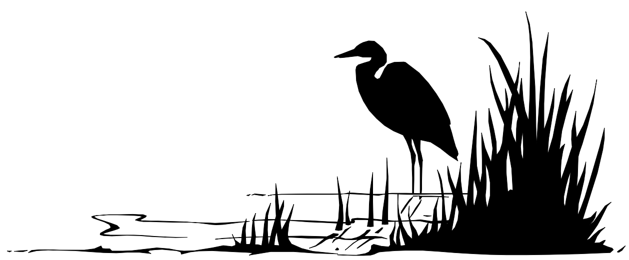
ECOLOGICAL MONITORING AND ASSESSMENT NETWORK

TERRESTRIAL VEGETATION MONITORING PROTOCOLS



EMAN Occasional Paper Series
Report No.9
EMAN Coordinating Office
1999

Environment Canada
Environnement Canada

Canada

TERRESTRIAL VEGETATION BIODIVERSITY MONITORING PROTOCOLS

by

Patricia Roberts-Pichette and Lynn Gillespie

on behalf of the

Vegetation Monitoring Protocols Working Group
of the
Biodiversity Science Board of Canada

for the

Ecological Monitoring and Assessment Network

EMAN Occasional Paper Series
Report No. 9

EMAN Coordinating Office
Canada Centre for Inland Waters
P.O. Box 5050
Burlington, Ontario, Canada
L7R 4A6
1999

Note to Readers

Occasional Papers are produced by the Ecological Monitoring Coordinating Office for the Ecological Monitoring and Assessment Network to enable circulation of a variety of documents. These can include meeting proceedings, contract reports or internal reports. The ideas and opinions expressed are those of the authors and do not necessarily represent those of the Ecological Monitoring Coordinating Office or of Environment Canada.
There is a limited number of each report produced; once they are distributed, no reprints are planned. Copies of these reports can be obtained through your library on Interlibrary Loan from Environment Canada Library at Ottawa. The report will also be posted on the EMAN web site <http://www.cciw.ca/eman>. Material from the reports may be copied without permission, but credit would be appreciated.

This report should be cited as follows:

Roberts-Pichette, Patricia, and Lynn Gillespie 1999. Terrestrial vegetation biodiversity monitoring protocols. EMAN Occasional Paper Series, Report No. 9. Ecological Monitoring Coordinating Office, Burlington, Ontario.

Copies of the report, and information on the Ecological Monitoring and Assessment Network, are available from:

The EMAN Coordinating Office
Canada Centre for Inland Waters
P.O. Box 5050
Burlington, Ontario
L7R 4A6

tel. (905) 336-4414
fax. (905) 336-4499
email: eman@cciw.ca

Aussi disponible en français sous le titre : *Protocoles de suivi de la biodiversité végétale terrestre*.

VEGETATION MONITORING PROTOCOLS WORKING GROUP

Terry Carleton
Faculty of Forestry/Department of Biology
University of Toronto
33 Wilcocks St
Toronto, ON, M5S 3B3

Bert Finnamore
Provincial Museum of Alberta
12845 - 102 Avenue
Edmonton, AB, T5N 0M6

Lynn Gillespie
Canadian Museum of Nature
PO Box 3443, Station D
Ottawa, ON, K1P 6P4

Ole Hendrickson
Canadian Forest Servce
Natural Resources Canada
Booth St
Ottawa, ON, K1A 0E4

Janet Lamb
EMAN Coordinating Office
CCIW
PO Box 5050
Burlington, ON, L7R 4A6

Bruce MacDonald
Kejimkujik National Park
Maitland Bridge, NS, B0T 1B0

Patricia Roberts-Pichette
430 Besserer St, Suite 300
Ottawa, ON, K1N 6C1

Jennifer Shay
Department of Botany
University of Manitoba
Winnipeg, MB, R3T 2N2

Liette Vasseur
Department of Biology
Saint Mary's University
Halifax, NS, B3H 3C3

ACKNOWLEDGEMENTS

We gratefully acknowledge the members of the Biodiversity Science Board Canada and the following people for their critical observations and practical suggestions during the preparation of this document: Alice Casselman, Jean-Yves Charette, Bill Clemens, James Cominsky, Brian Craig, Leslie Free, Erich Haber, Peter Hall, Heather Hamilton, Tim Hopkins, Robin Hughes, Sue Hughes, Gary Ironside, Jill Johnstone, Susan Laurie, Annick LeHénaff, Jennifer Moore, Louis Noreau, Sally O'Grady, Diane Palen, Pedro Pereyra, Judit Peterfi, Paul Quinn, Ginette St Laurent, and Pixie Williams.

