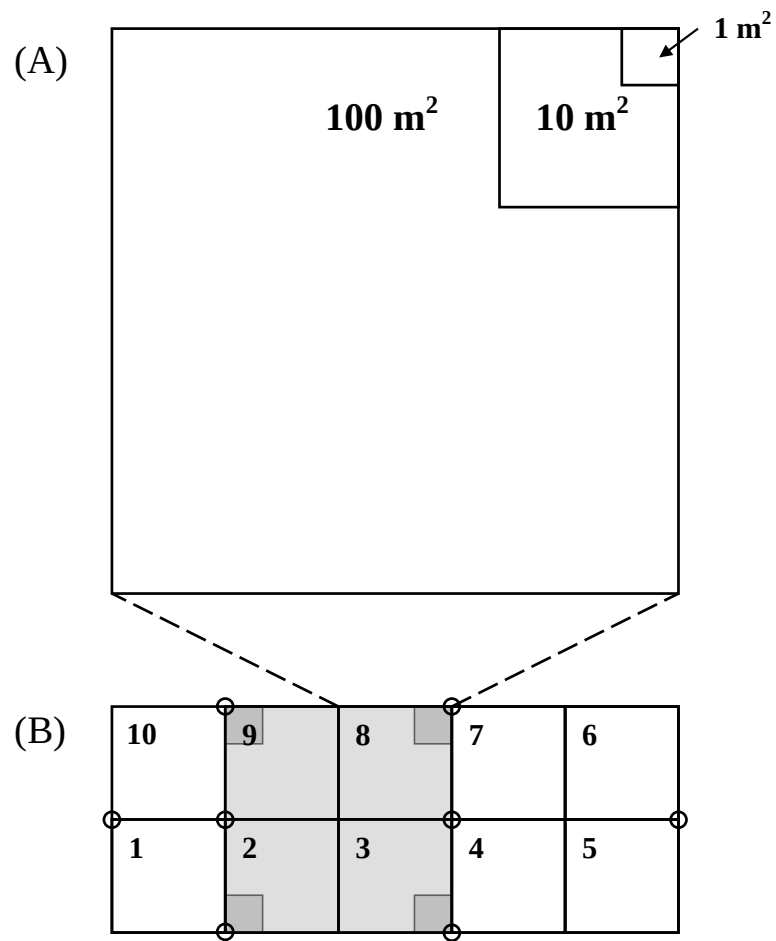


Figure 2. Layout of an intensive module (A), and a set of 10 modules as a 0.1 ha plot (B). Modules are numbered (1-10) and intensive modules (2, 3, 8, and 9) are shaded. Permanent stake (rebar) locations are marked with circles in B. Adapted from Peet et al. (1998).

Sampling Frequency

The following assessment of sampling frequency and logistical design is based upon two assumptions about staffing. First, it is assumed that funding will allow two GS-5 biological science technicians to be hired. Second, it is also assumed that funding will be available to hire two Student Conservation Association (SCA) interns. This level of staffing ensures a minimum crew size of four. In addition, when available, the addition of the park ecologist results in a five person crew. Due to the complexity and intensity of sampling, a four person crew is the minimum functional unit that can efficiently complete plot sampling.

On average, a four person crew can lay out and sample a plot in a single day. Typically, after completing a plot there is also sufficient time to locate and begin laying out the next plot in the cluster. In the best case, it is possible for a crew to complete 4 plots a week since the standard field season work schedule is 4 ten hour days per week. However, since many plots require overnight camping, time must also be allotted for hiking into and out of study sites. In addition, field days are lost each season due to required training, severe weather, and periodic office days required for data entry and planning. Because SCA interns are typically college students, the field season lasts only the 12 weeks of a standard internship. Typically, a single field crew can complete 30-40 plots in a season.

Based upon the conservative estimation of 30 plots sampled per field season, sampling of the full plot array of 150 plots will be completed on a 5 year cycle. Plots will be sampled by cluster, but clusters will be selected for sampling to best capture selected forest types within a single year. For example, clusters within the western end of the Park might all be sampled in the same year to capture the best representation of oak-hickory and oak-pine forest types. Clusters at elevations above 1500 m might be sampled in a single season to capture change in northern hardwood, spruce, and spruce-fir forests. However, information needed for management decisions may preempt the pre-designated sampling cycle. For example, information needed about the effects of a new exotic disease may require shifting of sampling priorities.

Rationale for Selected Design

The program and measurable objectives of this protocol were carefully considered when devising spatial and field plot designs. The selected design offers a balance between statistical rigor and real-world applicability. For tracking changes in vegetation community composition and structure through time, the overall survey design offers several important advantages.

1. *Selected strata are stable through time*
Since the strata are based upon physical landscape features, they will not change through time. Most guides to study design emphasize the importance of strata not changing through time.
2. *Spatial design maximizes sampling efficiency*
Although the stratification includes plots in inaccessible areas, it places most plots in areas where travel into the site and sampling can be accomplished in a day or as part of a full week backpacking trip. By clustering plots, this stratification reduces time lost in

transit between plots. The stratification by accessibility and clustering of plots will greatly increase the number of plots that can be sampled as part of the long-term monitoring program.

3. *Plot design is appropriate for a variety of vegetation types and structures*

The plot design may be readily modified to fit various vegetation types, topographic conditions, or study designs. While most of GRSM consists of closed canopy forests, it also contains non-forested areas such as grassy balds, pastures, and heath balds (shrublands). In addition many vegetation types, such as rock outcrops and cliff tops, cannot be sampled with a standard dimension plot. Since the basic sampling unit is the 10 X 10 m module, any subset of modules can be used to tailor the sampling design to a given area.

4. *Plot design addresses community and species dynamics related to sampling scale*

Since the CVS protocol is based upon a modular design with nested subplots, subplots and modules may be added together to examine relationships at a variety of spatial scales. Since these modules are adjoining, analyses of scale dependent relationships are possible. Many other plot designs contain more spatially distributed, non-adjoining subplots. These other designs encompass a greater amount of spatial variability, which may be desirable for examining gross species richness. However, the distance between the plots is arbitrary and is not related to the spatial variability unique to each of the vegetation communities sampled. Therefore, greater variability accounted for by these plots may be an artifact of the sampling design and not a product of natural variation within the plant community.

5. *Design is compatible with other active sampling designs and studies*

The CVS design has been used to sample over 3000 plots in North Carolina, Tennessee, South Carolina, and Georgia. A similar design is used to monitor vegetation in the Prairie Cluster Parks, which includes sites in Colorado, Minnesota, and Missouri. The Fire Monitoring Protocol of the National Park Service also measures overstory trees within a 20 X 50 m plot. The standard plot design used by NatureServe in its classification of vegetation in the Southeast also uses a 20 X 50 m plot design and records species cover by stratum. In addition, this basic modular design has been used by the Smithsonian Institution/Man and the Biological Diversity Program and the Biological Diversity in Latin America Program in establishing 1 ha² plots throughout the world.

6. *Design is compatible with historic studies*

During the late 1970s-early 1980s, over 400 permanent vegetation plots were established and sampled in western GRSM. These plots have near complete overlap with the CVS design. Between 1995-2001, graduate students from the University of North Carolina-Chapel Hill and GRSM staff relocated and sampled over 200 of these plots. Analysis of these data have provided critical information about nearly thirty years of change in forests of GRSM.

7. *Techniques are easy to learn and use*

Field procedures are easily taught and repeatable over time by different sampling crews. Plot establishment and sampling do not require extensive time or expensive equipment. In addition, once established, the rectangular plots are very quickly located and laid out for successive sampling.

III. Field Methods

This section provides a broad overview of techniques used to establish and sample plots. The sequence of pre-field-season preparation and processing of samples (tree cores, soil samples, unknown species) are also addressed. Detailed descriptions of plot establishment and sampling techniques are provided in Standard Operating Procedure (SOP # 3) “Establishing New Plots” and SOP # 4 “Field Data Collection.”

Field Season Preparations

Prior to the field season in January and February, the ecologist should identify the plots scheduled for sampling during the upcoming field season. Location information, including maps and Universal Transverse Mercator (UTM) coordinates should be assembled. After the seasonal biological science technicians begin work in March or April, they should review the equipment and supplies listed in SOP # 1 “Preparations and Equipment Setup Prior to the Field Season.” All equipment should be located and inspected and supplies should be organized to determine if anything need to be replaced or replenished. The ecologist should review the entire protocol and all SOPs and appendices with the technicians. Once all members of the field crew have been assembled, the ecologist should ensure that all personnel are listed on a research permit.

In May and June, when the SCA interns begin, the emphasis should shift to training (see SOP # 2 “Field Crew Training”). The ecologist and technicians should demonstrate the use of all equipment to the interns and insure that they can perform basic measurement independently. In addition, the ecologist should demonstrate how all field sheets should be filled in and provide all seasonal staff with basic training in local flora and taxonomy. Generally, SCAs are responsible for learning common woody trees and shrubs. Typically, one technician will have superior taxonomy skills and training. This person is designated to do all herbaceous species sampling and identification when the ecologist cannot participate in field work. Time must be set aside weekly to work with this technician on plant taxonomy by identifying and discussing unknown species collected during the prior week of field work. Unless funding becomes available for a permanent technician, this process of vetting and training a field taxonomist must be repeated every year. The other technician is responsible for supervising the woody species identification and data collection by interns.

Sampling Methods

This section provides a general description of how new plots are established and how plots are sampled. A detailed description of plot establishment is provided in SOP # 3 “Establishing New

Plots.” To establish a new plot, four module corners along the plot center line (0, 10, 30 m, and 50 m) are marked with a length of rebar and two additional corners are marked along each base line at 10 and 30 m (Figure 2). Both end stakes (0 and 50 m) are associated with two witness trees picked for their uniqueness and durability, and the distance and azimuth from each witness tree to the end stake are measured. Other unique characteristics of the area are noted and UTM coordinates of all plots are determined with a GPS unit (settings provided in SOP # 1). Data collected in each plot are summarized in Table 2. Examples of data sheets are provided in Appendix D. A complete description of field data collection is provided SOP # 4.

Table 2. Summary of vegetation data collected within each plot.

Component	Sampling
Species presence and cover	Recorded for all species in nested subplots within each of 4 intensive modules. Cover recorded separately for three height strata (0-0.49 m; 0.5-4.9 m; ≥ 5 m). Presence and cover of additional species not found in intensive modules recorded in other six 10 X 10 m modules.
Trees ≥ 10 cm dbh	Dbh to nearest 0.1 cm in all modules; mapped to nearest 0.5 m; cores collected from 3 dominant or co-dominant trees. Canopy position and tree condition classified.
Dead trees ≥ 10 cm dbh	Dbh to nearest 0.1 cm in all modules; mapped to nearest 0.5 m.
Woody stems < 10 cm dbh; ≥ 1.4 m height	Tallied in all modules by species into 4 diameter classes.
Dead woody stems < 10 cm dbh; ≥ 1.4 m height	Tallied in all modules by species into 4 diameter classes.
Woody stems < 1.4 m height	Density tallied by species in 3.2 X 3.2 m subplot in 4 intensive modules.
Herbs	Cover by species in four 10 X 10 m modules; additional species in other 6 modules.
Down deadwood ≥ 10 cm midpoint diameter	Midpoint diameter to nearest cm; length to nearest 0.1 m; decay stage, all modules.
Bryophytes (summed) and Lichens (summed)	Cover in 4 intensive modules.

Environmental Variables

Before vegetation sampling begins, information describing the plot microenvironment is recorded. These data include elevation, percent slope, aspect, topographic position, landform type, soil a-horizon depth, and forest type. General information about past disturbance (old-field, historic fire, livestock grazing, logging, etc.), recent disturbance (fire, wind, etc.), presence of canopy gaps, rock outcrops, and other site conditions are also recorded.

Species Presence and Coverage

Within the CVS protocol, species presence and coverage quantify vegetation across all strata (overstory, understory, and herbaceous layers). Species presence is recorded in nested subplots (1, 10, and 100 m²) within 4 intensively sampled 10 X 10 m modules (Figure 2; Table 2). The cover class (Table 3) of each species is recorded by height stratum (< 0.5 m; 0.5-5 m; > 5 m) within each of these 4 intensive modules. The presence and cover of bryophytes and lichens are also recorded, although individual species are not identified. The other 6 non-intensive modules are searched for species not found in the 4 intensive modules, and each species is assigned a cover class value based on its coverage across the entire 20 X 50 m plot.

Overstory Trees

All living and dead trees ≥ 10 cm dbh (measured at 1.4 m) are measured for dbh to the nearest 0.1 cm within each 10 X 10 m module (total area = 0.1 ha). All trees are tagged and mapped by module to the nearest 0.5 m using an XY coordinate system. The CVS protocol tallies overstory trees into 6 diameter classes. However, since trees on these plots will be remeasured at regular intervals, precise measurement and mapping are needed. Each tree is assigned to a canopy position class (suppressed, intermediate, codominant, or dominant; see SOP # 4 “Field Data Collection” for a description of each class) and a condition class (1 = No dieback; 2 = 1-25% dieback; 3 = 26-50% dieback; 4 = 51-75% dieback; 5 = > 75 % dieback; 6 = dead; 7 = down; 8 = missing). On each plot, 2-4 codominant trees are cored to determine stand age.

Down Deadwood

The length and midpoint diameter of all down deadwood with a midpoint diameter ≥ 10 cm are measured. Only portions of logs ≥ 10 cm within the plot will be measured. Portions of logs outside the plot boundary are not measured. Branches larger than 10 cm midpoint diameter are measured as separate segments. Each log is classified into one of six decay stages based upon Pyle and Brown (1998; Illustration and tabular description are provided in SOP # 4 “Field Data Collection”). Portions of individual logs comprised of different decay stages are measured as individual segments.

Understory Sampling

All woody stems ≥ 1.4 m in height but < 10 cm dbh (saplings) are tallied in four size classes (0-0.99 cm, 1.0-2.49 cm, 2.5-4.99 cm, and 5.0-9.99 cm) by species. Typically, stems are tallied in all 10 modules, but modules may be subsampled in plots with extremely high understory densities. Vine species (*Vitis* spp., *Parthenocissus quinquefolia*, etc.) are tallied only if they are rooted within the plot. The density of dead stems will be inventoried separately. Woody stems < 1.4 in height are inventoried by species within the 3.2 X 3.2 m subplots nested in the 4 intensive modules.

Herbaceous Sampling

Cover is recorded within the 4 intensive 10 X 10 m modules. The coverage of additional herbaceous species present in the 6 modules not sampled with nested subplots is recorded. The density (number of stems) of rare, threatened, or other herbaceous species of interest on a given plot is recorded in the nested subplots. Voucher specimens of unknown species are collected. To avoid seasonal variation in plant cover, whenever possible plots of a given forest type are sampled during the same month of year they were last sampled.

Table 3. Cover-abundance scale classes used in permanent plot sampling (Peet et al. 1998).

