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Standard Guide for Sampling Terrestrial and Wetlands Vegetation[1]

This standard is issued under the fixed designation E 1923; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers environmental studies such as risk assessments, planning projects, or research typically including characterization of ecological resources. Compliance with federal statutes (for example, National Environmental Policy Act 1970, (NEPA); Comprehensive Environmental Response, Compensation and Liability Act 1981, (CERCLA: with its Remedial Investigation/Feasibility (RI/FS) and Natural Resource Damage Assessment (NRDA) components); Resource Conservation Recovery Act (RCRA), and Federal Insecticide, Fungicide, and Rodenticide Act, (FIFRA)) as well as state regulations addressing projects such as hazardous waste site assessments and environmental impact analysis often requires characterization of vegetation. This guide presents a framework for selection of terrestrial vegetation sampling methods based on project-specific objectives. Method-specific practices are associated with this basic guide as annexes.

1.2 As with any data gathering activity, the value of information is affected by the strategy and sampling design. Determining the number of sample points, temporal and spatial location of sample points, relationships among sampling points, and the correspondence of other sampling activities are important considerations. Strengths and limitations of various methods are described in general terms in this guide. However, the key issues linked to data quality relate to the specific question being addressed and the adequacy of the field sampling plan.

1.3 The values stated in SI units are to be regarded as the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 No related ASTM standards on field sampling are available.

2.2 This guide is intended only as a framework for vegetation sampling, not as an in-depth discussion of methodology. Greig-Smith **(1)**[2] provided a detailed theoretical treatment of vegetation sampling. Other excellent treatments of vegetation sampling, typically with fewer theoretical considerations, are also available. The user of this guide is referred to general literature on field sampling methods and designs **(2-8)**.

3. Terminology

3.1 The words "must," "should,"" may," "can," and "might" have specific meanings in this guide. "Must" is used to express an absolute requirement, that is, to state that the test ought to be designed to satisfy the specified condition, unless the purpose of the test requires a different design. "Should" is used to state that the specified condition is recommended and ought to be met if possible. Although violation of one" should" is rarely a serious matter, violation of several will often render the results questionable. "May" is used to mean "is (are) allowed to," "can" is used to mean "is (are) able to," and "might" is used to mean "could be possible". Thus, the distinction between "may" and "can" is preserved, and "might" is never used as a synonym for either "may" or "can".

3.2 *Definitions of Terms Specific to This Standard:* Consistent use of terminology is essential for any vegetation sampling effort. Below is a list of terms that are used in this guide, as well as others that may be encountered commonly during the course of vegetation sampling. This list is not exhaustive, and it includes terms that do not apply to every project or method. Definitions are from Barbour et al. **(9)** and Hanson **(10)**, or the author of this guide.

3.2.1 *abundance*—the number of individuals of one taxon in an area; equivalent to the term *density* as used in botanical literature (relative abundance = density).

3.2.2 *association*—a particular type of community with relatively consistent floristic composition, a uniform physiognomy, and a distribution characteristic of a particular habitat.

3.2.3 *basal area*—the cross-sectional area of a tree trunk at 1.4 m (4.5 ft) above ground (see *diameter at breast height*).

3.2.4 *basal area factor (BAF)*—in variable radius sampling, the number that is multiplied by the number of tallies to obtain basal area in m^2/ha or ft^2/ac.

3.2.5 *biomass*—the mass of vegetation per unit area.

3.2.6 *canopy*—the uppermost layer, consisting of branches and leaves of trees and shrubs, in a forest or woodland.

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[2] The boldface numbers given in parentheses refer to a list of references at the end of the text.

3.2.7 *community*—a group of interacting plant (or animal) populations in a defined area.

3.2.8 *constancy*—the percentage of all relevés that contain a given taxon (see Annex A1 for description of relevé method).

3.2.9 *cover*—the area of ground covered by plants of one or more taxa.

3.2.10 *density*—the number of plants rooted in a given area.

3.2.11 *diameter at breast height (DBH)*—the widest point of a tree trunk measured 1.4 m (4.5 ft) above the ground.

3.2.12 *dominance*—a measure of a taxon's contribution to cover or basal area in a community (physiognomic dominance), or a taxon's impact on the reproduction and continued existence of a community (sociologic dominance).

3.2.13 *ecosystem*—a biological community plus the physical-chemical environment in a particular area.

3.2.14 *flora*—a list of all the taxa in an area.

3.2.15 *forb*—a non-graminoid herbaceous plant.

3.2.16 *frequency*—the percentage of total sampling units that contains at least one rooted individual of a given taxon, a measure of uniformity of a taxon's distribution.

3.2.17 *geographic information system (GIS)*—an integrated spatial data base and mapping system in which geographical information can be used to produce digital maps, manipulate spatial data, and model spatial information. Allows overlay of layers of information, such as habitats or plant ranges.

3.2.18 *global positioning system (GPS)*—a survey system in which a GPS unit is used to receive signals from satellites. Signals are then interpreted to provide information such as latitude and longitude or bearings for navigation, positioning, or mapping.

3.2.19 *graminoid*—a grass (Poaceae), sedge (Cyperaceae), or rush (Juncaceae).

3.2.20 *herb*—a plant with one or more stems that die back to the ground each year (that is, graminoids and forbs).

3.2.21 *importance*—the relative contribution of a taxon to a community; defined as the sum of relative cover, relative density, and relative frequency.

3.2.22 *importance percentage*—the mean of the normalized density, cover, and frequency values, on a 0 to 100 % scale.

3.2.23 *physiognomy*—the surface features of an area.

3.2.24 *population*—a group of individuals of the same species occupying a habitat small enough to permit interbreeding.

3.2.25 *presence*—the percentage of all stands that contain a given taxon.

3.2.26 *quadrat*—an area of any shape that can be delineated in vegetation so that cover can be estimated, plants counted, or taxa listed.

3.2.27 *relevé*—a method to survey vegetation in a structured, subjective manner that generates categorical descriptions of species abundance, dominance, and sociability.

3.2.28 *rhizosphere*—an unspecified volume of soil closely surrounding plant roots.

3.2.29 *remote sensing*—the use of satellites or high-altitude photography to measure geographic patterns such as vegetation.

3.2.30 *shrub*—woody plant typically smaller than a tree when both are mature (typically with DBH < 10 cm), often with multiple main stems from the base. Should be defined specifically at start of project.

3.2.31 *sociability*—an estimate of the dispersion of members of a taxon.

3.2.32 *species*—groups of morphologically and ecologically similar natural populations that may or may not interbreed but that are reproductively isolated from other such groups.

3.2.33 *species diversity*—the number of species in an area weighted by the number of individuals of each species. Calculated in a species index. (See Barbour et al. **(9)** for discussion of commonly-used species diversity indices.)

3.2.34 *species evenness*—the relative number of individuals of the species in an area. Evenness is at a maximum when all species have the same number of individuals.

3.2.35 *species richness*—the number of species in an area.

3.2.36 *stand*—a local example of vegetation. A synthesis of many similar stands is an association.

3.2.37 *taxon*—any taxonomic group, that is, variety, species, genus (plural = taxa).

3.2.38 *tree*—woody plant with a single main stem from the base, typically > 2 to 3 m tall when mature (typically DBH ≥ 10 cm). Should be defined specifically at start of project.

4. Sampling Approaches

4.1 Vegetation sampling methods can be divided into two broad divisions, namely (a) those that use a defined plot or area; and (b) the plotless methods that have no defined area. Regardless of the method used, the information obtained in sampling includes a list of species and some measure of the dominant taxa. With defined area plots, direct measures of cover, size of individuals, numbers of individuals, or biomass of each taxa are possible. Subsequent calculations allow the information to be presented in normalized or relative terms. The plotless methods, except for the point-quarters method, generate only normalized or relative comparisons of taxa. Therefore, if a measure of the number of individuals per unit area (that is, plant density) is needed, one should not use a line-intercept or point-frame method. In general, the defined area methods require a greater level of effort per unit data than the plotless methods.

4.1.1 Defined area methods employ discrete sampling plots. The shape of the plot may be circular, square, or rectangular. Key factors regarding choice of the shape relate to the vegetation conditions and terrain. Circular plots are delineated in the field by using a center post and a measuring device (meter tape, rope, pipe, or stick) as a radial arm to trace the circumference. Alternatively, a rigid hoop may be placed in the field. Tall vegetation or rugged terrain impede efforts to establish good boundaries of circular plots. Square or rectangular plots are more easily placed in the field as straight lines and are typically easier to establish compared to arcs. For a given area, a circular plot has less perimeter than a square plot which has less perimeter than a rectangular plot. Consequently, in an ideal situation, circular plots would present fewer "edge-related" sampling decisions and therefore make the effort more objective. However, as field conditions compromise the ability to place circular plots, this advantage is quickly lost.

4.1.2 Plotless methods range from relatively loosely structured reconnaissance strategies to rigorous techniques that employ either dimensionless points, as in various line and point-sampling methods, or geometric relationships that factor size and distance into the measures, as in the variable radius technique.

5. Significance and Use

5.1 Vegetation sampling is useful for investigating plant succession and community composition for a variety of purposes including land use planning, resource surveys, assessment of vegetation response to toxic materials and other environmental stresses, and for ecological research **(11)**.

6. Interference

6.1 Topography, vegetation type to be sampled, and skill of personnel are the main limitations in vegetation sampling. Rock outcrops, steep slopes, and open water limit the effectiveness of all methods discussed here, but study areas can be designed to avoid potential problem areas with a limited amount of bias (see Section 9). Limited sight distances due to topography or dense vegetation may cause difficulties in placing transects, defining plot areas, and sighting vegetation in variable radius sampling. Impenetrable vegetation, such as blackberry or floating bogs may impede establishment of line transects or points. Beyond these physical interference factors, caution should be exercised to understand spatial distribution patterns inherent in many vegetation types. Aggregate or patchy distribution of plants may limit the validity of certain calculations of density, frequency, or dominance. Project-specific quality assurance plans should address each of the potential interference factors (physical as well as biological) that might confound sampling efforts. See Annex A6 for further discussion of the limitations of each method.

7. Sampling Materials

7.1 *Field Notebooks/Data Sheets*—Proper recording of data and observations is essential for any vegetation sampling effort. Field notebooks or data sheets, or both, should be useable in all expected weather conditions, and waterproof ink should be used when possible. Field notebooks should contain consecutively pre-numbered pages, and notebooks should be project-specific. Daily observations should include personnel, weather, date, time, location, and any other observations of conditions that may affect the project. All mistakes should be crossed out with a single line, initialed, and dated. Data sheets should be photocopied weekly and stored separately from originals to avoid costly loss of data and time.

7.2 *Site Maps, Aerial Photos, Compass, and GPS (Optional)*—Topographic maps and aerial photos can be used in designing a study to identify sampling areas, vegetation types, and access to a study area before field sampling begins. In the field, maps can be used in conjunction with a compass and GPS (Global Positioning System) unit to precisely locate and record study areas, lay transect lines, and to define plot areas. Site or point locations obtained with a GPS can be recorded for entry into a GIS (Geographic Information System) for future analysis. Information on the use and limitations of compasses and GPS units can be obtained where such devices are sold. Current United States Geological Survey (USGS) 7.5 Minute Topographic Maps are available from a variety of sources and contain the appropriate compass declination for the study area. Aerial photographs are usually available for several different dates from government agencies, colleges, and universities near the project area. Most of the continental United States has been photographed repeatedly since 1938. Although the photographic record is incomplete and sporadic, and technical limitations (such as varied camera angle and altitude) are typically great, the photographic records contain valuable qualitative information on vegetation and land use patterns over a time span of 50 or more years. If a larger area with less resolution is acceptable, LANDSAT imagery is available for most areas since 1972. Even subjective knowledge of generalized trends over five decades can offer important interpretive perspectives to ecological assessment.

7.3 *Tape Measures*:

7.3.1 *Distance*—A 100-m tape with cm increments and a metal hook at one end should be used for distance measures, line transects, and quadrat measurements. Tapes should be flexible for ease of use and to avoid the damage caused by bending metal tapes, but strong enough to withstand snagging on vegetation and rocks. When measuring distances, tapes should be taut and held at the same height above the ground at both ends of the tape (usually at breast height), and care should be taken to avoid stretching the tape. In many cases, rangefinders can be used for the above measurements, but their instructions and limitations should be considered carefully. Distance measures on hills may require correction for slope when mapping vegetation.

7.3.2 *Diameter*—Tree and shrub diameters should be taken as close as possible to breast height using a diameter tape that converts circumference to diameter. If possible, do not measure stem diameter on a section of tree trunk with interfering branches or any abnormal lateral stem growths or wounds. Any deviations from breast height should be minor and noted in the daily log book. An a priori decision should be made about how to measure trees or shrubs with multiple major stems. Depending on the goals of a project, a single main stem may be selected for measurement or all stems over a certain diameter may be measured.

7.3.3 *Height*—For plants under about 2 m, heights can be measured with a tape measure or meter stick. On slopes, heights should be taken on the uphill side of the plant. Tree heights are commonly estimated with instruments known as hypsometers, which include a variety of devices that use trigonometry and a sighting device **(7)**. Some devices require a horizontal distance measure to obtain a trigonometric relationship. The reliability of height estimates vary widely with personnel skill, topography, stand density, and tree height. Measuring the height of tall trees is especially difficult in densely-stocked stands.

7.4 *Specimen Collection*—Plants may be sampled in order to assay for toxic materials or for later identification. When using a sampling scheme that involves pre-mapped sample points, plant samples should be taken as close as is practical to each sample point. Acceptable distance for sampling from each sample point should be predetermined. Plant tissue collection for bioassay requires strict care to avoid possible contamination of sample or collector. Plant material should be collected in the following manner:

7.4.1 The cutting edge of scissors or trimmers should be wiped with paper toweling or tissues to remove any contamination before the initial sample is taken and prior to taking each subsequent sample.

7.4.2 The collector should wear latex gloves, changed after each sample is collected.

7.4.3 Plant material should be selected from prominent plants in the collection area according to predetermined data quality objectives and quality assurance practices.

7.4.4 Depending on the study objectives, it may be advisable to collect plant tissue from a specified height (for example, > 10 cm of the soil surface) to reduce the contribution of splashed soil adhering to the material. Alternatively, predetermined portions of the plant canopy, either designated by height, relative position (for example, mid-canopy), or developmental stage (for example, buds, fully expanded leaves, twigs, or senescent leaves, etc.) may be sampled. The sampling plan should specify guidelines for use in collecting tissue.

7.4.5 The cutting edge of scissors or trimmers should be wiped with paper toweling or tissues to remove any contamination before collecting materials from different samples.

7.4.6 The plant material should be placed in an appropriately labeled bag, which is folded and taped shut, and as soon as practical placed in a portable cooler cooled with ice for transport to the laboratory.

7.4.7 A plant press can be used to store and preserve plant specimens for later identification. A simple, relatively lightweight plant press can be constructed by stacking layers of newspapers between layers of rigid cardboard. Plant specimens are placed between the newspapers and then the entire stack is compressed with straps in a semi-rigid frame. Appropriate notation in field lab books and with the specimens should be made according to the quality assurance practices for the given project.

7.5 *Taxonomic Reference Books*—While a variety of taxonomic references are available, there is a dominant flora for most regions of the US, often published by a major university press in the project region. Consult local workers or a local library for the appropriate reference.

8. Hazards

8.1 Certain hazards are inherent to any field work in a rugged natural environment. The following is a general discussion of hazards that may be encountered in vegetation sampling. Specific situations may require additional precautions. In the absence of specific guidelines for general field activities that may incur elements of hazard, it is expected that all reasonable care will be taken by field crews. Common sense and sound judgment will usually minimize or prevent health and safety problems. Seek medical attention immediately if any of the following occur: sudden onset of high fever, severe headache, disorientation or disequilibrium, rash, or swollen, tender bite wound (especially if associated with lymph gland tenderness or pain).