Cover Range	Scale Value	Class Midpoint
Missing but nearby	--	--
Solitary or few individuals	1	0.3
0-1%	2	0.5
1-2%	3	1.5
2-5%	4	3.5
5-10%	5	7.5
10-25%	6	17.5
25-50%	7	37.5
50-75%	8	62.5
75-95%	9	85.0
95-100%	10	97.5

Post-Collection Processing of Samples

Samples collected in this protocol consist of tree cores, soils, and voucher specimens of unknown plant species. Unlike other types of ecological monitoring, sample processing in this program is relatively straightforward and simple. Regardless of sample type (tree cores, soils, plants) proper labeling is critical. All sample labels must include the plot number, date collected, and collector. Tree core labels also include the species from which the core was taken, core number, and dbh at which the core was taken. Specimens of unknown plants should also include a unique identifier that corresponds to that recorded on the datasheet.

All tree cores, which are placed in drinking straws after they are taken, are placed in the freezer until they can be properly processed. Tree cores are mounted on wood strips with wood glue, and label information is written in pen below the core on the mounting strip. After cores are mounted, they no longer need to be refrigerated.

Soil samples are stored in sealed and labeled 1 quart Ziploc bags. Like tree cores, they should be stored in the freezer until they can be properly processed. Soil samples are transferred to storage bags provided by a certified soil testing lab and mailed to the lab within a day of being removed from the freezer. As with all samples, great care must be taken to properly track the plot from which each sample was taken.

Specimens of unknown plants are sealed in a Ziploc bag and stored in the refrigerator (not freezer) until they can be processed. The technician and ecologist (with assistance from the botanist) should meet once a week to identify unknowns. After the unknowns are identified, datasheets should be updated to include the proper species code. Some specimens may be permanently pressed and mounted for future use in identification. However, only specimens that are likely to be used for future identification should be kept permanently. As with other samples/specimens, great care must be taken to properly track label information until the species is identified and the datasheets are updated.

IV. Data Handling, Data Analysis, and Reporting

The sampling of a single vegetation plot produces thousands of observations about the abundance, condition, size, and distribution of plant species. When these observations are compiled across an entire network of plots measured repeatedly through time, the accumulation of data can be staggering. Proper data management is critical to the long-term maintenance, organization, and dissemination of such a large and ever expanding database. Specific data management objectives are driven by four essential themes: (1) database design, (2) data analysis and trend evaluation, (3) data quality assurance and control, and (4) long-term data integrity and security. Themes 1 and 2 are discussed below and in SOP # 5 “Data Management.” Themes 3 and 4 are discussed in SOP # 5. Data products and metadata will be posted at the NPS DATASTORE. Quality assurance and quality control (QA/QC) guidelines in this document are based upon recommendations of Rowell et al. (2004) and S. Fancy at <http://science.nature.nps.gov/im/monitor>.

Overview of Database Design

Microsoft Access 2003 is the NPS standard database software program and is used for managing long-term vegetation monitoring data at GRSM. ESRI ArcGIS 9 is the NPS standard for validation and manipulation of spatial data. Below, the current database structure is discussed.

Vegetation monitoring data are stored in 8 different tables. Occurrence and cover data for all species are stored in the table `tbl_Nests`. Overstory data (trees ≥ 10 cm dbh) are stored in the tables `tbl_Overstory_Trees` (plot information, XY coordinates, species and tag numbers) and `tbl_Overstory_Data` (dbh, canopy position class, tree condition class). Data for woody stems <10 cm dbh are stored in the table `tbl_Saplings` and data for woody stems <10 cm dbh are stored in the table `tbl_Seedlings`. Data for down deadwood are stored in the table `tbl_Deadwood` and include plot, module, midpoint diameter, length, and decay class. Event information (sample date, crew members, notes and observations) are included in the table `tbl_Events` and location information is in `tbl_Locations`. Reference tables used for look-up or query selection include `tlu_SpeciesCode`, `tlu_NatureServeClass`, `tlu_CanopyPosition`, `tlu_TreeCondition`, `tlu_DecayClass`, and `tlu_CoverClasses`.

Core tables are used to link vegetation, environmental, and sampling data. Two core tables are employed: locations and events. For each plot, the locations table (`tbl_Locations`) includes the

USGS quad, watershed, NatureServe association, UTM coordinates, accuracy of coordinates, elevation, etc. The table tbl_Events tracks the precise day, date, and year each plot is resampled.

Overview of Data Analysis, Results, and Reporting

Historically, the NPS has done an excellent job of collecting field data but has long suffered a “file drawer” problem with regard to analyzing data and sharing results. Great strides have been made in recent years to conduct timely analyses of data and share results with park managers, other agencies, academics, and the general public. The analysis of data and writing of reports are critical to the long-term survival of long-term monitoring programs. Reporting important trends observed from long-term data is not only important to on-going NPS management, but provides important exposure for the Inventory and Monitoring (I&M) program and highlights its importance beyond the NPS. Analysis of long-term data is done “in-house” by the program manager, but data are also shared with outside scientists to allow more in-depth analysis. In addition, monitoring data often suggests trends or relationships that require closer investigation via research. The GRSM vegetation monitoring program has actively pursued collaborative research to provide a better understanding of change in GRSM vegetation communities and how negative impacts (such as exotic plants, insects, and fungal pathogens) can be reduced through active management. In this section, data preparation, analysis, and reporting methods are discussed.

Due to the complexity of long-term vegetation data, analysis techniques vary with the type of data being analyzed and the question that the analysis is intended to address. For example, repeated measures one-way analysis of variance (ANOVA) is used to test differences between samples classified by one criterion. Regression analysis also offers a powerful technique to assess relationships between two variables, or between a single dependent variable and several independent variables. For example, the GRSM Vegetation Monitoring Program has used multiple linear regression to examine how the density of *Cornus florida* (dependent variable) has changed in response to elevation, soil cation availability, and stand basal area (independent variables). Multivariate techniques, such as non-metric multidimensional scaling, are frequently used to examine the distribution of samples and species across environmental gradients.

There are multiple audiences for the information generated by long-term monitoring programs. Park managers constitute the most immediate audience and have the most critical need for information. Reports made to managers will typically address changes in a resource of management concern. For example, a summary of mortality resulting from an exotic pathogen or a description of site recovery following a wildfire would be of interest to managers. Other divisions within GRSM are another audience. This audience may be less interested in technical reports but are likely to be interested in summary information describing broad trends in biotic resources. Other parks, I&M networks, and other land management agencies comprise another important audience. This audience is interested in trends that may also be occurring within other parks, across networks, or on other public lands.

The general public is another audience for long-term monitoring information. Information is best shared with this group through the Park Resource Education Staff who can provide

summaries of trends through presentations and visitor center contact. In addition, Resource Education Staff can integrate monitoring information into displays and publications.

The final audience for long-term monitoring information is the scientific community. Long-term monitoring data contain a wealth of information that is of great interest to outside scientists. A goal of any long-term monitoring program should be to reach this audience through presentations at scientific meetings and publication in peer-reviewed journals. Publishing in peer-reviewed journals not only shares results with this audience, but also validates findings by holding them up to review by outside scientists. In addition, trends evident in monitoring data can lead to more focused studies of potential management treatments/controls and more in-depth examinations of cause and effect. By making data available to outside scientists and researchers, additional study and research that may be outside the scope of an I&M program can be accomplished.

V. Personnel Requirements and Training

Roles and Responsibilities

The I&M Branch ecologist serves as the program manager and is responsible for implementing the vegetation monitoring protocol. The ecologist is responsible for selecting and training biological science technicians and student interns. The ecologist works with the data manager to develop a functioning system of database management. The ecologist is responsible for data collection, data entry, data verification, and data validation. The ecologist is also responsible for data analysis and works with the data manager to facilitate data dissemination to other programs and outside researchers. The data manager and program manager share responsibility for data archiving, data security, dissemination, and database design. The data manager, in collaboration with the ecologist, also develops data entry forms and other database features needed for quality assurance. The database manager has ultimate responsibility for ensuring that adequate QA/QC procedures are built into the database management system and the appropriate data handling procedures are followed.

Qualifications

Ecologist: The ecologist should have training and/or experience in experimental design, forest measurement techniques, and statistical analysis. The ecologist should also have basic GIS skills and experience writing scientific and technical papers.

Biological Science Technicians: Ideally, technicians should have a bachelor's degree in botany, biology, forestry, or a similar discipline. Field experience collecting ecological data is highly desirable. Basic computer skills and experience in data entry are also desirable. Both technicians should also have basic woodland navigation skills and the ability to use topographic maps. At least one technician should have academic training and/or experience in plant taxonomy and a familiarity with the flora of the southern Appalachians.

Training Procedures

Training procedures are outlined in SOP # 2 “Field Crew Training.” In general, field crew training will cover 4 major areas: (1) woodland navigation, (2) plant species identification, (3) forest measurements, and (4) safety.

VI. Operational Requirements

Annual Workload and Field Schedule

Monitoring requires a minimum crew of four people. Two crew members are GS-5 biological science technicians with experience conducting field vegetation surveys. In general, field crews will work four 10 hour days per week. The field season generally runs from mid-May to mid-August. If staffing permits, time before and after the field season may be used to locate and establish plots for the next field season.

Facility and Equipment Needs

All equipment and supplies needed for the long-term vegetation monitoring program are described in SOP #1 “Preparations and Equipment Setup Prior to the Field Season.” Beyond basic equipment and supplies, shared office space is required for all four crew members and a minimum of two computers should be available for plot coordinate downloading/uploading and data entry. A minivan or other multi-passenger vehicle with sufficient storage space for four full sized backpacks is also needed.

Budget Considerations

Because of the in-depth nature of vegetation monitoring, a competent and fully staffed crew is a must for the program to function. Without this minimum staffing, plots cannot be established and data cannot be collected.

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Vegetation Monitoring Protocol
Great Smoky Mountains National Park

Standard Operating Procedure # 1
Preparations and Equipment Setup Prior to the Field Season

Version 1.0 (Date)

This SOP describes preparations for the field season. It includes a list of equipment needed and GPS unit settings. Typically, the steps outlined below should be completed between late March and mid-April, prior to the field.

General Preparations

1. All crew members should be given a copy of the entire protocol, including all SOPs. All training materials, including a copy of the GRSM I&M Branch Backcountry Safety Guide, should be assembled.
2. The schedule of plots slated for establishment or resampling should be determined. Plots should be grouped into sampling trips (single day and multi-day backcountry), and the order of trips should be determined.
3. Supplies (rebar, nails, tags, etc.) should be assessed to determine if current levels are sufficient to complete the schedule of plots. If needed, additional supplies should be purchased. A list of all supplies needed for a single plot is provided in Table 1. Equipment and supplies for backpacking trips are listed in Table 2.
4. All sampling equipment should be compiled and inventoried. Equipment should be inspected to insure proper function. All missing/broken equipment should be replaced or repaired. A list of all equipment needed by a single field crew is provided in Table 1.
5. All backcountry camping equipment and supplies should be compiled and inspected. Broken or torn equipment should be repaired or replaced. Water filters and stoves should be tested. A list of recommended backcountry camping equipment is provided in Table 2. Some seasonals may prefer to use their own equipment.
6. Available freezer space should be assessed to confirm that sufficient space is available for the storage of tree cores and soil samples. Any remaining samples from the previous field season should be processed and sent in for analysis.

Non-Default Setup Options for the Garmin 76S GPS Units

WAAS—Disabled

Vertical Speed—m/min

Distance and Speed—metric

Location Format—UTM UPS

Map Datum—NAD8327 CONUS

Zone—17N

Table 1. Equipment and supplies required to establish and sample long-term vegetation monitoring plots.

<u>Equipment Needed for Each Field Crew</u>		
Quantity	Item	Use
2	Suunto sighting compass	Plot establishment, plot relocation
3	50 m Keson open reel tape (with a replacement reel)	Plot establishment, plot sampling
2	20 m Keson open reel tape (with a replacement reel)	Plot establishment, plot sampling
1	50 m replacement tape for Keson reel tape	Plot establishment, plot sampling
1	20 m replacement tape for Keson reel tape	Plot establishment, plot sampling
1	Clinometer	Plot establishment
1	Garmin GPS 76S (recommended model)	Plot establishment, plot relocation
1	Claw hammer	Plot establishment, plot sampling
1	Digital camera	Plot and vegetation documentation
1	Increment borer	Plot establishment
1	Hand stamp steel die set (witness tree tags)	Plot establishment
1	5 or 10 m dbh tape	Plot sampling
1	Hand trowel	Plot sampling
2	Lufkin executive 2 m dbh tapes	Plot sampling
1	Nail pouch	Plot sampling
1	Hammer loop for belt	Plot sampling
2	65 cm caliper	Plot sampling
1	20 m loggers tape	Plot sampling
2	3 m locking tape measure	Plot sampling
1	Aluminum storage clipboard	Plot sampling
1	First aid kit	All fieldwork
<u>Supplies Needed for each Plot</u>		
8	18" length of rebar	Plot establishment
150	2.25-3 inch aluminum nails	Plot establishment
150	Consecutively numbered aluminum tree tags	Plot establishment
8	Permatag aluminum markers	Plot establishment
3	Pencils	Plot establishment, plot sampling
18	Wire flags	Plot establishment, plot sampling
1	Can of WD-40	Plot establishment
1	Roll masking tape	Plot establishment
1	Pack of unjointed drinking straws	Plot establishment
1	Roll of flagging	Plot establishment, plot sampling
4	Chaining pins	Plot sampling
2	1 gallon Ziploc bag	Plot sampling
1	1 quart Ziploc bag	Plot establishment
1	Full set of datasheets	Plot sampling

Table 2. Equipment and supplies recommended for backcountry camping.

<u>Equipment Needed for Each Field Crew</u>	
Quantity	Item
4	Full size extended trip backpacks
2-4	Lightweight backpacking tents; 1-3 person
2-4	Lightweight ground tarps
2	MSR whisperlight stoves
2	MSR fuel bottles
4	Mess kits
2	Two-liter water bags
2	Pur Hiker water filters
4	Therm-a-rest self inflating sleeping pad
4	Lightweight sleeping bags w/compression sack
4	LED headlamps
<u>Supplies Needed for Each Field Crew</u>	
2	Water filter replacement cartridges
2	MSR stove repair kits
2	Gallons of stove fuel “white gas”
2	First aid kits

Vegetation Monitoring Protocol
Great Smoky Mountains National Park

Standard Operating Procedure # 2
Field Crew Training

Version 1.0 (Date)

This SOP describes the types of training (navigation, species identification, forest measurements, and safety) that will be conducted prior to each field season. Specific methods are not discussed since they are described in SOP # 4 “Field Data Collection.”

Navigation:

All employees will be trained in the use of a hand held, commercial grade GPS unit. Currently the GRSM Vegetation Monitoring program uses Garmin GPSmap 76S. MapSource version 6.3 software is used with the Garmin units to upload digital topographic maps for field navigation. Each crew member will be provided with the manuals for both the Garmin unit and the MapSource software. Proper use of the Garmin Unit and uploading of topographic maps will be demonstrated by the ecologist. All non-default settings for the Garmin Unit are provided in SOP # 1 “Preparations and Equipment Setup Prior to the Field Season.”

In GRSM, the Universal Transverse Mercator (UTM) Coordinate System is used for all point location and navigation. Each crew member will be trained in using this system to locate points on a topographic map.

Species identification:

All crew members will be trained in the identification of common woody species (trees, shrubs, and woody ground cover). This training will consist of hikes on trails that run through forest types/elevations/landforms that will be sampled during the field season. Each crew member will be quizzed on their ability to identify common species.