8.2 *Biohazards*

8.2.1 *Insects and Other Arthropods*—All personnel who have previously had systemic allergic reactions to insect bites or stings should carry "bee sting kits" into the field. If a reaction is suspected by any personnel, they should be taken to the nearest medical facility as soon as possible. Spider, scorpion, and tick bites should be carefully monitored due to the possibility of particular complications. Ticks can transmit Lyme Disease, Rocky Mountain Spotted Fever, and Colorado Tick Fever. Use of tick and mosquito repellents may be advisable.

8.2.2 *Snakebite*—Care should be taken to avoid snakebites in areas known to be inhabited by poisonous snakes, especially on summer mornings or evenings when snakes are likely to be active. Never place a hand or foot behind or under a rock or log where it cannot be seen. In poisonous snake areas, it is advisable to wear protective clothing including high-top boots. If bitten, the limb with the bite should be immobilized and the patient evacuated as soon as possible to a medical facility. If the patient is far from a vehicle or medical facility, additional measures may need to be taken while pursuing medical attention. Consult a current first aid guide for snakebite first aid. Even if bitten by a nonpoisonous snake species, thorough cleaning of the wound is necessary to minimize the possibility of infection.

8.3 *Physical Hazards*—As with the above biohazards, environmental hazards can often be avoided with proper awareness and prevention. In all the cases below, adequate attention to personal hydration, food and salt intake, layered clothing, and sun protection are the best measures for ensuring safety regarding these hazards.

8.3.1 Dehydration and loss of electrolytes should be avoided by drinking large quantities of water and by the replacement of salts, if necessary. Minimum consumption of water should be approximately 3 L per day. However, perspiration from heavy activity can be responsible for the loss of several liters per day, increasing the necessary consumption to as high as 8 L per day per person. Drink enough fluids to maintain clear urine. If perspiration loss is significant, electrolyte replacement may be necessary, though salt in food sources should be adequate to maintain electrolyte balance.

8.3.2 *Heat Illness*—Heat syncope, heat exhaustion, and heat stroke represent a range of heat illnesses from mild to extreme, and can usually be avoided by consuming adequate quantities of water, maintaining electrolyte balance within the body, and adequately adjusting clothing. Generally, heat illnesses are the result of metabolic heat production exceeding the capacity of homeostatic heat loss mechanisms. Recognizing hyperthermic conditions where body heat cannot be adequately dissipated and taking appropriate measures can prevent potentially serious consequences. Thirst and "hunger" for salt are not adequate indicators of requirements for these elements and conscious effort is needed to prevent onset of symptoms. Heat syncope and exhaustion are caused by vasodilation of the skin to a degree where cerebral blood flow is diminished. Syncope is a mild form of heat exhaustion with increased core body temperature less pronounced than in the more acute exhaustion. In both cases, symptoms similar to fainting occur, with possible nausea, rapid pulse, dizziness, weakness, etc. Immediate shelter from sun, rest, and fluid and electrolyte input will usually rapidly diminish symptoms. It is usually necessary to curtail field activities for the rest of the day or until urine output returns to normal levels. In cases of heat exhaustion, body temperatures should be closely monitored until back to normal levels. Heat stroke is a much more severe result of the same process, where symptom onset may be sudden and accompanied by changes in mental acuity. Shock may occur, and the addition of mental confusion to the above symptoms should be considered a medical emergency. Immediate measures should be taken to reduce body temperature, and evacuation should be initiated as soon as possible.

8.3.3 Sunburn can occur with relatively small exposures to the sun, especially in mountain altitudes due to the thinner atmospheric protection and increased UV exposure. Approximately two-thirds of daily solar radiation occurs between 10 AM and 2 PM, making adequate protection from sunlight most important during these hours. Sunscreen of 15 SPF or greater, proper clothing, and a hat will prevent most sunburn, and acclimatization will lessen the possibility of severe sunburn. Sensitivity to sunlight may be increased by the use of many drugs and cosmetics.

8.3.4 Hypothermia is a result of the lowering of core body temperature that can produce serious medical complications, including shock symptoms. The opposite of hyperthermia, hypothermia is the relative loss of body heat faster than internal warming mechanisms can provide. It can occur at ambient air temperatures as high as 10°C and the onset of symptoms can be sudden. Symptoms can include mental confusion, uncontrollable shivering, and possible shock. Warming, hydration with warm liquids, and reduced exposure will usually relieve symptoms quickly, but a patient suspected of being hypothermic should be monitored carefully. If core body temperature lowers more than several degrees, medical assistance is extremely important to recovery. Special care should be taken in wet weather to stay as dry as possible. Adequate clothing to avoid excessive heat loss and prevention of dehydration significantly reduce the likelihood of hypothermia.

8.3.5 *Other Hazards*—One of the most common field injuries is a sprained ankle caused by loose rocks or logs. Thorns, spines, and sharp sticks can produce surprisingly bad injuries, especially when work is being conducted a long distance from a vehicle. Extra care should be taken in stormy weather, when lightning, flooding, and high winds may produce life-threatening situations. Hard-hats may be required when working in forests during windy periods. Finally, all personnel should be instructed in field identification of toxic or irritating vegetation.

8.4 A well-stocked first aid kit should accompany each crew into the field.

8.5 *Clothing*:

8.5.1 *General Clothing Requirements*—Hiking boots with proper ankle support and long pants are basic suggested clothing items. Appropriate clothing for variable weather should be carried by each individual, including several layers with an outer shell for rain and wind protection. Wool or synthetic socks are highly recommended.

8.5.2 *Protective Clothing and Gear*—When field exercises include exposure to specific hazardous or suspected hazardous substances, personnel must plan for and include all protective gear necessary for the minimization of exposure to such substances. Such protective gear may include, but is not limited to, dust masks, respirators, safety glasses, latex gloves, boots, and protective body suits.

9. Sampling Design

9.1 The most important goal of any sampling scheme is that samples be representative of the range of variation in the community or area under study. If sampling is designed to quickly compare the species assemblages of the same community type in different locations using the semi-quantitative relevé, determining the optimal plot size to adequately characterize the community is important. If, for example, the goal of a study is to compare grassland vegetation in several locations, it is necessary to determine the optimal plot or relevé size that will adequately describe the grassland. A plot that is too small will not adequately characterize vegetation, while sampling an excessively large area wastes valuable resources.

9.2 If the goals of a study are to quantitatively characterize the area of a property or other arbitrarily defined area, then the size of the project area is defined by these boundaries and by the range of vegetation variation within the area. Plots or points should be distributed across the sample area in a manner that allows sampling of the full range of variability of the area and allows statistical use of the data.

9.3 The distribution of organisms is governed by a variety of environmental, biological, and behavioral factors. These distributions may result from reproductive tendencies, success of germination and establishment, biological interactions, dispersal mechanisms, and microhabitat variation. Three fundamental patterns of distribution are recognized: regular, random, and aggregate (See Fig. 1). Combinations such as random aggregates may exist and in practice, populations of various species in a community grade across all classical distribution patterns.

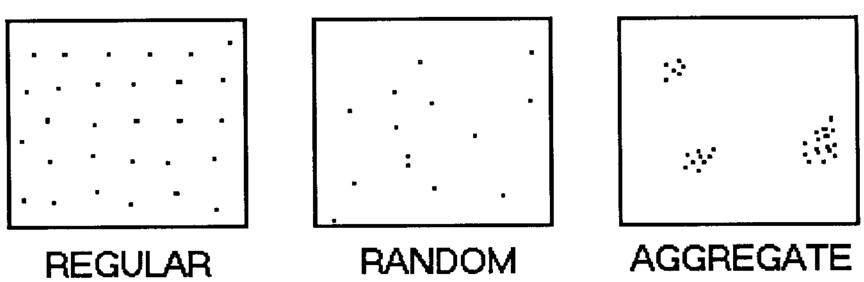

FIG. 1 Plant Distribution Pattern

9.4 The type of distribution one anticipates may dictate the specific sampling regime adopted and introduce constraints on statistical analysis. There are various possible approaches to quantitative vegetation sampling. Often, details of the sampling procedure are varied to accommodate the structural and distributional features of the vegetation type. If random distributions or random distributions within aggregates are assumed, the ideal method of data collection would dictate random positioning of the sample locations. Though feasible under some conditions, in most field situations it is difficult or impossible to determine the location of a predetermined random point. Generally, one of two approaches is adopted:

9.5 *Transect*—The origin of a line is located in the site with the line following a compass bearing. At predetermined regular or random intervals along the line, sample points are established and sampling information recorded. The orientation or bearing of the line may be selected randomly. Often, however, topographic features are taken into account. The investigator may wish to establish the transect perpendicular to ridges or parallel to ridges, or to some other recognizable boundary. The major objective is to minimize sampling bias.

9.6 *Stratified-Random Sampling*—The area to be sampled is dissected into a grid system. Each point or cell within the grid is identified by a unique number. Cells or points where sampling will be conducted are selected randomly. Upon locating the approximate location of a grid cell or point using maps, compasses, and/or GPS, or a combination thereof, sample units are positioned through some unbiased "random" process (for example, a random number of paces north and west of the southeast corner of the grid cell).

9.7 *Sample Units/Specimens*—In vegetation sampling, sample units are the plots or points in which vegetation is sampled. While sample units are typically land areas, they may also represent diverse concepts, such as the vertical strata in a forest canopy, or the rhizosphere in a study of root competition. Generally, field plant ecological studies do not focus on individuals, but rather on populations or communities. For example, the cover values associated with all individuals of a species are summed to produce the cover, density, and frequency values for that species, which then may be used in data analysis. However, in plant ecology there are opportunities to evaluate environmental conditions at the individual level, such as when individual mortality indicates localized zones of disease or contamination in air or soil.

10. Calibration and Standardization

10.1 Before the start of sampling all instruments must be calibrated as directed by manufacturers instructions accompanying the instrument. Compasses should be adjusted to account for local magnetic variations, which are available on USGS topographical maps, and declinations from true north should be taken into account. Of special importance to plant ecological studies is standardization of terminology. All personnel must use the same terminology when describing such concepts as diameter at breast height, tree, shrub, etc.

10.2 Depending on the site, multiple visits at different seasons may be needed to accurately measure species richness in a community. The utility of synthetic community measures (such as species diversity indices, indices of similarity, etc.) depends greatly on the degree of taxonomic discrimination during primary data collection. Thus, botanists familiar with the regional and local flora should be employed to compile a checklist of expected plants and to spot unusual gaps in the species assemblages.

11. Procedure

11.1 See specific annexes for detail for vegetation sampling procedures.

11.2 *Planning Activities*:

11.2.1 Determine the data quality objectives for the specific project. This should include at a minimum a narrative description of the expected use of the information as it relates to the project questions, any statistical comparisons of vegetation data that are anticipated, and the level of precision needed.

11.2.2 Select an appropriate sampling method that meets the data quality objectives and takes into account extenuating circumstances such as ruggedness of terrain, accessibility, time available to complete sampling, and cost of sampling. If the extenuating circumstances impose serious limitations, reconsideration of the data quality objectives may be advisable.

11.2.3 Design the sampling strategy that is tailored to the data quality objectives and the specific method selected. The design should specify how many samples will be taken, where the samples will be taken, and when the samples will be taken. The design should also provide guidelines for modifying details of the design while in the field.

11.2.4 Assemble gear, reference documents, field books, data sheets, and appropriate safety gear before going to a remote area.

11.3 *Field Activities*:

11.3.1 Upon arrival at the project site, conduct an orientation and training session for field crew prior to gathering data. This step can be an important means to minimize interpersonnel differences in data quality. During this step, field crew members refresh their skills in identification of local flora for the particular season, rules for handling unknown specimens, decision rules regarding edge (for example, include every other specimen bisected by a boundary line; count only those specimens rooted in a plot, etc.) decision rules regarding precision of measures of distance, height, or circumference.

11.3.2 Establish sampling locations, either transects, points, or plots as defined in the sampling plan.

11.3.3 Collect all data and specimen samples as directed in the sampling plan. All entries on data sheets and in field notebooks should be made using water proof ink and paper. At a minimum, field notebooks and data sheets should be dated and initialed by the field crew leader.

12. Calculation or Interpretation of Results

12.1 The sampling techniques vary in their thoroughness (accuracy) and in the time and therefore cost required to execute properly. Generally, the techniques that can be performed rapidly in the field have inherent limitations on subsequent data manipulation and interpretation. Data summaries commonly calculated include estimates of density, cover (basal area for trees), frequency, and sometimes importance percentage (IP). These calculations can be prepared for each species or plant type and should be accompanied by standard error or deviation estimates. Typically in the herbaceous plant sample methods, measures of density are not obtained. See specific annexes for calculations associated with each sampling method.

12.2 The summary values acquired from sampling may be used to calculate synthetic indices such as species diversity. Density, frequency, cover or a combination thereof, can also be used in statistical analysis in many different ways, including describing communities or interspecific relationships, or to perform hypothesis testing.

12.3 Caution must accompany interpretation of vegetation patterns as the result of natural or anthropogenic mechanisms, since natural succession and stress affect the structure and composition of a community in non-linear patterns. Correlation between environmental and biological variables often implies causation in ecological studies, but confusing correlation and causation can result in false interpretations or assessment of liability.

12.4 Precision is, in essence, the repeatability of a measurement. Precision is seldom possible to measure in vegetation sampling without repeating a study exactly, which is rarely feasible or possible. Bias occurs when samples are not representative of the community being sampled. Bias can occur when a sampling scheme is purposely or inadvertently designed to measure only certain parts of a community (when complete community representation is desired), or when test units or specimens are chosen to yield certain results. Vegetation sampling is most susceptible to bias in the sampling design, where plot or point placement determines what vegetation is sampled. Randomization of sampling locations will eliminate much bias, but choice of statistical methods and test units and specimens should also be examined for bias.

13. Report

13.1 The report the following information:

13.1.1 *Introduction*—A description of the project setting.

13.1.2 *Scope*—The purpose of the study and a statement of the questions being addressed by the sampling effort.

13.1.3 *Methods*—A description and rationale of sampling design, equipment, and statistical procedures.

13.1.4 *Results*—A narrative description of the sampling effort plus summary tables of quantitative information collected for the various sampling units. Statistical comparisons of data should be presented as appropriate.

13.1.5 *Discussion/Conclusions*—An interpretation of results, possible errors, and relationship of results to those of other studies. Special attention should be given to descriptions of interference that were noted in the course of conducting the field work.

13.1.6 *Literature Cited*—Relevant reports of earlier vegetation studies of the project area, sampling and analysis methods, and any project specific documents.

13.1.7 *Appendixes*:

13.1.7.1 The appendixes should provide attachments of data summaries or alternatively stipulate where archived data may be accessed.

13.1.7.2 A quality assurance report should be attached or summarized describing the nature of independent review that was conducted and any findings such as protocol deviations, modifications, and corrective actions undertaken. This appendix should conclude with a discussion on the acceptability of the results.

14. Keywords

14.1 mensuration; phytosociology; plant community sampling; vegetation

ANNEXES

(Mandatory Information)

A1. RELEVÉ METHOD

A1.1 Scope

A1.1.1 The relevé method **(7, 9, 12)** is a structured, subjective, and often cost-effective reconnaissance that uses flexible, loosely-defined sampling areas and generalized ranges of cover estimates. As a semi-quantitative method, it has certain limitations. However, the method can be performed rapidly and may provide sufficient information to satisfy the objectives for many sites (for example, highly disturbed and biologically isolated locales, or sites that satisfy criteria for remote sensing analysis and only require generalized“ ground-truthing”).