The crew member responsible for doing the nested plot sampling will be trained in the identification of common herbaceous species as well. While this person will typically have some training or experience in taxonomy and species identification, this training will serve as a refresher and an introduction to local species with which they may not be familiar. This person will be quizzed at the end of the training to insure their proficiency in herbaceous species identification. In addition, this person will be trained in the appropriate techniques for collecting, preserving, and mounting specimens of unknown species for future identification.

Forest measurements:

All crew members will be trained in conducting forest measurements based upon the methodology outlined in SOP # 4 “Field Data Collection.” All training will be conducted on a demonstration plot established at the Twin Creeks Natural Resources Center. To begin, 50 and 20 m tapes will be used to layout the plot. Crew members will be trained to use a clinometer,

sighting compass, dbh tape, calipers, and increment borer. Each crew member will also determine dbh (1.4 m; 4.5 ft) relative to their height. Examples of all five down deadwood decay stages will be shown, and crew members will be asked to classify additional logs. Crew members will also practice discerning sapling diameter, tree canopy position, and tree condition classes. Proper soil collection techniques will be demonstrated.

Crew members responsible for doing the nested plot sampling will also be trained in the use of the 10 point cover class scale. A visual representation of this scale is provided in SOP # 4 “Field Data Collection.” The ecologist will sample all four intensive modules on the demonstration with all crew members responsible for sampling the nested plots. During this time, all crew members will discuss their estimates of species cover and calibrate their individual estimates. This calibration of cover class estimates will be repeated periodically throughout the field season.

Safety

All crew members will review the GRSM I&M Branch Backcountry Safety Guide and will be periodically quizzed to ensure that they have adequately learned its content.

Vegetation Monitoring Protocol
Great Smoky Mountains National Park

Standard Operating Procedure # 3
Establishing New Plots
Version 1.0 (Date)

Because they will be part of a permanent network, the proper location and establishment of new plots are critical. All new plot locations are in the database of plot locations derived by Jobe and McKnight (2003). The equipment required for plot establishment is listed in SOP # 1
“Preparations and Equipment Setup Prior to the Field Season.”

Locating Plot

Plot Rejection Criteria (I know the JOBE model is suppose to be the cure all for this, but I think this past year have proven it untrustworthy.)

- High percentages of rock outcrops, barren spots, soil, and/or vegetation anomalies (e.g., a small meadow in a forest)
- Locations close (<30 m) to a road, trail, potential development site, proposed fireline, developed area, or monitoring type boundary (ecotone) other plot.
- Inclusion of archeological sites
- Areas with >50% slope (installing and monitoring plots on steep slopes can result in excessive damage to the herbaceous vegetation and fuel bed. Where practical, it is recommended that you avoid such slopes)
- Substantial disturbance by hogs, vehicular traffic, or blow downs, fire etc.
- Intersection by a stream; seep or spring present
- Safety issues, e.g., known high density dead overstory trees
- Inventory, monitoring, or other research plots that would be compromised by the co-location of plots
- Other locally defined conditions that present problems

By establishing clear monitoring type descriptions and rejection criteria, you can avoid bias. Examples of reasons **not** to reject monitoring plot locations:

- **Not typical:** Plot location is thought to be atypical (a plot is either in the type or not; it should be rejected only because it does not meet the monitoring type description)
- **Too difficult to sample:** It would be too difficult to put in transect at this location (shrubs too dense, or plot location is hot and lacking shade trees)
- Placement of Centerline, Sidelines, and Rebar

Placement of Centerline

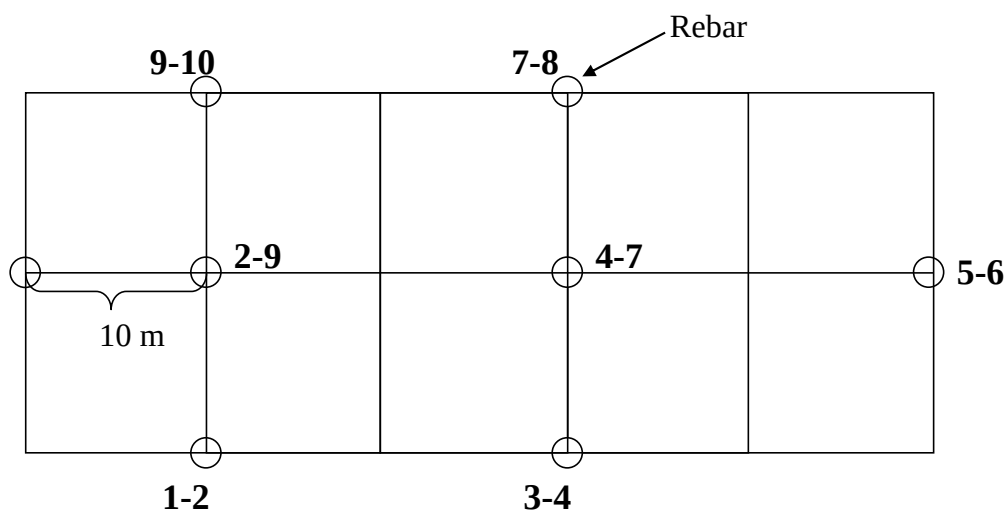
- All plot locations will be determined with the Garmin GPSmap ~~76S unit~~ 60CSX or the most current and accurate unit. Once a point is selected, walk along the contour approximately 25 m (email on this sent to Mike 9/29) to ensure that the first installed rebar marks the outer edge (or 1-10) of the plot. If the point lands in a potentially dangerous area (ex. yellow jacket nest) the crew leader has the authority to move the plot a random distance and azimuth from that point. to the left and push a length of rebar into the ground. This rebar point will serve as the beginning of the plot centerline.
- On side slopes, the centerline will run with the contour, perpendicular to the slope. The centerline should run parallel to ridges and streams/ravines (see below Figure 1). Use a sighting compass to determine the appropriate bearing for the centerline.



Figure 1. Proper orientation of plots on the landscape. The centerline should run parallel to ridges (A), parallel to contours (B), and parallel to streams (C).

Placement of Centerline Cont...

Run a 50 m tape the full 50 meters along this bearing. Take great care to keep the tape straight and on-line. In thick vegetation, it will be necessary to retake your bearing repeatedly. The tape should lie flat on the ground; avoid hanging the tape in tree branches or shrubs. If a tree trunk occurs on the line, run the tape around the side of the tree that least distorts the straightness of the line. Keeping the centerline straight is essential to accurately establishing a plot of proper orientation and dimension. After the centerline is in place, drive a length of rebar into the ground at 0, 10, 30, and 50 m (Figure 2). Avoid trampling vegetation at these locations where nested plot and seedling sampling occur.



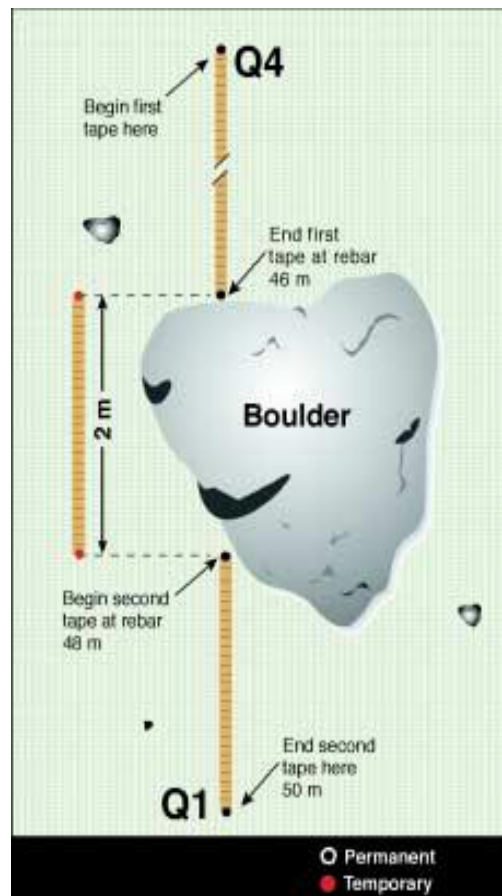
Placement of Sidelines

- Use a sighting compass to place rebar at the two corners. This protocol change was made in 2009 to aid reestablishing the plot on return trips. Also, place rebar on the two sidelines at 10 and 30 m. The bearing for the sideline rebar should be 90° from the centerline bearing. Care should be taken to precisely place these rebar. This task is best performed by two people, one to sight the appropriate bearing while the other moves and places the rebar as directed.
- After all four end-line rebar are placed, measure between each set on each sideline and insure that they are 20 meters apart. Tapes should be within + 0.5 m (or 1%) in plot length and + 0.2 (or 1%) in plot width.

Large Obstructions Encountered on the Transect

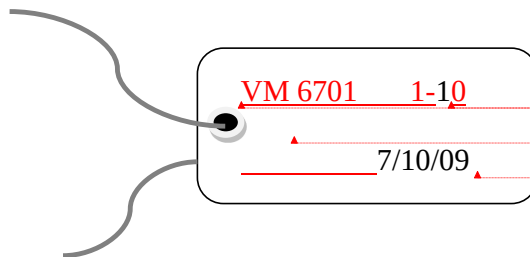
Follow this procedure if you encounter a large obstruction, like a very large tree or tall rock, along a forest plot boundary line:

- Lay the tape straight, along the transect, until the point at which the obstruction is encountered.
- Pound a permanent stake at this point.
- Deviate from the transect at a 90-degree angle in the direction enabling the shortest offset, until you are clear of the obstruction, and pound a temporary stake there.
- Lay the tape to the end of the obstruction, following the original transect azimuth, and pound another temporary stake there.
- Measure and record the distance between the two temporary stakes.
- Divert 90 degrees again back to where the original line would pick up and pound another permanent stake.
- At this point, you may remove the temporary stakes and secure the tape back at the permanent stake preceding the obstruction.
- Add the distance measured between the two temporary stakes to the distance on the tape at the point at which the deviation was made and the first permanent rebar was installed.
- Unwind a second tape out to this distance and attach it at this point to the permanent stake following the obstruction, then lay the remainder of it out to the end of the transect.



Labeling Rebar and Collecting Coordinates

- Place die-stamped aluminum tags ~~labeled permat~~ on each rebar with wire.



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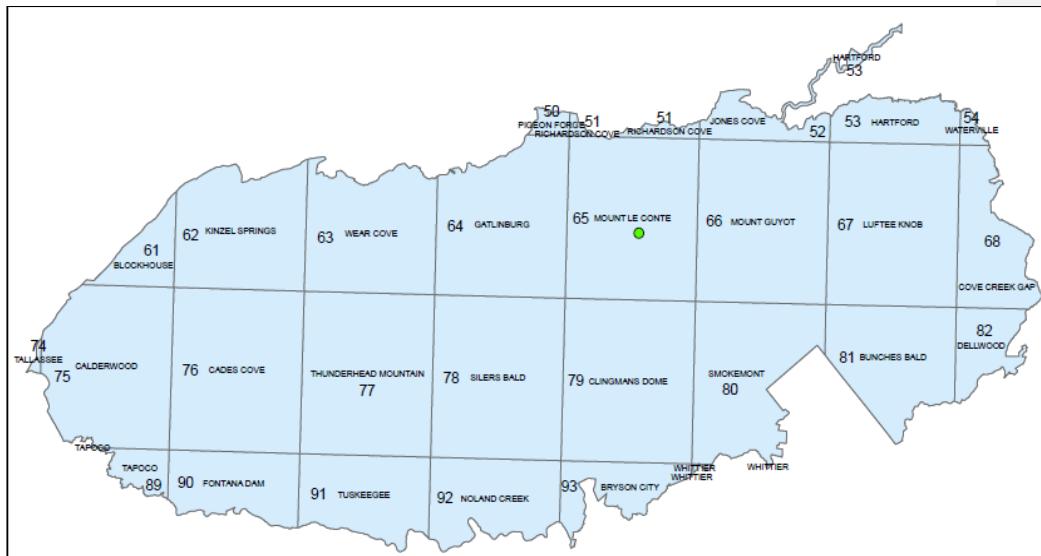
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- Each tag should include the plot identification code, the rebar location and date of initial plot install. In the figure above the plot identification code is VM 6701. VM stands for Vegetation Monitoring, the following two numerals indicate the USGS quadrangle where plot is located and the last two indicate which plot it is within the quad. In the example above the plot is the first one to be installed in the Luftee Knob quad.

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- After the plot is laid out, a UTM coordinate should be taken from the 2-9 rebar and recorded, along with the error in meters, on the plot coversheet. Due to the constantly changing error of commercial grade GPS units, it is nearly impossible to locate the exact plot coordinates delineated by Jobe and McKnight (2003). Consequently, this new coordinate is recorded and will serve as the coordinate of record for the newly established plot.

Selecting and Establishing Witness Trees

1. Witness trees are used to relocate the rebar at the beginning and end of the centerline (1-10 and 5-6). Two witness trees are selected from inside the plot for each rebar.
2. Only overstory trees that are likely to remain alive and standing between surveys should be selected. Trees should show no evidence of significant crown dieback or heart rot/hollowness. Short-lived species such as black locust (*Robinia pseudoacacia*) and fire cherry (*Prunus pensylvanica*) should be avoided. In addition, trees that are likely to die as a result of insects or disease should be avoided. These species include American beech, yellow pines (*Pinus* species other than *P. strobus*), elms (*Ulmus* spp.), and, ~~unfortunately,~~ eastern hemlock.
- ~~3. Once selected, witness trees should be tagged with the tag FACING the rebar. The tag should include the number of the rebar being witnessed (1-10 or 5-6) and the witness tree number (WT#1 or WT#2).~~
- ~~4.3.~~ The distance from the witness tree to the rebar is measured to the nearest 0.1 m and recorded on the cover datasheet along with the tag number (see Appendix D for all datasheets).
- ~~5.4.~~ The bearing FROM the witness tree TO the rebar should be determined and recorded.
5. The dbh and species of each witness tree should be recorded on the cover sheet.
6. If there are no suitable trees in the plot, select trees outside of the plot and tag them FACING the rebar. The tag should include the number of the rebar being witnessed (1-10 or 5-6) and the witness tree number (WT#1 or WT #2)

Collecting Site Description

Slope Shape – The shape of the slope at the plot scale should be recorded using the following values:

- Convex
- Concave
- Straight
- Undulating

Slope – The slope location will be recorded at three locations for each plot. Record the angle of slope at each end of a plot and across the 4-7 rebar to the nearest 1 degree. Slope is determined by sighting the clinometer along a line parallel to the incline (or decline). To measure slope, Observer 1 should stand at the uphill edge of the plot and sight Observer 2, who stands at the downhill edge of the plot. When the observers cannot see each other, Observer 2 should move closer. Observers should sight each other at eye level. Read the slope directly from the degree scale of the clinometer. Slope measurements of the two observers should be compared for accuracy. With practice, slope measurements can be taken by only one observer. If slope changes across the plot, but the slope is predominately of one direction, code the predominant slope angle rather than the average. If the plot falls directly on or straddles a canyon bottom or narrow ridge top, code the average slope of the side hill(s).

Aspect – The direction toward which a slope faces in relation to the points of a compass. Record aspect in compass degrees (e.g. 270°) to the nearest 1 degree and at the same locations the slope

was recorded. Aspect is determined for land surfaces with at least 5 percent slope in a generally uniform direction.