A1.2 Sampling Design Considerations

A1.2.1 The relevé method is a structured, subjective reconnaissance that uses flexible, loosely-defined sampling areas (see Table A1.1) and generalized ranges of cover estimates (see Table A1.2). Additional information on growth habit (technically referred to as sociability), may be taken (see Table A1.3). Because of its subjectivity, this method may be the most cost-effective means of describing community composition or detecting differences in community organization or species assemblages associated with environmental stresses. However, because relevé is highly subjective and only semi-quantitative,

TABLE A1.1 Estimated Minimal Area For Each Relevé Survey For Selected Vegetation Types

Vegetation Type	Surface Area (M^2)
Temperate Forest	200 to 500
Trees	200 to 500
Shrubs/herbs	50 to 200
Grassland	50 to 100
Wetlands/Meadows	5 to 25

TABLE A1.2 Modified Braun-Blanquet Cover Class Ranges[A]

Cover Class	Percent Cover Range	Mean Cover
1	75 to 100	87.5
2	50 to < 75	62.5
3	25 to < 50	37.5
4	5 to < 25	15.0
5	1 to < 5	3.0
+	< 1 to 0.5	0.75
r	Observed but so rare as to not contribute measurably	0.1

[A] The algebraic mid-point of the cover class range is routinely used in calculations, even though the values do not carry as many significant figures as implied.

TABLE A1.3 Braun-Blanquet Plant Sociability Classes

Class	Criteria
1	Occurring in large, nearly pure stands
2	Occurring in large aggregates, coppice or in carpets
3	Occurring in small aggregates, clusters, or cushions
4	Occurring in clumps or bunches
5	Occurring singly

traditional parametric statistics are inappropriate to analyze the data. Categorical data analysis can be used on the incidence data generated through the subjective descriptions.

A1.3 Sampling Procedure

A1.3.1 A traditional relevé begins with an investigator selecting representative stands within a particular vegetation type. The investigator walks through the stands, compiling a list of all species encountered. Based on this preliminary reconnaissance, the minimum area (see Table A1.1) necessary to characterize the species assemblage vegetation is determined. The resulting sample area, based on the minimal area, is a relevé.

A1.3.2 At each relevé, the list of species is compiled and scored for cover class (see Table A1.2 and Fig. A1.1) and sociability (see Table A1.3).

A1.3.3 Modifications to the relevé method are possible to increase its rigor while maintaining its cost effectiveness. Sample locations may be randomly distributed across the study area. A relevé-type survey may be made of each location, recording species and cover values. This method allows meaningful comparisons of vegetation across large study areas where limited resources may preclude a more rigorous design.

A1.4 Summary Equations for Relevé Sampling

A1.4.1 Several general data summaries are readily derived

Relevé Field Data Sheet

<<PROJECT NAME>>

Sample Site I.D.: ____________ Date: ________

Field Sampling Team: ________ ________ ________ ________

Data Management Filename: ______________ QA Check: ______

COVER CLASS	RANGE, IN %
1	75 to 100
2	50 to <75
3	25 to <50
4	5 to <25
5	1 to <5
+	<1 to 0.5
r	Observed, rare

SOCIABILITY CLASS	CRITERIA
1	occurring in large, nearly pure stands
2	occurring in large aggregates, coppice or in carpets
3	occurring in small aggregates, clusters, or cushions
4	occurring in clumps or bunches
5	occurring singly

Taxon	Cover Class	Sociability Class	Taxon	Cover Class	Sociability Class
1.			16.		
2.			17.		
3.			18.		
4.			19.		
5.			20.		
6.			21.		
7.			22.		
8.			23.		
9.			24.		
10.			25.		
11.			26.		
12.			27.		
13.			28.		
14.			29.		
15.			30.		

General Comments: [Other taxa observed.]

FIG. A1.1 Example Data Sheet for Relevé Sampling

from relevé data. Species richness (that is, the number of taxa) can be tallied for a group of relevé sample locations in a specific area or habitat type. Frequency of occurrence and cover are scored for each taxon in a sampling area as:

$$Frequency = Number\ of\ relevés\ with\ Taxon\ X \div Number\ of\ relevés \quad (A1.1)$$

$$Cover = \Sigma\ Cover\ Class\ Mid{-}Point\ Percentage\ for\ Taxon\ X\ from\ all\ relevés \quad (A1.2)$$

A1.4.2 The normalized or relative values are calculated as:

$$Relative\ Frequency = (Taxon\ \mathrm{X}\ Frequency \div \Sigma\ Frequency\ of\ all\ taxa) \times 100 \quad (A1.3)$$

$$Relative\ Cover = (Taxon\ \mathrm{X}\ Cover \div \Sigma\ Cover\ of\ all\ taxa) \times 100 \quad (A1.4)$$

A1.5 Example Summary Table—See Table A1.4.

TABLE A1.4 Example Summary Table for Presenting Relevé Sampling Results

Taxon	Frequency	Cover	Relative Frequency	Relative Cover	Importance Percentage
Sp. 1	. . .	. . .	. . .	. . .	. . .
Sp. 2	. . .	. . .	. . .	. . .	. . .
Sp. 3	. . .	. . .	. . .	. . .	. . .
Sp. *n*	. . .	. . .	. . .	. . .	. . .
Totals	. . .	. . .	100.0	100.0	100.0

A2. LINE-INTERCEPT METHOD

A2.1 Scope

A2.1.1 *Line-Intercept*—This technique offers a rapid means of assessing the relative importance of major taxa. It may also be used with images such as aerial photographs or microscope views. Typically, a line transect is established along some bearing through the sampling area, and at predetermined intervals along the line, a segment of the line is examined for contact with vegetation to be sampled.

A2.2 Sampling and Design Considerations

A2.2.1 Using this method, a line transect is established along some bearing through the area to be sampled. The bearing and line origin may be chosen randomly or chosen to reflect study objectives, such as to sample the center of a community or stand, or to determine changes along a gradient or between community type. At predetermined even intervals along the line, a segment of the line is examined for contact with vegetation or other objects to be sampled. The length of interval to be observed can be determined just as plot size (see Annex A6 for discussion on plot size). In a low-growing grassland, for example, one might record the contacts along 1-m segments every fifth meter. Percent cover may be measured as the fraction of a transect covering a species multiplied by 100 %. Density and frequency may be measured by either combining the line transect with quadrats running continuously alongside the line, or by dividing the line into intervals. The line intercept method was originally developed for shrub-dominated vegetation **(2, 7, 9)**. It is appropriate for plants with relatively unbroken cover, although use of the method in impenetrable thickets is clearly not feasible. Various sighting devices have been devised to allow measurement of tree crowns with the line intercept method. When measuring layered vegetation, strata should be defined and cover should be measured for each stratum separately **(2)**.

A2.3 Sampling Procedure

A2.3.1 See Fig. A2.1 and Fig. A2.2.

A2.4 Summary Equations for Line-Intercept Sampling

$$Frequency{:} = No.\ of\ Intervals_{Species\ I\ Present}\ /\ No.\ of\ Intervals\ Sampled \quad (A2.1)$$

$$Cover\ (Dominance) = (\Sigma Intercept\ Length\ Species\ I \times 100)\ /\ \Sigma Transect\ Length \quad (A2.2)$$

$$Relative\ Frequency = (Frequency_{Species\ I} \times 100)\ /\ \Sigma frequency_{All\ Species}$$

$$Relative\ Cover = (\Sigma Intercept\ Length_{Species\ I} \times 100)\ /\ \Sigma Intercept\ Length_{All\ Species} \quad (A2.3)$$

$$Importance\ Percentage = (Rel.\ Frequency + Rel.\ Dominance)\ /\ 2 \quad (A2.4)$$

A2.5 Example Summary Table

A2.5.1 See Table A2.1.