Topographic Position - Topographic position refers to the position of the plot on the land surface and should be recorded using one of the following values:

- INTERFLUVE: (crest, summit, ridge): linear top of ridge, hill, or mountain; the elevated area between two fluves (drainageways) that sheds water to the drainageways.
- HIGH SLOPE: (shoulder slope, upper slope, convex creep slope): geomorphic component that forms the uppermost inclined surface at the top of a slope. Comprises the transition zone from backslope to summit. Surface is dominantly convex in profile and erosional in origin.
- HIGH LEVEL (mesa): level top of plateau
- MIDSLOPE (transportational midslope, middle slope): intermediate slope position
- BACKSLOPE (dipslope): subset of midslopes which are steep, linear, and may include cliff segments (fall faces).
- STEP IN SLOPE (ledge, terracette): nearly level shelf interrupting a steep slope, rock wall, or cliff face.
- LOWSLOPE (lower slope, foot slope, colluvial footslope): inner gently inclined surface at the base of a slope. Surface profile is
- generally concave and a transition between midslope or backslope, and toe slope.
- TOESLOPE (alluvial toeslope): outermost gently inclined surface at base of a slope. In profile, commonly gentle and linear and
- characterized by alluvial deposition.
- LOW LEVEL (terrace): valley floor or shoreline representing the former position of an alluvial plain, lake, or shore.
- CHANNEL WALL (bank): sloping side of a channel.
- CHANNEL BED (narrow valley bottom, gully arroyo): bed of single or braided watercourse commonly barren of vegetation and formed of modern alluvium.
- BASIN FLOOR (depression): nearly level to gently sloping, bottom surface of a basin.

Elevation – Elevation is collected in feet and is most easily collected with the GPS when updating plot coordinates.

A-Horizon Depth – A-Horizon is also known as 'topsoil', and it is the topmost layer of the mineral soil. It lies beneath the litter and duff. Depth should be recorded at a representative location near the point between the intersection of the four intensive modules.

Litter Depth – This is the top layer of non-woody organic material composed of plant parts. Litter is defined as undecomposed or only partially decomposed organic material that can be readily identified (e.g., plant leaves, twigs, etc.). Measure the litter at the same point the A-Horizon depth is recorded. Do not include the duff layer in this measurement. The duff layer is directly below the litter and is distinguished from the litter layer in that the original organic material has undergone sufficient decomposition that the source of this material (e.g., individual plant parts) can no longer be identified.

NatureServ Association- The park is divided into vegetation classes and mapped accordingly. blah blah blah. I think I will include an attachment of the nature serve key to be taken out in the field.

Photos ???- Looking through other I&M protocols revealed that most people take photographs. I think the best fit for us would be either a single photo taken at the 1-10 towards the 5-6 or two, one from both ends. CVS recommends taking a photo of the plot location sheet as an identifier. I like this idea because you don't have to worry about photo boards etc. A DECISION NEEDS TO BE MADE ON THIS AND A CAMERA POSSIBLY PURCHASED.

Tree Core Sampling

- Three to five overstory trees are cored at each plot to roughly determine stand age. Trees directly adjacent to the plot, but not on it, should be selected.
- Generally, two cores (upslope and side slope) are taken per tree. Cores are stored in plastic drinking straws and labeled with the plot number, tree number?, DBH, core number, and tree species; this information is also recorded on the coversheet under "Tree Core Information."
- Hitting pith: (1) Be sure to pull the core as it was oriented in the tree. (2) Gauge the distance to pith (e.g., 1 cm) by looking at the curvature on innermost rings of the core. (3) Insert the extractor into the hole for a guide. (4) Take a second core, but offset the auger by the distance originally estimated from pith. Keep it parallel to the extractor.
- Tree cores are often in several pieces when removed from the tree. Great care should be taken not to drop the pieces and to place them in the straw in the proper order.
- Once the entire core is in the straw, the remainder of the straw is folded over and taped onto the portion of the straw that contains the core. This is done to prevent pieces from moving around within the straw.
- Cores should be stored in a length of PVC pipe or other rigid container to avoid damage during transport and then frozen immediately upon return.
- Additional information on maintaining equipment can be found at <http://web.utk.edu/~grissino/alltips.htm>

Soil Collection

- A single pooled soil sample is gathered per plot. Subsamples are taken from modules 1, 3, 5, 7, and 9. Approximately 1 full trowel of surface (A horizon) mineral soil should be collected in the center of the module. The leaf litter and duff layers should be pulled back prior to sampling.
- All subsamples are placed in the same one-quart Ziploc bag. Typically, 0.5 to 0.75 quart of soil is collected per plot. With a permanent marker, bags should be labeled twice (ink often rubs off) with the plot number and sample date.
- Soil samples should be frozen immediately upon return from the field.

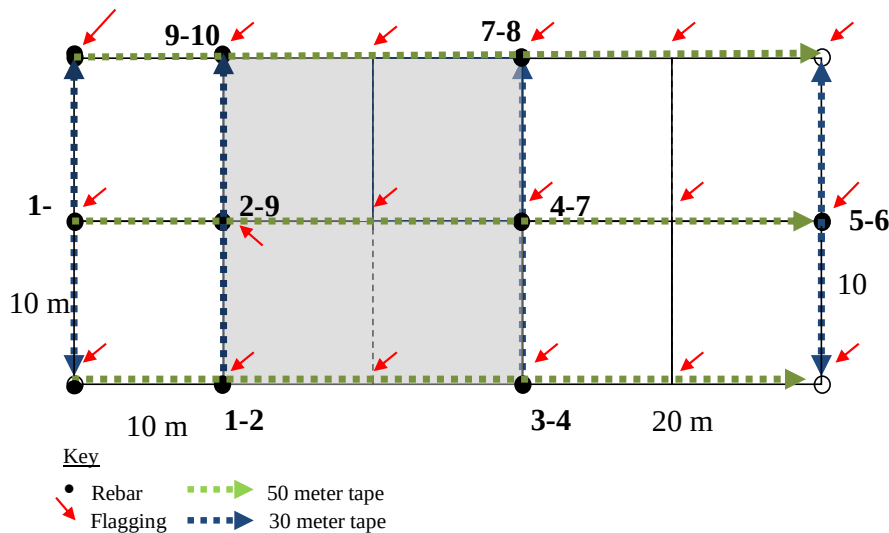
Vegetation Monitoring Protocol
Great Smoky Mountains National Park

Standard Operating Procedure # 4
Field Data Collection

Version 1.0 (Date)

Layout of Existing Plot

- Before returning to a previously established plot, review data collected on prior visits. By reviewing old data the new crew has an opportunity to rectify the mistakes of the past. Examples of common mistakes include forgotten rebar, missing tags or duplicate tag numbers or misidentified species.
- The first step in sampling a plot is to locate all the rebar and delineate the plot boundaries. When searching for rebar it is often easier to look for tag trees and/or use the overstory XY coordinates recorded on an old datasheet to locate the rebar. It is helpful to concentrate efforts on finding the 1-10 or 5-6 rebar and then shooting an azimuth to find remaining rebar as the tape is being strung out. Use visible flagging to mark the rebar and module corners (i.e. every ten meters). After locating the rebar, use a wire flag to mark them.— In plots with thick understory vegetation, an additional strip of flagging is tied to vegetation above the rebar.
- A 50 m tape is used to mark the centerline and should be run out first. The metric side of the tape should face upward. Next, lay out the 20 meter tape across the 1-10 rebar marking the end of the plot. This line is at a 90° angle from the original plot azimuth. These corners are marked with rebar for plots installed beginning in 2009. At this point if there are four people, two can lay out a tape between the 9-10 and 1-2 rebar and two can begin running the outside 50 meter lines of the plot.



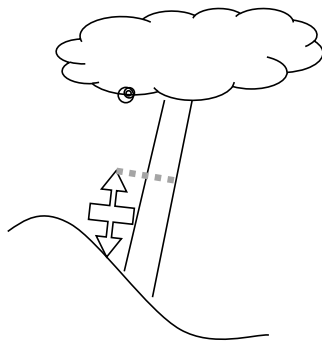
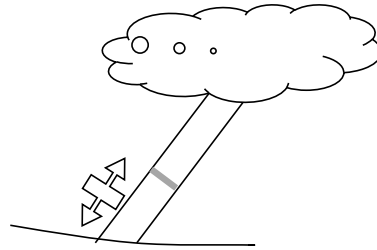
Layout of Existing Plot cont...

- While running out the tapes it is important to check the precision at the intersection between tapes. For example the outside 50 meter lines should cross the rebar at 10 meters and 30 meters. As mentioned earlier, tapes should be within + 0.5 m (or 1%) in plot length and + 0.2 (or 1%) in plot width.
- It is important to use a tape at the opposite end of the plot to determine that each corner is exactly 10 meters from the 5-6 rebar. Bearings are often skewed in the last 20 meters and there are no rebar at this end for guidance.

Overstory Sampling

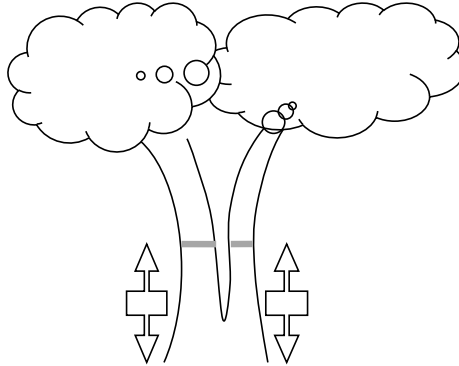
DBH

- **Dbh** - (diameter at breast height) is measured at 1.4 m (4.5 feet) above the ground surface.
- All trees ≥ 10 cm dbh are measured, tagged, mapped by coordinates, and assessed for condition and canopy position.
- When measuring dbh, always make sure that the tape is wrapped around the tree at a right angle to the lean of the tree.
- Dbh is always measured on the uphill side of the tree.

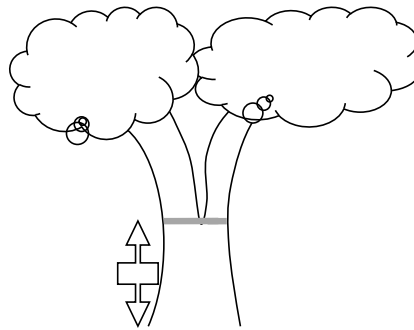


DBH Cont...

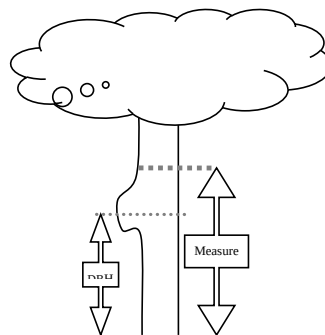
- Coppice stems that fork below dbh are measured as two stems.



- Coppice stems that fork right at dbh should be measured above the fork.



- Measure above any bulges or other deformities that occur at breast height on the tree. On the datasheet, record the height at which dbh is measured. This will be the height of future dbh measurements.



Mapping

Trees are mapped to the nearest 0.5 m using an XY coordinate system within each module.

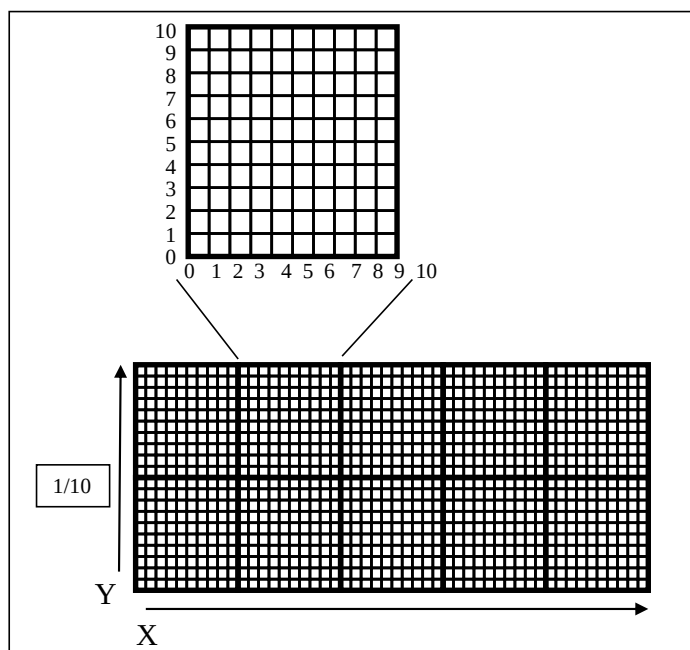


Figure 3. Coordinate system used to map overstory trees (≥ 10 cm dbh). Each module is a separate 10 X 10 grid. See Appendix D for datasheet entry of

Tagging

- Each tree is tagged at approximately 1.5 m above the ground facing the plot centerline.
- An aluminum tag and nail are used.
- The nail is angled towards the ground and driven in less than one-half its length. This allows for tree growth between surveys and prevents the tree from growing around the nail.

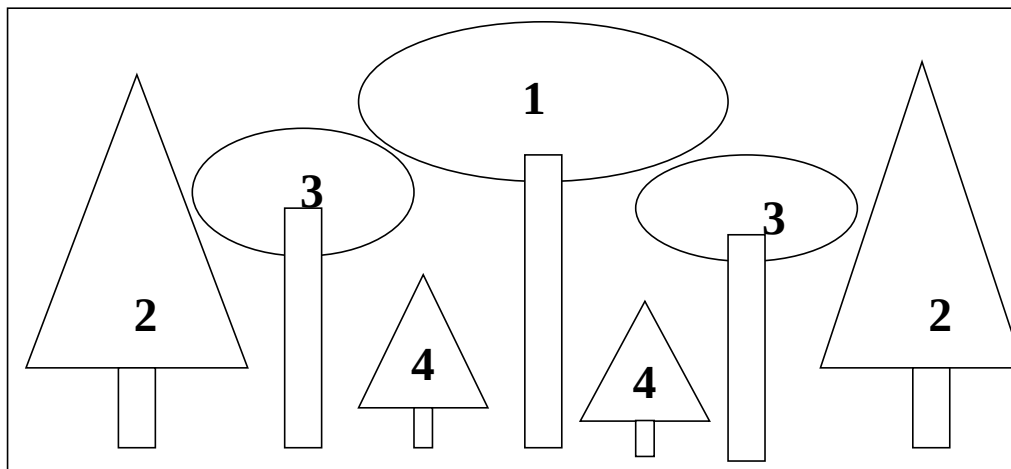
~~for dbh, tagged, mapped by coordinates, and assessed for condition and canopy position. This sampling is best done by a two person team. One person will tag, measure, and identify the species of each tree. The other will determine the coordinates of the tree (discussed below), assess its canopy position, assess its condition (crown dieback), and record all data.~~

Canopy Position and Tree Condition or Vigor and/or Damage codes

- After visual inspection, each overstory tree is assigned to one of four canopy position classes: dominant, codominant, intermediate, and suppressed. Descriptions of each class are provided in Table 1 and Figure 4.
- Dead trees are not assigned to a canopy class. This classification is based upon height and crown size, and dead trees have often lost branches in their crowns and may be broken-off snags.
- Other canopy position classifications include a separate class for open grown trees. The GRSM protocol does not include this classification since many of the Park's dominant and codominant trees were open grown prior to the suppression of fire and other disturbances. As stands have increased in stocking over the past half century, many open grown trees are now better described as dominant or codominant.
- After visual inspection, trees are assigned to one of 6 tree condition classes based upon percent crown dieback: 1 = No dieback; 2 = 1-25% dieback; 3 = 26-50% dieback; 4 = 51-75% dieback; 5 = > 75 % dieback; 6 = dead; 7 = down; 8 = missing. Dieback is defined as percent of branches in the crown that are either dead or missing. Classes 7 and 8 are used only in resampled stands to note dead trees that have fallen.

Table 1. Canopy position class descriptions. Canopy class primarily describes the amount of sunlight received.

Class	Description
1	<i>Dominant</i> —trees with crowns extending above the overall level of crown cover and receiving full sunlight from above and partly from the sides. Trees are larger than the average overstory tree in the stand and have well-developed crowns.
2	<i>Codominant</i> —trees with crowns forming the general overstory-level canopy and receiving full light from above, but comparatively little from the sides.
3	<i>Intermediate</i> —trees shorter than those of the two preceding classes, but with crowns either below or extending into the crown cover formed by dominant and codominant trees. Trees receive little light from above and none from the sides. Trees may be located in single tree gaps that have closed in from lateral growth of surrounding trees.
4	<i>Suppressed</i> —overtopped trees with crowns entirely below the general level of crown cover. Trees receive no light either from above or from the sides.



So, we discussed changing up the overstory protocol a bit below are a couple of suggestion from the CVS protocol and FMH protocol.

Vigor Codes

Vigor Code Definitions

<u>Vigor Code</u>	<u>Vigor Code Definition</u>
<u>4, excellent</u>	<u>No more than minor tissue damage to leafy material exists and a generally normal amount of foliage is present.</u>
<u>3, good</u>	<u>Minor damage to both leaf material and bark tissue exists or moderately less than a normal amount of foliage is present.</u>
<u>2, fair</u>	<u>More than minor damage to leaf material and/or bark tissue exists.</u>
<u>1, unlikely to survive year</u>	<u>Significant damage to leaf and/or bark tissue that is likely to lead to mortality or resprout.</u>
<u>0, dead</u>	<u>The entire plant appears to be dead.</u>
<u>M, missing</u>	<u>Neither the living plant nor any remains could be found.</u>

Damage Codes

Some damage codes may not be applicable to all species. For example, some species of oak are characterized by complex forking above BH, so the FORK code would not indicate damage or abnormality and would not be of use. If several types of insect damage are present, it may be desirable to distinguish among them in the comments field. After the initial data collection visit, you may find it advantageous to copy the damage codes, crown position codes and comments from the previous visit's tagged tree data sheet to the current visit's data sheet. This will encourage consistency between visits and minimizes the risk of one data collector seeing something like mistletoe one year, the next year's data collector missing it and the subsequent visit's collector seeing it again, leading to the erroneous assumption that it has actually come and gone. **Note:** Document any damage noted in past years that you could not find

- **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. Consultation with local plant pathologists may assist in identifying specific blight conditions.

- **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, dwarf mistletoes, or insects. Brooms caused by dwarf mistletoe and from yellow witches' broom disease are common in the west.
- **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.
- **DTOP** Dead top.
- **EPIC** Epicormic sprouting, adventitious shoots arising from suppressed buds on the stem; often found on trees following thinning or partial girdling.
- **EPIP** Epiphytes present.
- **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, e.g., sequoia, coast redwood. 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.
- **LICH** Lichens present.
- **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.
- **MISL** Mistletoe is visible in the tree (as opposed to signs of mistletoe, such as broom, without visible mistletoe).
- **MOSS** Moss present.
- **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.
- **TWIN** A tree that forks below BH and has two or more boles. Use this code for tree species that typically have single boles.

- **UMAN** Human-caused damage such as axe marks, embedded nails or fence wire, or vandalism.
- **WOND** A wound to a tree that cannot be identified by one of the other damage codes, including wounds or cracks of unknown cause.

Woody Stems

This section describes sampling of all woody stems ≥ 1.4 m height but < 10 cm dbh.

- Saplings are inventoried by species into four dbh classes: 0-0.99 cm, 1.0-2.49 cm, 2.5-4.99 cm, and 5.0-9.99 cm.
- Calipers are used to determine the dbh classification of a sapling. Because the break points between classes are at readily recognizable measurements (1 cm, 1 inch = 2.5 cm, 5 cm), after some practice crew members will be able to visually assign most stems to a class without using the calipers.
- To be tallied as a sapling, a woody stem must be at least 1.4 m tall (dbh height). Woody stems below this height are considered seedlings.
- Because rhododendron (*Rhododendron maximum* and *Rhododendron catawbiense*) and mountain laurel (*Kalmia latifolia*) often branch multiple times below dbh height, only branches that are individual stems branching below 0.5 m are tallied (Figure 5). This is commonly referred to as the “Rhodo Rule” and is based upon Peet et al. (1998). From experience, it is too time consuming to count all below-dbh-height branches of these two species, which frequently form almost impenetrable thickets that cover entire plots.

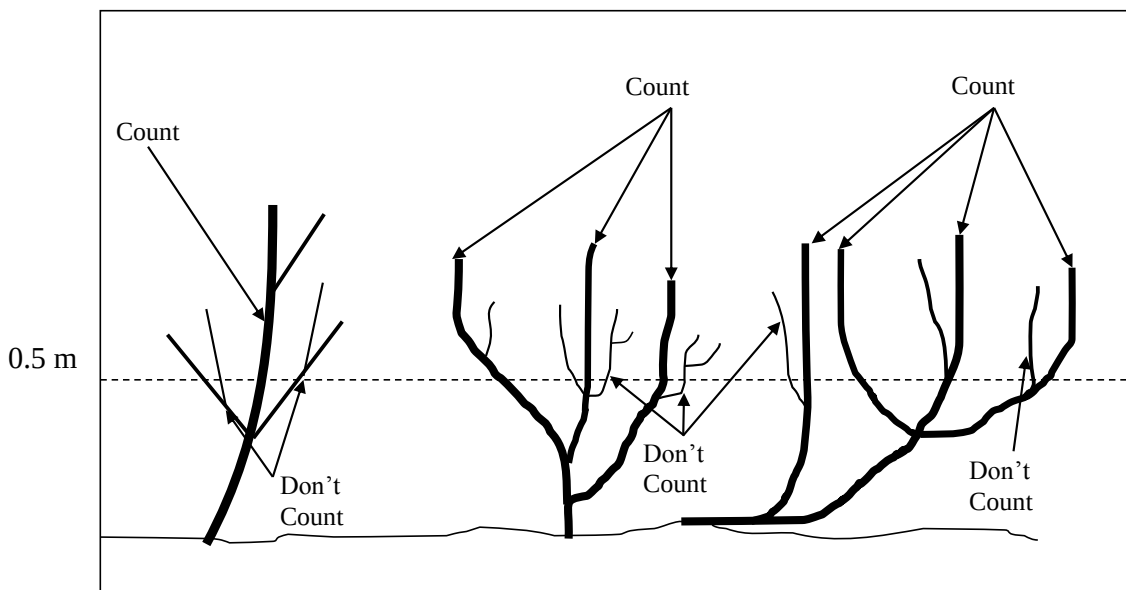


Figure 5. Examples of how the “Rhodo Rule” should be employed to tally rhododendron and mountain laurel stems. Only coppice stems that form distinct individuals should be counted; true branches should not be counted.

- When shrub cover is thick and relatively uniform across all modules, a subset of 5 modules may be selected and tallied for saplings. Examples of when a subset may be used are *Rhododendron* and *Kalmia* thickets, dense Fraser fir regeneration, and large recently-formed tree-fall gaps.
- A column has also been provided to indicate whether the species is alive or dead. A “0” is recorded for living plants and a “1” for dead. Dead saplings are tallied as a separate “species.” The entry on the datasheet should be the species code followed by a capital “D.” For example, a dead *Rhododendron maximum* stem is entered as “rhodmaxD.”
- Vine species (*Vitis* spp., *Parthenocissus quinquefolia*, etc.) will be tallied only if they are rooted within the plot. They are recorded within the module in which they are rooted.
- On the datasheet, dot notation (dot and stick) tally marks should be used to save space and allow easy data entry. This technique consists of four dots connected by 4 lines with an “X” in the middle (Figure 6).

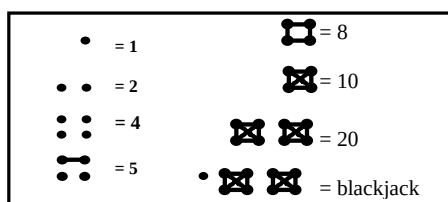


Figure 6. Example of dot notation tallies. This technique allows a large number of individuals to be tallied in a relatively small space on the datasheet.

Seedlings Density

This section describes the sampling of all woody stems < 1.4 m in height.

- Seedlings are inventoried in the four 10 m² (3.16 X 3.16 m) subplots located in the corners of the 4 intensive modules (Figure 7).
- Dead seedlings are not tallied since they are typically impossible to identify to species and decompose quickly.
- If seedlings of a given species are very numerous and relatively uniform in distribution across the subplot, a subplot is divided into quarters. Seedlings are then tallied in one randomly selected quarter. On the datasheet, the number of seedlings tallied in that quarter of the plot should be multiplied by 4 to represent the entire 10 m² subplot.
- Individual stems of all woody species are tallied. This includes woody vines, shrubs, and woody ground cover species.

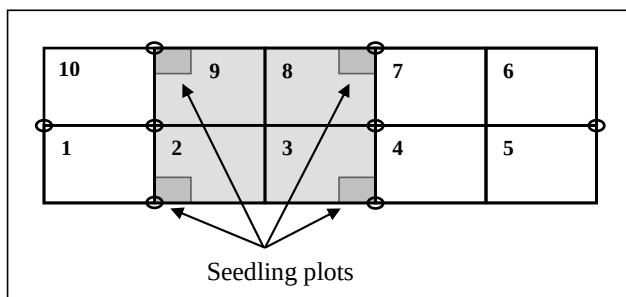


Figure 7. Location of the four 10 m² (3.16 X 3.16 m) seedling subplots within the four intensive modules (shaded).

Nested Plot Sampling

Nested plot sampling is performed to inventory all vascular plant species on the plot and determine their percent cover class in three height strata.

- While this sampling is done mostly in the four intensive modules (2, 3, 8, and 9; Figure 8), the entire plot is surveyed for species that did not occur in the intensive modules.
- Species occurrence is recorded in three nested subplots: 1 m², 10 m² (also used to tally seedlings), and the 100 m² module. On the datasheet for nested plot sampling, the first occurrence of a species is noted in the columns labeled 2-2, 3-1, 8-4, and 9-3. These labels refer to the module and module corner in which the nested plot is placed. For example 3-1 refers to corner number 1 in module 3. Corner numbers are shown in Figure 8.
- Species found in the 1 m² are given the presence value of “3” on the datasheet, species found in 10 m² are given the presence value of “2” and species found in the 100m² are given the presence value of “1”.
- Percent cover is estimated by class for each species within the 100 m² intensive module. Cover classes are shown in Table 2 and graphically illustrated in Figure 9. Cover classes are estimated for three height strata; S1 = herbaceous layer (<0.5 m height), S2 = understory (0.5-4.99 m), and S3 = overstory (≥ 5 m). These data are entered in the corresponding columns labeled S1, S2, and S3, on the nested plots datasheet. Individual plants rooted outside the plot but overhanging a module contribute to species cover.
- After all four intensive modules have been sampled, the other six modules are searched for species that didn't occur in the intensive modules. For each new species in the entire plot, the estimated cover class is entered into the columns labeled R1(herbaceous layer), R2 (sapling layer), and R3 (overstory layer).
- Unknown species should be listed on the datasheet with a unique identifier (for example, (scroph unk #1). An entire specimen is collected and placed in a Ziploc bag labeled with the plot number and date. If possible, specimens should be collected off-plot. Specimens should be collected on the plot only if there are multiple individuals on the plot and the species does not occur off-plot.

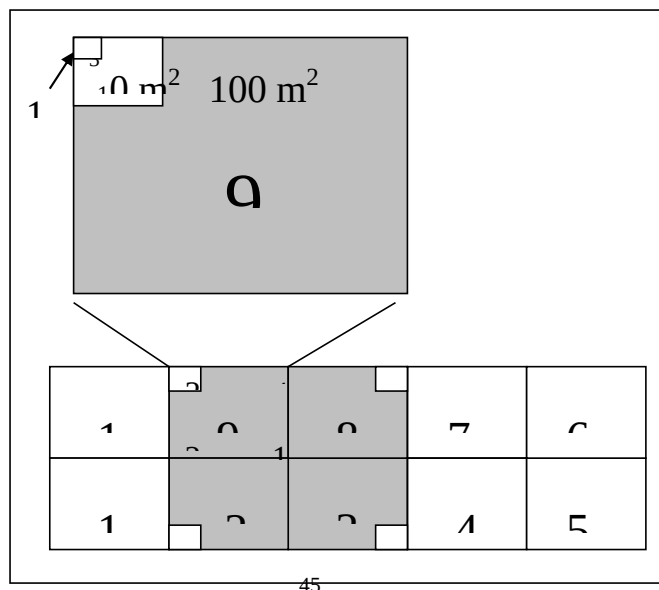
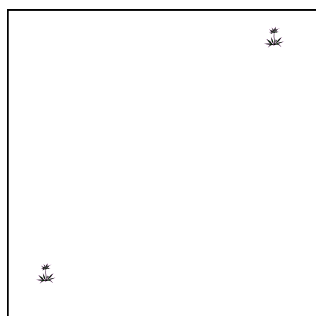
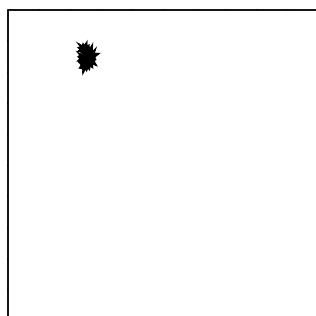


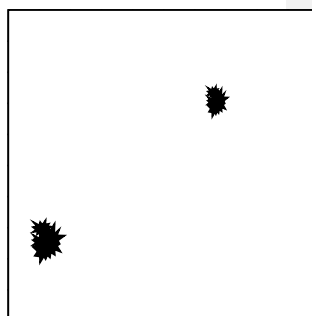
Figure 8. Location of nested subplots within the 0.1 ha long-term vegetation monitoring plot. These nested plots are



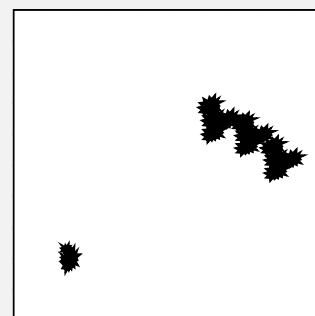
Class 1: Solitary or few



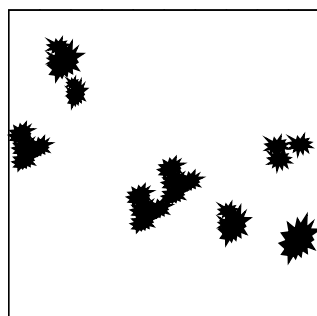
Class 2: Midpoint = 0.5%



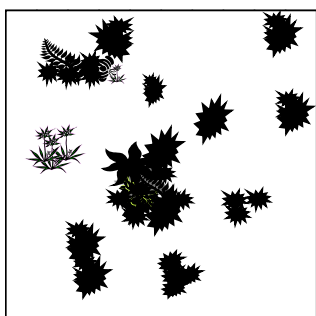
Class 3: Midpoint = 1.5%



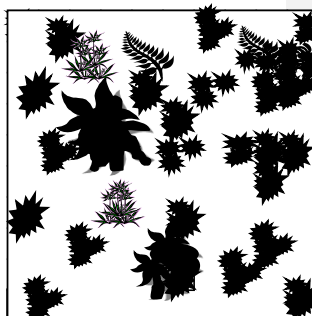
Class 4: Midpoint = 3.5%



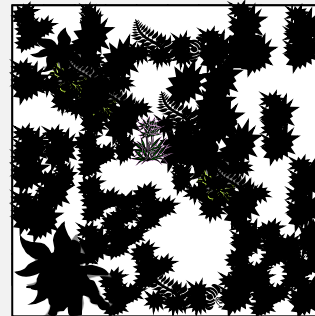
Class 5: Midpoint = 7.5%



Class 6: Midpoint = 17.5%



Class 7: Midpoint = 37.5%



Class 8: Midpoint = 62.5%



Class 9: Midpoint = 85%



Class 10: Midpoint = 97.5%

Figure 9. Graphic representation of cover class midpoints as defined by Peet et al. (1998).