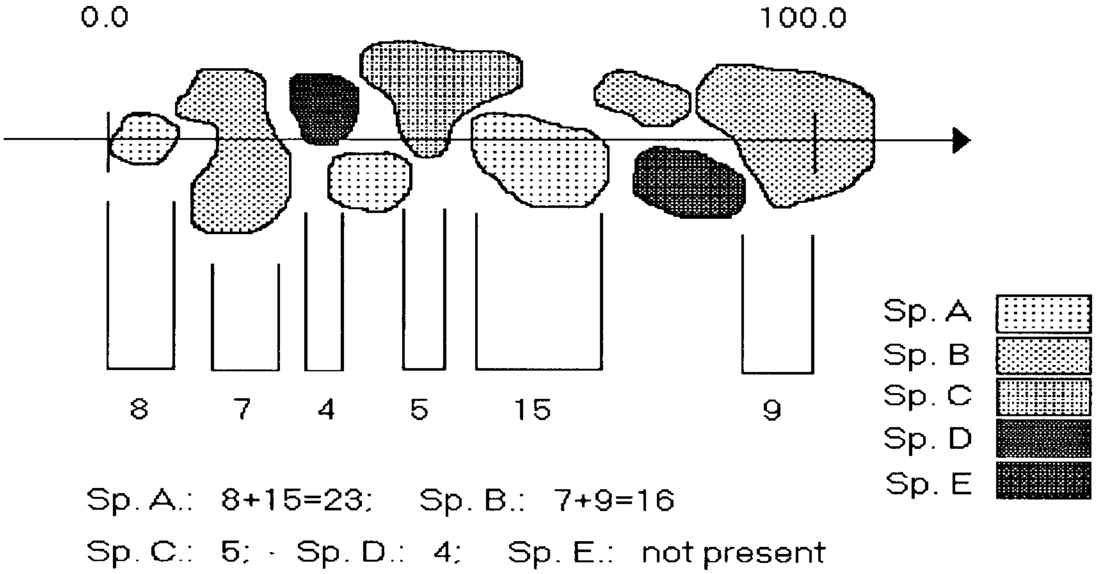

FIG. A2.1 Schematic illustration of Line-Intercept Sampling Method

Line-Intercept Field Data Sheet

<<PROJECT NAME>>

Sample Site Interval I.D.: ______________ Date: __________

Field Sampling Team: ______________ ______________ ______________ ______________

Data Management Filename: ____________________________ QA Check: ________

Taxon	Intercept Lengths (cm)	Total
1.	____; ____; ____; ____; ____; ____	
2.	____; ____; ____; ____; ____; ____	
3.	____; ____; ____; ____; ____; ____	
4.	____; ____; ____; ____; ____; ____	
5.	____; ____; ____; ____; ____; ____	
6.	____; ____; ____; ____; ____; ____	
7.	____; ____; ____; ____; ____; ____	
8.	____; ____; ____; ____; ____; ____	
9.	____; ____; ____; ____; ____; ____	
10.	____; ____; ____; ____; ____; ____	

General Comments: [Other taxa observed.]

FIG. A2.2 Example Data Sheet for Line-Intercept Sampling

TABLE A2.1 Example Summary Table for Presenting Line-Intercept Sampling Results

Taxon	Frequency	Dominance	Relative Frequency	Relative Dominance	Importance percentage
Sp. 1	. . .	. . .	. . .	. . .	. . .
Sp. 2	. . .	. . .	. . .	. . .	. . .
Sp. 3	. . .	. . .	. . .	. . .	. . .
Sp. *n*	. . .	. . .	. . .	. . .	. . .
Totals	. . .	. . .	100.0	100.0	100.0

A3. POINT-FRAME METHOD

A3.1 Scope

A3.1.1 *Point-Frame*—Use of the point-frame technique is restricted to low-growing herbaceous vegetation or cryptogams. The point-frame or pin-frame consists of ten sharp pins mounted at uniform frames in channels in a frame. The frame is lowered over the area to be sampled and plants are recorded at point of pin contact.

A3.2 Sample Design Considerations

A3.2.1 The point-frame or pin-frame consists of ten pins mounted at uniform frames in channels in a frame. The pins should have a needle-like point, theoretically giving the point no dimension. As a pin becomes blunt and "acquires dimension," the contact of the "point" is enhanced, leading to an over-estimate of cover. Usually, the frame is supported by braces such that the pins are angled at 45° to the surface. The frame is positioned at a given location and the pins are lowered through the channels. Because of these nuances it is crucial to have the same technical staff using the same or essentially the same sampling device to minimize bias.

A3.2.2 As with any of the techniques, there must be some plan to locate the frame within the area to be sampled and to determine the number of pins to be scored. A common practice is to position the frame at predetermined locations along a transect. Some analyses suggest that 1,500 pins might be needed to acquire an adequate sample **(7,9,13)**, although this is a function of variability of the site and the accuracy required.

A3.3 Sampling Procedure

A3.3.1 Use of the point-frame technique is restricted for practical purposes to low-growing herbaceous vegetation or cryptogams. Two major variations in point-frame sampling are aerial contacts and basal contacts. In the case of aerial contacts, each pin is lowered through the canopy and each contact of the point of the pin with a plant part is scored. Thus, a single point may contact zero to several leaves or stems of one or more species. To accomplish this procedure, there must be virtually no wind moving the plants, since any movement will alter the potential contact loci. The aerial contacts variation provides information on the vertical structure of a community. When sampling basal contacts, only the objects touched by the point of the pin as it rests on the ground surface are scored (see Fig. A3.1). The information is recorded separately for each frame (set of ten pins).

A3.4 Summary Equations for Point-Frame Sampling

$$Frequency: = No.\ of\ Frames_{Species\ I\ Present}\ /\ No.\ of\ Frames\ Sampled \quad (A3.1)$$

$$Cover\ (Dominance) = (\Sigma Pins\ Species\ I \times 100)\ /\ \Sigma Frames\ Sampled \quad (A3.2)$$

$$Relative\ Frequency = (Frequency_{Species\ I} \times 100)\ /\ \Sigma frequency_{All\ Species} \quad (A3.3)$$

$$Relative\ Cover = (\Sigma Pins_{Species\ I} \times 100)\ /\ \Sigma Pins_{All\ Species} \quad (A3.4)$$

$$Importance\ Percentage = (Rel.\ Frequency + Rel.\ Dominance)\ /\ 2 \quad (A3.5)$$

A3.5 Example Summary Table

A3.5.1 See Table A3.1.

Point-Frame Field Data Sheet

<<PROJECT NAME>>

Sample Site I.D.: ____________________ Date: ____________

Field Sampling Team: ________________ ________________ ________________ ________________

Data Management Filename: ____________________________ QA Check: ________

Frame Identification Number: __________			
Contact: Taxon, Soil, Litter	No. Pins	Contact: Taxon, Soil, Litter	No. Pins
1.		6.	
2.		7.	
3.		8.	
4.		9.	
5.		10.	

General Comments: [Other taxa observed.]

FIG. A3.1 Example Data Sheet for Point Frame Sampling

TABLE A3.1 Example Summary Table for Presenting Point-Frame Sampling Results

Taxon	Frequency	Dominance	Relative Frequency	Relative Dominance	Importance Percentage
Sp. 1	. . .	. . .	. . .	. . .	. . .
Sp. 2	. . .	. . .	. . .	. . .	. . .
Sp. 3	. . .	. . .	. . .	. . .	. . .
Sp. n	. . .	. . .	. . .	. . .	. . .
Totals	. . .	. . .	100.0	100.0	100.0

A4. POINT-CENTERED QUARTER METHOD

A4.1 Scope

A4.1.1 The point-centered quarter method is most effective when used for trees and shrubs. In this method, points are often located at intervals along a transect. At each point a perpendicular line is projected through the transect, dividing the area into four quadrants (quarters). In each quadrant, the plant nearest to the point is identified and the point-to-plant distance and plant diameter are measured.