Table 2. Cover-abundance scale classes used in permanent plot sampling (Peet et al. 1998).

Cover Range	Scale Value	Class Midpoint
Missing but nearby	--	--
Solitary or few individuals	1	0.3
0-1%	2	0.5
1-2%	3	1.5
2-5%	4	3.5
5-10%	5	7.5
10-25%	6	17.5
25-50%	7	37.5
50-75%	8	62.5
75-95%	9	85.0
95-100%	10	97.5

Down Deadwood

This section describes how down deadwood (logs) are sampled and mapped across the entire 0.1 ha plot.

1. All logs ≥ 10 cm in diameter are measured in all 10 modules (Figure 10).
2. Portions of logs < 10 cm diameter are not measured (Figure 10). Branches ≥ 10 cm minimum diameter are measured as separate segments. Portions of logs that fall outside of the plot boundary are not measured (Figure 10).
3. For each log, the midpoint diameter is recorded to the nearest 0.1 cm and the length is recorded to the nearest 0.1 m.
4. All logs are assigned to one of five decay stages (Table 3; Figure 11). The decay stages we use were derived from stages originally developed in the Northwest and used nationwide. However, the stages in this protocol have been adapted for use in eastern forests. For example, a class (2A) has been added to describe the bark-less case-hardened logs that are often derived from American chestnut and oak species.
5. Portions of individual logs comprised of different decay stages are measured as separate individual segments.
6. On the datasheet, data for each log are recorded by module. A log is assigned to the module that contains most of its length. Logs are measured across modules; a log is not split into two segments if it falls across a module boundary.

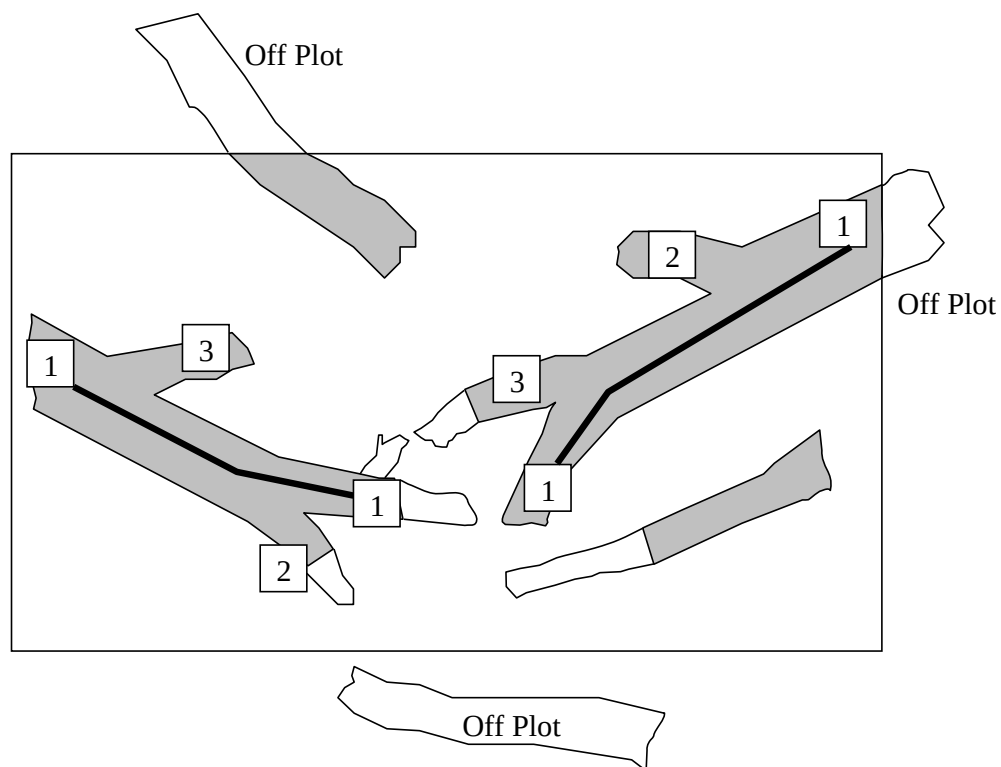


Figure 10. Measure only those parts of down deadwood that are within the 0.1 m² plot boundary and at least 10 cm in diameter. Record the length of each qualifying piece and the diameter at midpoint of its length. Measure branches ≥ 10 cm diameter as separate pieces, as shown by the numbered segments in this figure. Shaded areas represent portions of logs that should be measured.

Table 3. Characteristics of log decay stages (adapted from Pyle and Brown 1998)

Decay Stage Description
Stage 1 -bark firmly attached -exposed wood not stained by weathering -log is round -small branches present -log is resting on surface -primary surface substrate: sound bark
Stage 2 -bark not firmly attached, patchy -exposed wood may be bleached -log is round -small branches absent -wood is mostly solid -log is resting on surface -primary surface: hard wood, decayed bark
Stage 2A -surface is case-hardened, bark mostly absent -center of log often hollow (<i>Castanea</i>) -log is round -log may be partially sunk into ground -primary surface substrate: hard wood
Stage 3 -bark generally absent (except in <i>Betula</i> and <i>Prunus</i>) -log structure is solid, not brittle, firm when kicked -dry log surface flaky, appears shredded -wet log surface spongy -log partially sunk into ground -primary surface substrate: soft wood
Stage 4 -log is no longer solid, although some fairly solid segments remain -log breaks into pieces when kicked -log oval or flattened, one third or more sunk into ground -primary surface substrate: spongy or powdery wood
Stage 5 -log is flat, mostly sunken into the ground -log is soft and powdery in texture -log is often obscured by litter -primary surface substrate: loosely aggregated powdery wood

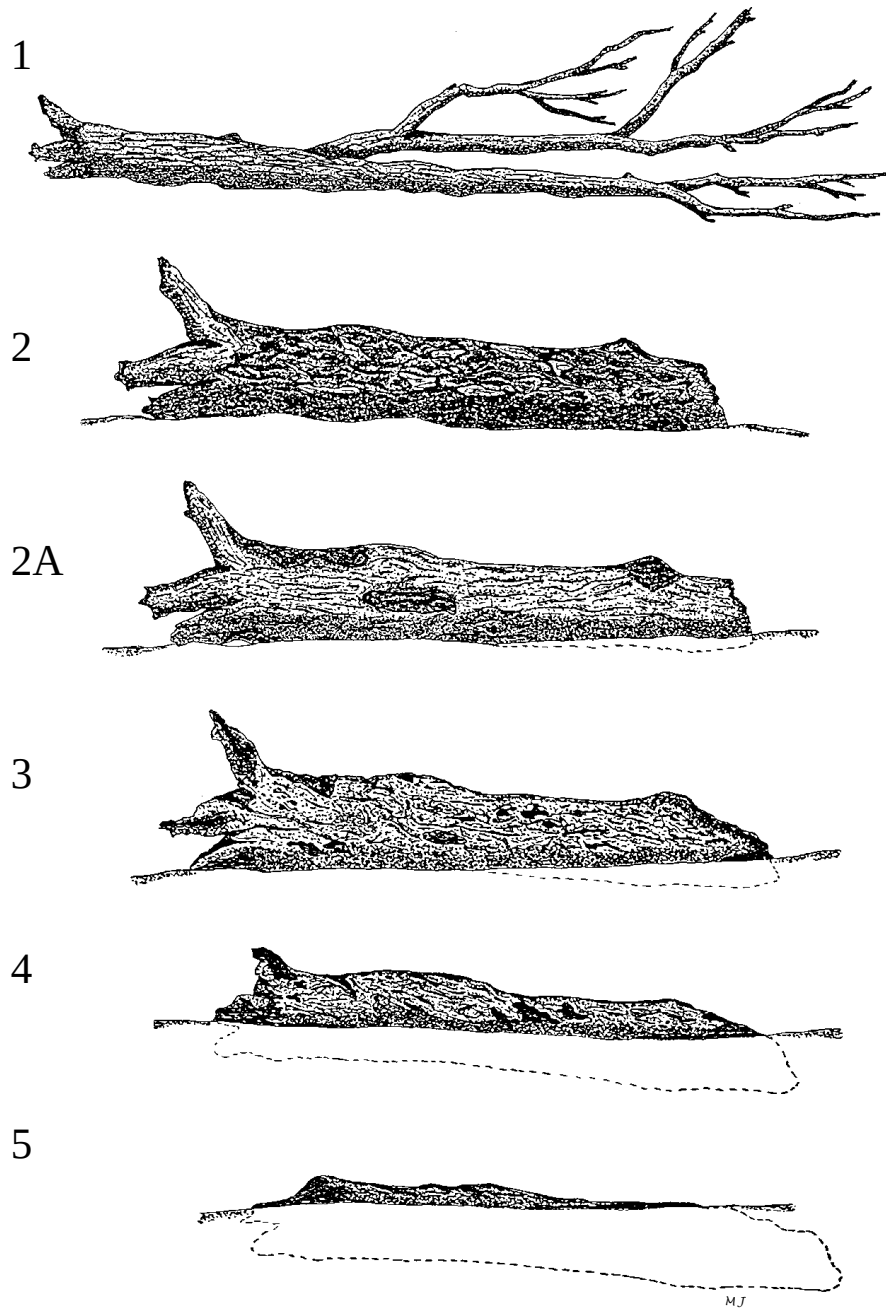


Figure 11. Decay stages of down deadwood in eastern deciduous forests. Classes are based upon Pyle and Brown (1998). Figure is adapted from Jenkins et al. (2004).

Sampling Method Modifications for Special Cases

In the SOP, the standard plot design and sampling have been described. Situations often arise for which the standard design and methodology require modification to meet a given monitoring need. Below are examples of modifications that have been made to allow specific types of vegetation monitoring.

1. Deer effects monitoring in Cades Cove: In 1997, a monitoring study was designed by the park botanist to examine the long-term impacts of deer herbivory. Five exclosures and five control plots were established at three different sites. Each plot (control and exclosure) consisted of a single 10 X 10 m module. Within this module, woody stems were inventoried by height class to better capture the impacts of deer. In addition, percent cover was estimated in six 1 X 1 m quadrats instead of throughout the entire module. In a separate study, individual *Trillium* plants and other spring ephemerals were tallied inside and outside of the exclosures.
2. Hemlock monitoring: To make long-term vegetation plots compatible with on-going hemlock monitoring, an additional effort was made to monitor hemlock foliage condition, crown density, crown dieback, and severity of adelgid infestation. These measurements followed the Forest Health Monitoring Protocol.
3. Vegetation monitoring on rock outcrops: To track overstory mortality and changes in composition resulting from drought, monitoring plots were established on rock outcrops at 4 sites in GRSM. Because these outcrops were long linear features, the plot design was a string of up to four modules instead of the standard 2 X 5 module design. The plot design that has been adapted from the CVS protocol allows this type of flexibility in unusual vegetation communities or landscape structures.

Vegetation Monitoring Protocol
Great Smoky Mountains National Park

Standard Operating Procedure # 5
Data Management

Version 1.0 (Date)

This SOP describes the structure, organization, maintenance, and management of the Vegetation Monitoring database. Database tables are described (Table 1), all fields from all data tables are defined in the data dictionary (Table 2), and interrelationships are described (Figure 1). Core tables are used to link vegetation, environmental, and sampling data. Two core tables are employed; locations and events. For each plot, the locations table (tbl_Locations) includes the USGS quad, NatureServe association, UTM coordinates, accuracy of coordinates, elevation, etc. The table tbl_Events tracks the precise day, date, and year each plot is resampled. Two tables, tbl_GIS_Info and tbl_ATBI_Species, are maintained as part of the larger park database and are described in the Park Data Management Plan.

Table 1. Description of contents of each table in the Vegetation Monitoring database.

Table Name	Description
tbl_Events	Describes sampling event.
tbl_Locations	Describes the location of plots.
tbl_Overstory_Trees	Provides information about each tree that does not change during the lifetime of the tree.
tbl_Overstory_Data	Provides information about each tree that may change at each remeasurement of the plot/tree.
tbl_Saplings	Comprised of sapling species, condition, and density data.
tbl_Seedlings	Comprised of seedling species and density data.
tbl_Nests	Comprised of occurrence and cover data for each species.
tbl_Deadwood	Comprised of data related to deadwood location, volume, and decay.

Data Dictionary

Introduction

This Data Dictionary documents the field names used in tables of Version 1.0 of the Vegetation Monitoring Database. The definitions provided in this dictionary are grouped by table and are repeated where they occur in multiple tables (see Figure 1).

Table 2. Data dictionary listing and describing all fields within each table included in the Vegetation Monitoring database.

Table	Field Name	Definition	Data Type	Range
tbl_Events				
	Location_ID	Unique plot name. All plots begin with VM. The first two numbers refer to the USGS Quadrangle number, the last two numbers are the plot number within that Quad.	Text	NA
	Event_Date	Month/day/year when plot was first established and sampled	Text	NA
	Crew_Members	Lists crew members who established and sampled each plot	Text	NA
tbl_Locations				
	Quad	Lists the name of the USGS 1:24K Quadrangle in which the map occurs	Text	NA
	Assoc.	NatureServe Association	Numeric	NA
	X_Coord	UTM Easting coordinate of the 1,10 stake	Numeric	NA
	Y_Coord	UTM Northing coordinate of the 1,10 stake	Numeric	NA
	Elevation	Elevation (meters) of the 1,10 stake	Numeric	250-2050
	County	County (Sevier, Blount, Cocke in TN and Haywood and Swain in NC) in which plot is located	Text	NA
	State	State (TN or NC) in which plot is located	Text	NA
	Coord_Units	Units for UTM coordinates (meters)	Numeric	NA
	UTM_Zone	Grid zone in which UTM coordinates for a plot occur (16S and 17S)	Text	NA
	Datum	Coordinate datum of	Text	NA

		UTM coordinates (NAD27 or NAD83)		
	Est_H_Error	Error of UTM coordinates ($\pm$ meters)	Numeric	1-100
	Accuracy Notes	Notes about the accuracy of plot locations	Text	NA
tbl_Overstory_Trees				
	Location_ID	Unique plot name. All plots begin with VM. The first two numbers refer to the USGS Quadrangle number; the last two numbers are the plot number within that Quad.	Text	NA
	Tag	Number stamped on the metal tag nailed to each tree	Numeric	1-1000
	Module	Module on plot in which tree occurs	Numeric	1-10
	X_Coord	Mapped location of a tree within a 10 X 10 m grid corresponding to each module. X axis runs with the long axis of the plot.	Numeric	0-10
	Y_Coord	Mapped location of a tree within a 10 X 10 m grid corresponding to each module. X axis runs with the short axis of the plot.	Numeric	0-10
	SpCode	Seven letter species code. Code consists of the first 4 letters of the genus name and the first 3 letters of the species name.	Text	NA
tbl_Overstory_Data				
	Location_ID	Unique plot name. All plots begin with VM. The first two numbers refer to the USGS Quadrangle number; the last two numbers are the	Text	NA

		plot number within that Quad.		
	Tag	Number stamped on the metal tag nailed to each tree	Numeric	1-1000
	Event_Date	Date when data were collected	Text	NA
	DBH	Diameter at breast height of each tree (cm)	Numeric	10-400
	CanPos	Canopy position class of each tree	Numeric	1-4
	TreeCond	Tree condition class of each tree	Numeric	1-8
	Notes	Information about individual trees	Text	NA
tbl_Saplings				
	Location_ID	Unique plot name. All plots begin with VM. The first two numbers refer to the USGS Quadrangle number; the last two numbers are the plot number within that Quad.	Text	NA
	Event_Date	Date when data were collected	Text	NA
	Module	Module on plot in which saplings were tallied	Numeric	1-10
	SpCode	Seven letter species code. Code consists of the first 4 letters of the genus name and the first 3 letters of the species name.	Text	NA
	DClass1	Density of saplings 0-0.99 cm dbh within a module	Numeric	1-500
	DClass2	Density of saplings 1.0-2.49 cm dbh within a module	Numeric	1-500
	DClass3	Density of saplings 2.5-4.99 cm dbh within a module	Numeric	1-500
	DClass4	Density of saplings 5.0-9.99 cm dbh within a module	Numeric	1-500

	Condition	Condition for saplings represented by a line of data. Conditions are 0 (alive) and 1 (dead).	Numeric	0 or 1
tbl_Seedlings				
	Location_ID	Unique plot name. All plots begin with VM. The first two numbers refer to the USGS Quadrangle number; the last two numbers are the plot number within that Quad.	Text	NA
	Event_Date	Date when data were collected	Text	NA
	Module	Module on plot in which seedlings were tallied	Numeric	1-10
	SpCode	Seven letter species code. Code consists of the first 4 letters of the genus name and the first 3 letters of the species name.	Text	NA
	Density	Number of seedlings that occur within the subplot located within each module	Numeric	1-1000
tbl_Nests				
	Location_ID	Unique plot name. All plots begin with VM. The first two numbers refer to the USGS Quadrangle number; the last two numbers are the plot number within that Quad.	Text	NA
	Event_Date	Date when data were collected	Text	NA
	SpCode	Seven letter species code. Code consists of the first 4 letters of the genus name and the first 3 letters of the species name.	Text	NA
	Module	Module on plot in which species cover was	Numeric	1-10

		determined.		
	Nests	Subplot within module where each species was first observed	Numeric	1-3
	CoverS1	Cover class of a species in height stratum 0-0.49 m	Numeric	1-10
	CoverS2	Cover class of a species in height stratum 0.5-4.9 m	Numeric	1-10
	CoverS3	Cover class of a species in height stratum ≥ 5 m	Numeric	1-10
tbl_Deadwood				
	Location_ID	Unique plot name. All plots begin with VM. The first two numbers refer to the USGS Quadrangle number; the last two numbers are the plot number within that Quad.	Text	NA
	Event_Date	Date when data were collected	Text	NA
	Module	Module on plot in which deadwood was tallied	Numeric	1-10
	Decay	Decay class of each log	Text	NA
	MPD	Midpoint diameter (cm) of each log	Numeric	10-300 cm.
	Length	Length of each log (meters)	Numeric	0.1-54 m.
tbl_PlantSpecies				
	Genus	Plant genus	Text	NA
	Subgenus	Plant subgenus	Text	NA
	Species	Plant species	Text	NA
	SpeciesCode	Six letter code used in VegMon program	Text	NA
	Author	Author of scientific name	Text	NA
	TSN	Taxonomic serial number	Text	NA
	Sensitivity	Release restrictions of voucher or observation record: 0 = access restricted to park botanist; 1 = restricted to staff specified in Park	Numeric	0-3

		Code; 2 = restricted to NPS staff; 3 = no access restriction		
	ValidGenus	Genus name used by GRSM	Text	NA
	ValidSubgenus	Subgenus name used by GRSM	Text	NA
	ValidSpecies	Species name used by GRSM	Text	NA
	ValidSubspecies	Subspecies name used by GRSM	Text	NA
	CommonName	Non Latin/scientific name used for species	Text	NA
	SpeciesNotes	Additional information about the species	Text	NA

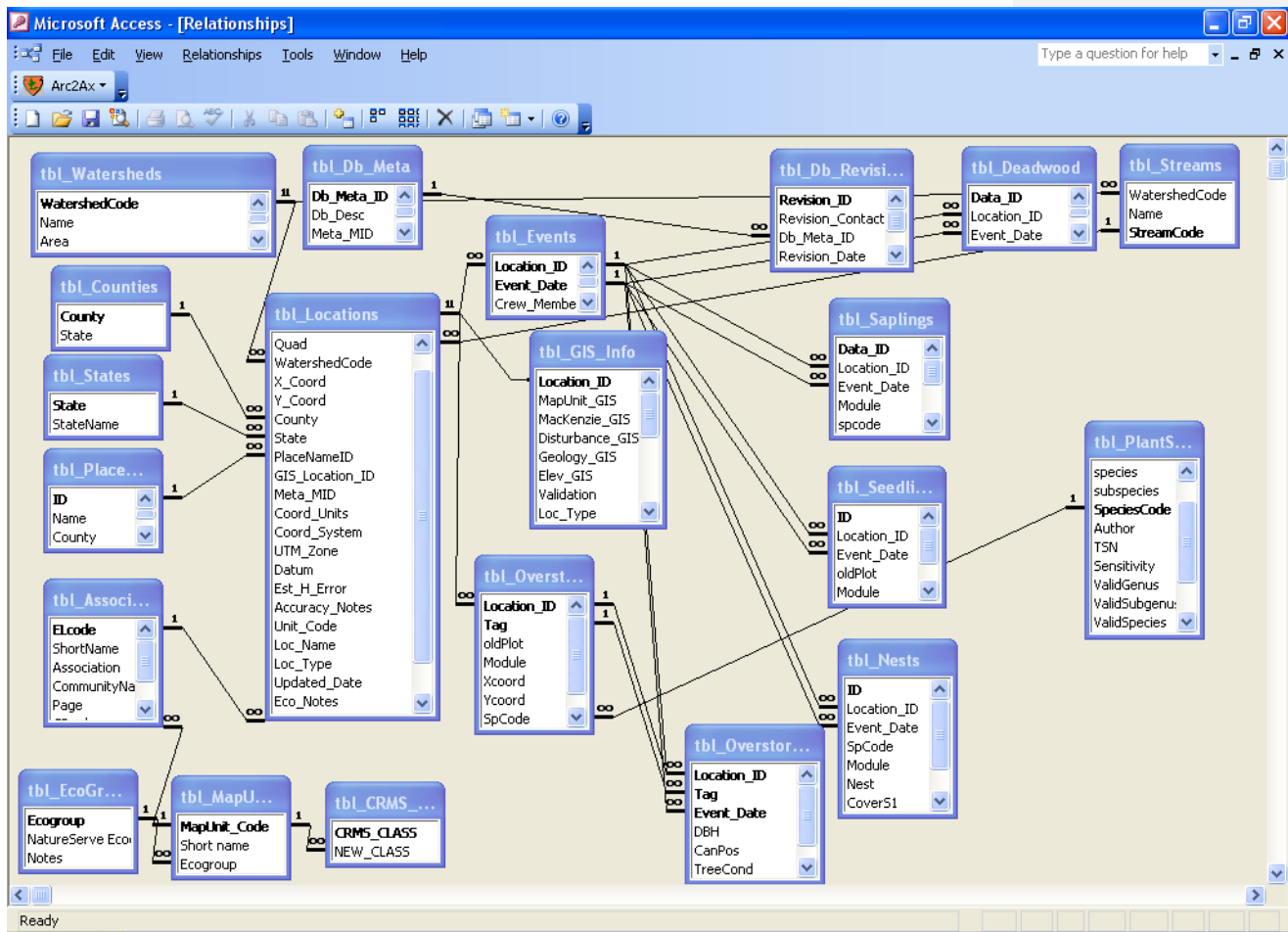


Figure 1. Schema showing relationships within the Vegetation Monitoring Database.

Workspace Setup and Project Records Management

The most up-to-date version of the Vegetation Monitoring Database is stored on the V drive. The most recent version will have the most recent date as part of its filename (e.g., Vegetation_Monitoring_October_17_2007).

Field Datasheet Handling Procedures

To avoid confusion over which version of field datasheets are the most recent, the MS Word document comprising the datasheets includes the date the datasheets were created. In addition, this document is stored in a subdirectory named “Datasheets_Current_Version.”

Before the field crew leaves a plot, the crew leader will inspect the datasheets for completeness and clarity. All lines should be filled in properly, and all data components (overstory, saplings, seedlings, etc.) should have a completed datasheet. Datasheets are stored in a file cabinet located in the Twin Creeks Science and Education Center. Datasheets are organized into folders based upon Quad Number and year of sampling.

GPS Setup and Usage Procedures

The setup and use of GPS units are discussed in SOP # 1 “Preparations and Equipment Setup Prior to the Field Season.”

Photo/Image Management

All digital images will be downloaded and labeled with a title that describes the subject of the photo. All image file names will be connected by underscores (i.e., fieldwork_vegmon_CWD). All images of sufficient quality for long-term archiving will be stored on the GRSM server (U drive).

Data Entry

Accurate data entry is a critical step in the development of a functional and accurate monitoring database. Because data entry is best performed by someone familiar with how data are collected in the field, days are set aside periodically during the field season for data entry. Inevitably, transcribing data from paper sheets into a digital format introduces error. This discussion describes how this transcription should be done to minimize error. Data entry forms and QA/QC features have been developed to minimize errors. When possible, pick list and value limits are employed. Look-up tables contain project specific data and prohibit entry of data into a field if a corresponding value is not included in the look-up table. This ensures that only valid entries are made and eliminates spelling and typographical errors.

Data Verification and Validation

Since considerable effort and expense are devoted to collecting long-term vegetation data, the high quality of these data must be assured. To maintain data accuracy, the following procedures are implemented:

1. Data are checked at all stages of collection and entry for obvious errors. In the field, datasheets will be inspected for completeness, readability, and accuracy. The crew leader confirms that all sheets have been filled in completely and species codes and other entries are correct. The crew leader is responsible for collecting and safeguarding datasheets until they are properly stored in the office.
2. After data transcription from field data sheets, GRSM Vegetation Monitoring staff verifies 100% of the records for accuracy. This is accomplished by checking entered values against field datasheets after data from each sheet is completely entered. In addition, the program manager/ecologist reviews 10% of all records for accuracy. If errors are found, additional checking of data from the same data entry date is performed.
3. Once computerized data are confirmed to accurately represent the original field data, the paper forms are archived and the electronic version is used for all subsequent data activities.
4. All electronic data are reviewed for range and logical errors. While data may have been correctly entered from field data forms, they may not be accurate or biologically logical. For example, living trees that decrease in diameter in subsequent sampling or understory species with large diameters represent logical and range errors. Many of these errors are avoided with data range limits built into data entry forms. Whenever possible, data entry forms have been limited to valid entries stored in the look-up tables. Species codes and other text/categorical fields are checked for compatibility within the appropriate table (i.e., table_SpCode).
5. After verification is complete, the program manager/ecologist validates the data. The program manager will schedule sufficient time with the data manager to accomplish this task. Validation identifies generic errors (such as missing, mismatched, or duplicate records) as well as errors specific to a given project, stratum, or community type. The ecologist also determines that data from all plots within a stratum were entered and that taxonomy is consistent between resamples.
6. The program manager/ecologist insures consistency between field forms and the database by noting how and why changes to the data were made on the original forms. Changes to the field data forms are made by marginal notes; original data entries are not erased.
7. Once data validation is complete, the dataset is given to the data manager for archiving and storage.

Data Archival Procedures

Changes to current datasets are frequently required as a result of additional data collection, changes in species nomenclature, and numerous other factors. When updating datasets, it is critical to maintain data integrity, document all changes, and insure that all mistakes made during editing are traceable and correctable. An edit log is maintained, and all editing should be done cooperatively between the program manager and the data manager. Each log entry should

include pre- and post-edit data descriptions. Table 3 provides an example of an edit log with a completed entry.

Table 3. Example of an edit log with a completed entry.

Edit Log			
Project: Vegetation Monitoring			
Date	Edited by	Reason for edit	Notes
07/01/2008	J. Heller	Addition of data from 2008 field season.	Data entered for 16 plots resampled in Quad # 08.

After a dataset is validated, a copy is archived with an appropriate version number to allow tracking of changes over time. With proper access control and tracking, versioning insures that the most current version is used in new analyses. Beginning with version 1.0, a sequentially higher integer (2.0) is assigned to each major revision and a sequentially higher decimal (1.1) is assigned to each minor revision. The original field data forms are never changed based upon an editing of archived data. Field forms are compared to the database through entries in an edit log.

Secure data archiving is critical for protecting data files from corruption and maintaining the continuity of long-term datasets. Metadata serve an essential role in maintaining continuity by documenting the history and contents of a dataset. After a dataset has passed the QA/QC procedures documented in this protocol, a new metadata record is created. In addition, a read-only version of the electronic dataset is created and stored on the GRSM I&M server. Backup copies of all data are maintained at GRSM, and an additional digital copy is forwarded to the NPS Inventory and Monitoring Archive.

Data Preparation

Before analysis can begin, field data must be summarized for statistical comparison. Data summaries are accomplished within the database through predefined queries. This summarization includes simple calculations of density, volume, and basal area, as well as importance values (relative basal area + relative density) and diversity indices. Generally, all measures of abundance, volume, and basal area are calculated on a per hectare basis. Equations used in data preparation are provided in Appendix A. This section provides a summary of how major data types should be summarized.

Overstory Data

Basal area/ha, density/ha, relative density, relative basal area, and importance value are calculated by species for living overstory trees on each plot. Basal area and density/ha are calculated for all standing dead trees. Overstory species richness (S), evenness (E), and Shannon-Weiner diversity (H') are also calculated for each plot.

Down Deadwood Data

The volume of individual logs is calculated using the formula for the volume of a cylinder (Appendix A). While this formula does not allow for the taper of logs, it requires only two in-field measurements and is widely used to quantify coarse woody debris (Jenkins et al. 2004). Summed volume/ha is determined for each plot by decay stage. Additional volumes are calculated by diameter class or by other criteria as needed.