A4.2 Sample Design Considerations

A4.2.1 The basic point-centered quarter method was initially developed for the land surveys conducted in the mid-1800's for forested vegetation. Subsequently, the equations were developed to convert the data into the standard ecological terms density, frequency, and dominance. A minimum of twenty points has been recommended to adequately sample vegetation **(1, 2, 7, 9, 10, 14)**.

A4.2.2 Since no defined plot is established in this sampling procedure, density is calculated indirectly. The density is computed on the assumption that the square of the mean point-to-plant distance represents a measure of the area occupied by the plants sampled. The total density for the sample is obtained by dividing the mean area per plant into the unit area of which the density is to be expressed.

A4.3 Sampling Procedure

A4.3.1 Points are typically located at intervals along a transect, although a compass heading alone may be used. A second line is then established perpendicular to the first, dividing the area into four quadrants, or quarters (see Fig. A4.1). From each point, the distance to the midpoint of the closest tree in each quadrant is measured and the diameter (to obtain BA) and species of each tree is recorded (see Fig. A4.2).

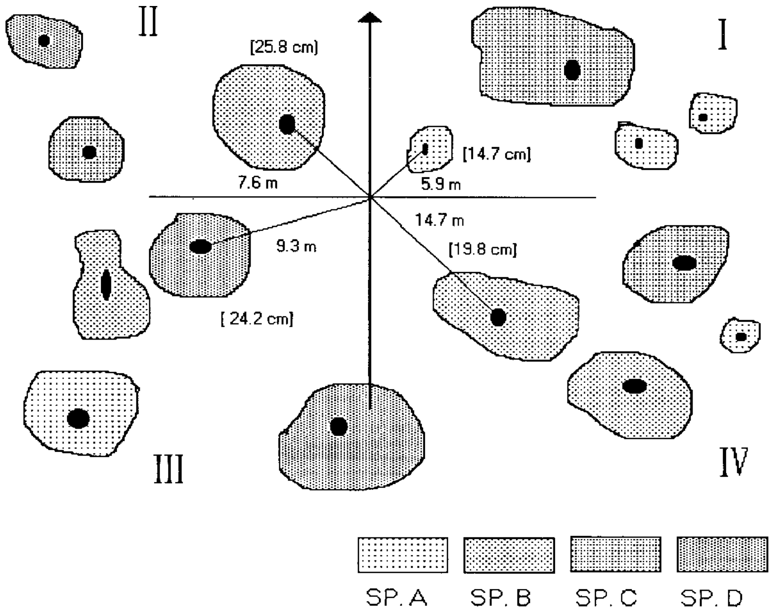

FIG. A4.1 Schematic Representation of Point-Centered Quarters Technique

Point-Frame Field Data Sheet

<<PROJECT NAME>>

Sample Site I.D.: ____________________ Date: ____________

Field Sampling Team: ________________ ________________ ________________ ________________

Data Management Filename: ____________________________ QA Check: ________

Point Number: __________			
Quadrant	Taxon	Distance	DBH
I			
II			
III			
IV			

General Comments: [Other taxa observed.]

FIG. A4.2 Example Data Sheet for Point-Centered Quarters Sampling

TABLE A4.1 Example Summary Table for Presenting Point-Centered Quarters Sampling Results

Taxon	Density	Frequency	Dominance	Relative Density	Relative Frequency	Relative Dominance	Importance Percentage
Sp. 1	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Sp. 2	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Sp. 3	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Sp. *n*	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Totals	. . .	. . .	. . .	100.0	100.0	100.0	100.0

A4.4 Summary Equations for Point-Centered Quarter Method

$$Total\ density = Unit\ Area / (Mean\ Point-To-Plant\ Distance)^2 \quad (A4.1)$$

$$Relative\ Density = (No.\ of\ Individuals_{Species\ I}) \times 100 / (No.\ of\ Individuals_{All\ Species}) \quad (A4.2)$$

$$Basal\ Area\ (Dominance) = (Density_{species\ I}) \times (Mean\ Basal\ Area_{Species\ I}) \quad (A4.3)$$

$$Relative\ Basal\ Area = (Basal\ Area_{Species\ I}) \times 100 / Basal\ Area_{All\ Species}) \quad (A4.4)$$

$$Frequency = No.\ of\ Points_{Species\ I\ Present} / No.\ of\ Points\ Sampled \quad (A4.5)$$

$$Relative\ Frequency = (Frequency_{Species\ I} \times 100 / Frequency_{All\ Species} \quad (A4.6)$$

$$Importance\ Percentage = (Rel.\ Density + Rel.\ Frequency + Rel.\ Dominance) / 3 \quad (A4.7)$$

A4.4.1 Important limitations of the basic point-centered quarter method are that it should be used to sample trees or shrubs only, and only where plants are randomly distributed with respect to points **(2)**. Single species in mixed stands tend to have nonrandom distributions, thus the method should not be used to sample single species in mixed stands. Several modifications have been proposed in the literature to overcome these limitations, but these are beyond the scope of this guide. (See Mueller-Dombois and Ellenberg **(2)** for details.)

A4.5 Example Summary Table

A4.5.1 See Table A4.1.

A5. VARIABLE RADIUS METHOD

A5.1 Scope

A5.1.1 Variable radius methods are commonly used in forestry to tally trees and shrubs as part of timber inventories. The various methods use instruments ranging from sticks with variable-sized apertures mounted at specific distances along the stick, to optical units with prisms and range-finder adjustments. Variable radius methods use geometric relationships to estimate basal area of trees or shrubs in BA/land area (that is, m^2/ha). They are used extensively in forestry, especially in relatively even-aged/even-sized stands. The basic method, that uses sticks with variable sized apertures mounted at specific distances along the stick, is commonly called the Bitterlich method after its German founder. Newer variations on the basic method use prisms or optical units with range-finder adjustments (available from engineering or forestry supply stores). The fundamental relationship used in these tools is that an object of a given size viewed from a distance occupies a percentage of an arc. The methods use an aperture of given dimension placed at a fixed distance from the eye, or a prism that visually offsets the trees, creating a double image of one tree trunk above the other.

A5.2 Sampling Design Considerations

A5.2.1 This method is called variable radius sampling because plot size is not fixed, but rather is determined by the basal area factor (BAF) of the instrument used (the number that is multiplied by the number of tallies to obtain basal area in m^2/ha or ft^2/ac) and the diameter of the trees. A larger tree will be tallied a farther distance away than a small one. Because plot size is not known, density cannot be measured directly as in other sampling methods. However, density can be obtained for each tree-diameter class if diameters are measured for the trees tallied.

A5.2.2 The number of sighting points needed for sampling and the appropriate BAF depend on the sample area and size of trees to be sampled, and are beyond the scope of this guide. Information on BAF choice and sampling designs can be obtained forestry tests **(6, 7, 8)** or in USDA Forest Service timber inventory procedures guides developed for each forest region of the U.S.

A5.2.3 Density measurements for unevenly aged-stands may be inaccurate when a single-sized instrument is used because large trees may block smaller ones, or one size class may be over- or underrepresented due to the BAF. Further limitations of the method are that accurate and precise variable radius sampling depends greatly on personnel skill, and dense understory vegetation may present a problem by restricting sight distances. (See **(6, 9)** for further discussion of methodology and theoretical considerations.)

A5.3 Sampling Procedure

A5.3.1 The variable radius tool is rotated through a full circle (360°) with the eye "fixed" at the center of the circle. Objects that appear to fill the aperture of an angle gauge or are not sufficiently offset by a prism are tallied and used to calculate the basal area of trees or shrubs (see Fig. A5.1).

A5.4 Summary Equations for Variable Radius Method

A5.4.1 Because each tree represents the same BA/land area in variable radius sampling, density may be calculated by totaling the BA/land area (m^2/ha) of all tallied trees and dividing by the BA (m^2) of a tree of a given size as shown below (adapted from Ref **(6)**).

$$Trees/Hectare = [No.\ Trees\ Tallied \times (BAF \div No.\ Points\ Sampled)] \div BA/Tree \quad (A5.1)$$

A5.5 Example Summary Table

A5.5.1 See Table A5.1.