Woody Understory Data

Density/ha and relative density of saplings (stems ≥ 1.4 m height but < 10 cm dbh) are calculated by species for each of the four size classes (0-0.99 cm, 1.0-2.49 cm, 2.5-4.99 cm, and 5.0-9.99 cm) on each plot. Density/ha and relative density of seedlings (woody stems < 1.4 m height) are calculated by species for each plot. S, E, and H' will also be calculated for saplings and seedlings on each plot.

Herbaceous Data

Midpoints of percent cover classes of individual herbaceous species are determined for each plot and will be used to calculate S, E, and H' for each plot (midpoints are given on page 13).

Bryophyte and Lichen Data

Percent cover of bryophytes and lichens is determined for each plot.

Potential Analyses

Due to the complexity of long-term vegetation data, analysis techniques vary with the type of data being analyzed and the question that the analysis is intended to address. For example, repeated measures one-way analysis of variance (ANOVA) is used to test differences between samples classified by one criterion. For example, this analysis could be used to examine changes in *Tsuga canadensis* importance value from a series of plots established in acid cove forests and sampled every 5 years for 15 years. If managers wanted to examine changes through time across multiple forest types, a two-way ANOVA would be appropriate. In this analysis, forest type would be one factor and sample year or time would be the second (repeated) factor. Regression analysis also offers a powerful technique to assess relationships between two variables, or between a single dependent variable and several independent variables. For example, the GRSM Vegetation Monitoring Program has used multiple linear regression to examine how the density of *Cornus florida* (dependent variable) has changed in response to elevation, soil cation availability, and stand basal area (independent variables).

Regardless of analysis techniques, initial tests should be performed to determine if data meet assumptions of normality and equal inter-group variance. Where these assumptions are sufficiently violated, data may be transformed or a nonparametric procedure may be used. Zar (1998) is an excellent reference for the use of univariate statistics with biological data.

Due to the complexity of data representing biotic communities, it is often desirable to analyze change across an entire community or groups of communities in relation to environmental

factors. In these types of analyses, it is necessary to track changes in multiple species across multiple plots at two or more points in time. Multivariate statistical techniques are typically used in these situations. Although computationally complex, ordination techniques, such as Canonical Correspondence Analysis (CCA) and nonmetric multidimensional scaling (NMS, if data do not meet assumptions of normality), allow the graphic depiction of environmental and temporal gradients underlying the distribution of plant communities. McCune et al. (2002) is an excellent reference for the use of multivariate statistics (including ordination techniques) in the analysis of ecological data.

APPENDIX A
FORMULAS AND EQUATIONS

General sample size formula (Cochran 1977)

$$n = \frac{CV^2 t^2}{AE^2}$$

where:

n = the number of samples required to estimate the population mean within an allowable error of AE, apart from a α chance of failing to meet the specified allowable error. Computed values of n should be rounded up to the next larger integer.

CV = estimated population CV where CV = standard deviation/mean expressed as a percent.

t = Student's t statistic for a specified α and n-1 degrees of freedom. For the typical two-tailed test, the appropriate values are $\alpha/2$ in the t-table.

AE = allowable error expressed as a percent of the mean.

$$\text{Relative Density} = \frac{\text{density of a species}}{\text{total plot density}} \times 100$$

$$\text{Relative Basal Area} = \frac{\text{basal area of a species}}{\text{total plot basal area}} \times 100$$

$$\text{Importance Value} = \frac{\text{relative density} + \text{relative basal area}}{2} \times 100$$

Species richness (S) = # of species per plot

$$\text{Shannon-Weiner diversity (H')} = \sum_{i=1}^S p_i (\log p_i)$$

where: p_i = proportional abundance of the i^{th} species.

$$\text{Evenness (E)} = H' / \ln S$$

$$\text{Volume of a cylinder (down deadwood volume)} = \pi r^2(h)$$

APPENDIX B

DESCRIPTION OF STRATIFICATION

SELECTION OF PERMANENT VEGETATION SAMPLES WITHIN GREAT SMOKY MOUNTAINS NATIONAL PARK

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Introduction

We stratified the park's environmental variation using the 45 environmental zip codes developed by Dean Urban, Julia Kintsch, and Peter White in a previous project. This stratification uses 3 factors: elevation (5 levels), hillshade (3 levels), and topographic convergence index (3 levels).

Sampling Design

The plots design to be employed in this study is adapted from the protocol of the North Carolina Vegetation Survey (Peet et al. 1998). Plots are 10 ares and consist of 10, 10m x 10m modules arranged in a 20m x 50m rectangle. Some plots may be larger or smaller (e.g., 1 are to 1 hectare in size), but the site selection algorithm assumes that the 50 x 20 m plot size is standard. That is, for purposes of non-overlap among plots in a cluster and for finding areas that were large enough that the plot had a single zip code, the 50 x 20 m plot size was assumed.

The sampling protocol used to select plots followed a stratified clustered design. This design consists of a number of clusters each containing multiple plots. The distance between plots within a cluster is always smaller than the distance among plots of two different clusters.

The maximum distance between any two plots within a cluster and the minimum distance among any two plots clusters between clusters was 500m. This threshold was set so that plots could be oriented in any direction, even line up in a row, and still not overlap. Specifically the maximum distance within a clusters D is calculated as:

$$D = 2 * L * (2 * N_c - 1) \quad (\text{Eq 1.}),$$

where L is the length of the longest size of a plot (50m), and N_c is the number of plots per cluster (3).

To stratify the sample by zipcode, each plot within a cluster has a unique zipcode. Further, every zipcode is present in at least 2 clusters. Thus, the design is stratified, not only by zipcode, but also by geography (the plots of the same zip code are constrained to be at least 500 m apart). The advantage of this design is that it controls for effects due purely to geographic proximity, and allows both small and large extent analyses.

Building the Model

Limiting the plot population

We began model construction by limiting the number of possible locations for plots. Not every location within the park was desirable as a plot location, nor even possible. We limited the population of possible plots using three criteria: 1) accessibility, 2) those areas large enough to contain a plot of a single zip code at the 10 are, and 3) areas containing 3 unique zip codes within the maximum diameter of a cluster (500 m).

First, the population of possible plots was limited to those areas within a certain threshold of accessibility. Accessibility was calculated following Jobe (unpublished) using the least-cost path to each cell from a given access point based on Euclidean distance, the human physiology

of slope walking, and difficulty of stream crossing. For this analysis stream crossings were considered impossible save on a trail, and trails were considered 10 times more traversable than off-trail areas. The resulting accessibility coverage was categorized into 10 quantiles. Thus, we could choose proportions of most accessible cells in multiples of 10% to use as possible plot locations (Figure 1). Models used in this analysis consisted of the 80%, 50%, of 20% most accessible cells and will be more fully described below.

Second, it was desirable that each selected plot contain only a single zip code. To accomplish this, we further limited the population of plots to contiguous areas of identical zip code greater than or equal to the area of a single plot. It should be noted, that this limitation was based on area, not shape. It was possible that some areas, though their overall area was greater than 1000m², had large perimeter to area ratio such that a 20m x 50m plot simply would not fit. We judged the effects of this type of error to be small relative to the difficulty of correcting it.

Next, since the sampling design consisted of 3 plots per cluster each from a unique zipcode, we needed to guarantee that each cluster within the population of all possible clusters contained at least 3 unique zipcodes. To accomplish this, we created a separate population of cluster centers, or the first plot to be selected in a cluster. This population consisted only of cells that, within a 1000m radius around them, captured at least 3 unique zipcodes area large enough to hold a plot. By selecting the first plot in a cluster from this population, we were able to guarantee that at least 2 other suitable plot locations were available within the 500m maximum extent of a cluster.

Sample Selection

Once the population of plot locations and the smaller population of cluster centers were created, we selected sample locations from them. First, a cluster center of a specified zipcode was randomly chosen from the population of cluster centers. The zipcode of this cluster center depended on the current cluster number and the abundance of the zipcode.

Not all zip codes had equal abundance, and, therefore, random samples of the entire plot population would have to be very large to capture all the zip codes. To allow a sample to capture rare zipcodes with a small number of clusters, we created a list of zip codes ordered by their abundance in the population of cluster centers. We then chose cluster centers beginning with the least abundant zipcode and ending with the most abundance zipcode.

By forcing the first plot to be a specific zipcode, we could control the minimum of replicates per zipcode. For instance, since there are 45 total zip codes, if the number of clusters sampled was set to be 90, then every zip code would be guaranteed 2 replicates regardless of its abundance. If the number of clusters were 70 then 2 replicates of each zipcode was still very likely, since the least abundant zipcodes were selected as cluster centers first, and more abundant zipcodes were likely to be selected in plots other than center plots.

After a center plot was selected, a buffer of radius 500m / 2 was created around it. This buffer guaranteed that all future plots were within the maximum extent of a cluster. All cells that had zipcodes equal to that of the center plot were removed. A random cell was selected from those remaining. This cell became the origin of the second plot. As with the center plot, all cells whose zipcode equaled the second plot were removed. The third and final plot was randomly selected from the remaining cells. This process was repeated over all clusters.

The output consists of a point coverage, each point having the following attributes: 1) Unique plot ID, 2) X, Y location, 3) Cluster Number, 4) Plot Number (within cluster), and 5) Zip code.

A set of samples varying accessibility, access point, and sample size

Multiple samples were chosen varying three factors that were important to the Park in site selection. These factors were: 1) relative accessibility, access point, and number of plots. Relative accessibility refers to the proportion of most accessible cells that were used to create the population of plot locations. The three levels were 80%, 50%, and 20%. For example, this means that, for the first level, plot locations were chosen from the cells that comprised the top 80% of the cells ranked by accessibility. The second factor, access point, deals with the manner in which researchers will arrive at the plot. The two access points used were access from trailheads and from trails themselves. Access from trailheads might be more realistic for researchers who use day trips to access their plots, while access from trails would be more suitable for researchers camping overnight in the park. The final and most important variable was sample size. Three levels of sample sizes were used: 45 clusters, 70 clusters and 90 clusters. At 3 plots per cluster, these levels equal 135 plots, 210 plots, and 270 plots respectively (additional scenarios with more plots can also be produced by our method). At the 45 cluster level, every zipcode is guaranteed to occur in at least 1 plot, while at 90 clusters every zipcode is guaranteed to occur in at least 2 plots.

Each of the factors varied across models were given an integer identifier. Thus each model had a unique 3 digit identifier. A worksheet in “hemlock representation.xls” summarizes these identifiers. Every output coverage conforms to this naming convention.

Special study on hemlock

I subset each of the created models to plots located in communities where hemlock is abundant. I created a table showing the frequency of zipcodes for hemlock as a whole and then within each model. The results are available in “hemlock representation.xls”

APPENDIX C

EXAMPLE OF SPECIES CODES

SPECIES	NEWCODE	EXOTIC
ACER LEUCODERME	ACERLEU	
ACER NEGUNDO	ACERNEG	
ACER PENSYLVANICUM PENSYLVANICUM	ACERPEN	
ACER PLANTANOIDES	ACERPLA	1
ACER RUBRUM	ACERRUB	
ACER SACCHARUM	ACERSAC	
ACER SPICATUM	ACERSPI	
ACER RUBRUM VAR. TRILOBUM	ACERRUBT	
AESCULUS OCTANDRA	AESCOCT	
IMPATIENS CAPENSIS	IMPACAP	
IMPATIENS OLIVERI	IMPAOLI	1
IMPATIENS PALLIDA	IMPAPAL	
CEANOTHUS AMERICANUS	CEANAME	
RHAMNUS CAROLINIANA	RHAMCAR	
AMPELOPSIS CORDATA	AMPECOR	
PARTHENOCISSUS QUINQUEFOLIA	PARTQUI	
VITIS AESTIVALIS	VITIAES	
VITIS BAILEYANA	VITIBAI	
VITIS CINEREA	VITICIN	
VITIS LABRUSCA	VITILAB	
VITIS ROTUNDIFOLIA	VITIROT	
VITIS VULPINA	VITIVUL	
TILIA HETEROPHYLLA	TILIHET	
HIBISCUS MOSCHEUTOS	HIBIMOS	
HIBISCUS SYRIACUS	HIBISYR	1
MALVA NEGLECTA	MALVNEG	1
MALVA SYLVESTRIS	MALVSYL	1
SIDA SPINOSA	SIDASPI	1
STEWARTIA OVATA	STEWOVA	

APPENDIX D
EXAMPLE OF DATASHEETS

VEGETATION MONITORING

Plot _____ Date _____ Crew _____

Location Description

M 1/10 Witness Tree # 1 Species _____ DBH _____
Azimuth _____ Distance to stake _____

M 1/10 Witness Tree # 2 Species _____ DBH _____
Azimuth _____ Distance to stake _____

M 5/6 Witness Tree # 1 Species _____ DBH _____
Azimuth _____ Distance to stake _____

M 5/6 Witness Tree # 2 Species _____ DBH _____
Azimuth _____ Distance to stake _____

Trailhead, directions from trail, other identifying site features:

Site Description

Slope (%) _____ Aspect _____ Slope shape _____ Topographic position _____
Elevation _____ A-Horizon depth _____ Litter depth _____

Disturbance

Agriculture/grazing _____
Logging _____
Fire _____
Pine beetle _____
Windstorm _____
Hogs _____
Other _____

Tree Core Information:

Additional Disturbance Notes and Other Comments:

[illegible]

NESTED PLOT PRESENCE AND COVER

Record cover in 10 X 10 module at depth where species first occurs. See plot diagram for module/corner layout.

Cover classes: Missing but nearby =; Solitary or few = 1; 0-1% = 2; 1-2% = 3; 2-5% = 4; 5-10% = 5; 10-25% = 6; 25-50% = 7; 50-75% = 8; 75-90% = 9; 95-100% = 10. Column #'s = module - corner #'s; S1= stratum 1, S2 = stratum 2, S3 = stratum 3; R = rest of plot (6 non-intensive modules, strata 1-3).

[illegible]

Arrangement of nested plots

10	3 9 2	4 8 1	7	6

Plot _____ Page _____ of _____

Column #'s on NESTED PLOT PRESENCE AND COVER datasheet refer to module and corner #'s. For example, 2 2 refers to module 2, corner 2.

Nests: 1 X 1 m
3.2 X 3.2 m
10 X 10 m

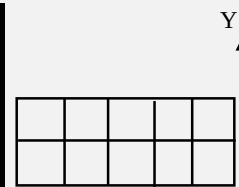
Plot _____ Page _____ of _____

SEEDLING DENSITY SAMPLING (3.2 X 3.2 m) Woody vegetation < 1.4 m height.

[illegible]

Plot _____ Page _____ of _____

OVERSTORY SAMPLING

[illegible]

X

Canopy Position (CP)

- 1 = dominant
2 = codominant
3 = intermediate
4 = suppressed

Tree Condition (TC)

- 1 = No dieback
2 = 0-25% dieback
3 = 26-50% dieback
4 = 51-75% dieback
5 = > 75 % dieback
6 = dead
7 = down
8 = missing

T# = tree number

WOODY STEMS ≥ 1.4 HEIGHT, < 10 CM DBH DENSITY

[illegible]

Plot _____
Page _____ of _____

DOWN DEADWOOD

[illegible]