Variable Radius Field Data Sheet

<<PROJECT NAME>>

Sample Site I.D.: ____________ Date: ________

Field Sampling Team: ________ ________ ________ ________

Data Management Filename: ____________ QA Check: ______

Basal Area Factor: ________

Taxon	Number	Taxon	Number
1.		6.	
2.		7.	
3.		8.	
4.		9.	
5.		10.	

General Comments: [Other taxa observed.]

FIG. A5.1 Example Data Sheet for Variable Radius Method

TABLE A5.1 Example Summary Table for Presenting Variable Radius Sampling Results

Taxon	Basal Area	Frequency	Relative Basal Area	Relative Frequency	Importance Percentage
Sp. 1	. . .	. . .	. . .	. . .	. . .
Sp. 2	. . .	. . .	. . .	. . .	. . .
Sp. 3	. . .	. . .	. . .	. . .	. . .
Sp. *n*	. . .	. . .	. . .	. . .	. . .
Totals	. . .	100.0	100.0	100.0	100.0

A6. DEFINED AREA METHOD

A6.1 Scope

A6.1.1 The vegetation sampling technique entails definition of an area to be sampled, enumerating all individuals by taxa, and measuring the size or cover values within the plot. It is the most basic and straight-forward vegetation sampling method available.

A6.1.2 Defined sampling is most commonly performed in a stratified random design, where a stand or unit of vegetation is chosen for sampling, and then quadrats are placed randomly within the stand. Defined-area sampling requires access to all parts of the quadrat, making this method potentially inappropriate in an impenetrable or hazardous area. Sampling may be non-destructive, in which plants are measured but not destroyed in a plot, or may involve harvest of plants within a plot. Harvest allows direct measure of biomass, and is most common in grassland vegetation. Harvest is clearly precluded in most sampling efforts.

A6.2 Sampling Design Considerations

A6.2.1 *Plot Shape*—Since any plot established within a community will result in the possibility of some individuals positioned on the boundary of the plot, some unbiased system must be established to decide whether an individual is to be tallied or not. One system may be to tally an individual if half or more of the plant stem is anchored within the plot. Another is to count every other individual that falls on the boundary, thus eliminating the need to decide how much of an individual crosses the line. In the field it will become obvious that determining the boundary is a difficult task. For a given area, the boundary or perimeter of the plot is greatest for a narrow rectangle, less for a wide rectangle, less for a square, and least for a circle. Consequently circular plots should result in fewer "in-out" decisions compared to squares. Squares should be better than rectangles. Wide rectangles should be better than narrow rectangles. However, site conditions, including vegetation type, must be considered before making the choice. Establishing a circular plot in thick vegetation is virtually impossible and will result in excessive sampling error. Sampling effort is greatly affected by the choice of plot shape.

A6.2.2 *Plot Size*—Ideally the plot size should be selected such that the data obtained fits (or at least approaches) a normal distribution **(1, 7, 9, 15)**. At the same time, the plot should not be too large, since a greater effort is required to tally the individuals and no additional information is gained (see Fig. A6.1). In fact, for certain purposes (for example, statistically determining associations) the larger plot may obscure the relationships. Plots for trees are commonly 100 m^2; shrub plots generally occupy 1 m^2 to 4 m^2; and herb plots range from 0.1 m^2 to 1.0 m^2. Generally as vegetation becomes more dense, smaller plot sizes are favored.

A6.2.3 *Number of Plots*—The number of plots to be sampled is dictated by several factors. Ideally, the sample number is driven by the statistical requirements defined in the data quality objectives. Heterogeneity of vegetation at the project area can impose practical limitations to the achievable statistical power. Also, cost and time constraints may be significant factors governing the number of plots sampled. Nevertheless, where practical, the sample size may be estimated as a function of variance and allowable error (or data quality objectives) using the equation:

$$N = (s^2)(t^2)/(d^2) \quad \text{(A6.1)}$$

where:
s^2 = the estimated or known variance (for example, trees per hectare),
t^2 = the Student's t value for the desired level of confidence (α), and
d^2 = the allowable error expressed in the same units as s^2.

A6.3 Sampling Procedure

A6.3.1 Data collection at each location includes notation of all pertinent information identifying the plot, enumeration of all individuals by taxa inside the plot, and a measure of size, age, cover or a combinantion thereof (for each individual in the case of trees and shrubs or collectively for herbaceous plants). See Fig. A6.2.

A6.4 Summary Equations for Defined Area Sampling

$$Density = No.\ of\ Individuals / Area\ Sampled \quad \text{(A6.2)}$$

NOTE A6.1—Dividing by unit area may be required to convert to a more desired individual per unit area measure (that is, from trees/m^2 to trees/ha)

$$Frequency = No.\ Plots_{Species\ I\ Present} / No.\ of\ Plots\ Sampled \quad \text{(A6.3)}$$

$$Dominance = \Sigma Phytomass_{All\ Species} / (Area\ Sampled / Unit\ Area) \quad \text{(A6.4)}$$

NOTE A6.2—Cover and basal area are commonly used in place of phytomass.

$$Relative\ Density = (Density_{species\ I} \times 100) / \Sigma Density_{Species} \quad \text{(A6.5)}$$

$$Relative\ Frequency = (Frequency_{Species\ I} \times 100|) / \Sigma Frequency_{All\ Species} \quad \text{(A6.6)}$$

$$Relative\ Dominance = (Dominance_{Species\ I} \times 100) / \Sigma Dominance_{All\ Species} \quad \text{(A6.7)}$$

$$Importance\ Percentage = (Rel.\ Density + Rel.\ Frequency + Rel.\ Dominance) / 3 \quad \text{(A6.8)}$$

A6.5 Example Summary Table

A6.5.1 See Table A6.1.

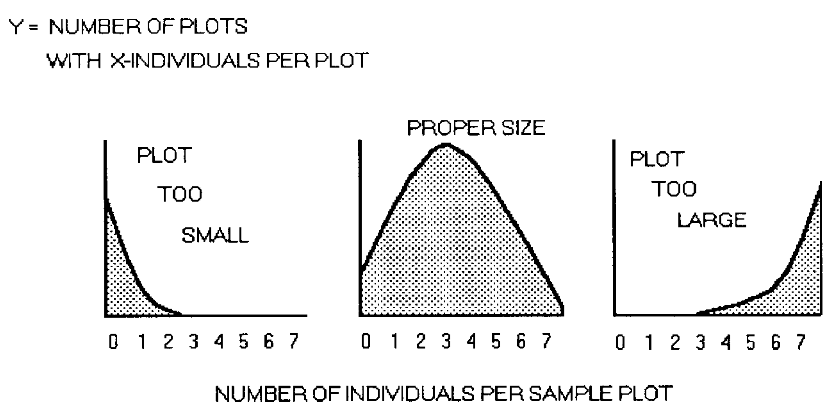

FIG. A6.1 Frequency Distribution Comparisons To Select Proper Plot Size

Defined Area Sampling Field Data Sheet

<<PROJECT NAME>>

Sample Site I.D.: ____________________ Date: ____________

Field Sampling Team: ________________ ________________ ________________ ________________

Data Management Filename: ____________________________ QA Check: ________

Taxon	DBH	Taxon	DBH
1.		16.	
2.		17.	
3.		18.	
4.		19.	
5.		20.	
6.		21.	
7.		22.	
8.		23.	
9.		24.	
10.		25.	
11.		26.	
12.		27.	
13.		28.	
14.		29.	
15.		30.	

General Comments: [Other taxa observed.]

FIG. A6.2 Example Data Sheet for Defined Area Sampling

TABLE A6.1 Example Summary Table for Presenting Defined Area Sampling Results

Taxon	Density	Frequency	Dominance	Relative Density	Relative Frequency	Relative Dominance	Importance Percentage
Sp. 1	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Sp. 2	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Sp. 3	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Sp. *n*	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Totals	. . .	. . .	. . .	100.0	100.0	100.0	100.0

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