We would particularly like to thank Edward Hearn for giving so generously of his time and experience in assisting us with the illustrations, Gerard Courtin for providing critical technical advice; and the independent peer reviewers for their constructive comments and encouragement. This document could not have been completed without the essential services provided by the EMAN Coordinating Office and the support for the translation received from the Canadian Museum of Nature.

TERRESTRIAL VEGETATION BIODIVERSITY

MONITORING PROTOCOLS

Contents

PREFACE

Change is a constant in ecosystems - the environment directs what will grow where and whether it will survive to maturity and reproduce. A forest community that was established after a fire 100 years ago is not the same as one that was established 50 years ago or which will establish after a fire next year. Plants, whether woody or herbaceous, eventually die and are replaced. Ecosystems may be very different at different stages depending on the requirements of their constituent species. Many plants rely heavily on animals for seed dispersal, and will eventually disappear without their aid. Other species may disappear because of the attack of insects or diseases; other species either exotics or natives, may invade. Recently, statements about the impact of climate change, toxins, UV-B and land use change have raised public concern about the loss of certain valued species or ecosystems, and the effect this might have on future human health and economic well-being. Long term ecological monitoring (greater than 50 years) is the way to document what is changing in plant ecosystems, at what rate, and with what results. Monitoring results should also give warning of what is likely to happen, and thus allow for preventive or adaptive action.

The protocols presented here are a set of robust methods recommended for long term monitoring of plant species diversity. Their use will enable observers to document changes in species (abundance, richness, and community structure) and therefore ecosystem change over the long term. They are to be used in conjunction with protocols for monitoring other terrestrial organisms living above or below ground, and for monitoring selected climatic and other abiotic variables (described in other EMAN reports).

What sets this monitoring program apart from many other research or monitoring programs is the quantitative data that is being collected - only that which can be counted or measured is recorded. Estimates are not made in the field, even though indices or scales may be derived from the data collected. Everything must be documented. This precision is what will prove of most value in the long run.

The focus of this set of protocols is the above-ground vegetation components of forest and non-forest ecosystems. In the future, methods for monitoring other plant groups are to be added. They all yield useful information on community composition and performance of the plant species that make up Canadian ecosystems.

Users of these methods are invited to provide feedback on the ease of use and usefulness of the methods described.

Patricia Roberts-Pichette
430 Besserer Street, Suite 300
Ottawa, ON, K1N 6C1
mabexsec@sympatico.ca

Lynn Gillespie
Canadian Museum of Nature
Ottawa, ON, K1P 6P4
lgillespie@mus-nature.ca

INTRODUCTION

"The use of permanent quadrats has been advocated by many ecologists, but few have followed their own excellent advice. Whenever there is the possibility that a sampling area may again be visited for further study, the quadrats should be marked permanently, for surprisingly worthwhile results may be obtained by restudying identical areas over a period of years. Such results are often valuable out of all proportion to the effort required, especially when compared to the initial study" (H. J. Oosting. The Study of Plant Communities. 1956).

This document has been prepared to aid groups starting a long-term species diversity monitoring program, or considering the expansion of current programs by the addition of more variables. The purpose of this document is to present in one manual a basic set of robust methods that can be used by a wide variety of people of differing skill levels. The methods are designed so that different research and monitoring groups can compare their results directly; and the results obtained by different groups can be pooled, making data gathered for local purposes useful in a broader context, ranging from regional to international. It is also a base upon which more sophisticated methods could be built.

Study of a variety of long-term data sets, each using the same standard methods, should provide insights about species change over broad regions, raise questions for additional research, and help define or circumscribe unexpected environmental problems. The methods included in this manual are not meant to supersede methods already in use (unless current methods are found to be wanting in some respect). Given that long-term biodiversity monitoring is so rare in Canada, it is far more important to continue with a monitoring program with original methods than to change to newly recommended ones (unless there is an adequate period of thorough testing of both methods together to ensure that the change-over will not be detrimental to the data set).

The terrestrial plant biodiversity protocols presented here are based on the use of permanent, square monitoring plots of differing sizes. The focus is on the above-ground vascular plants, and also includes lichens and mosses growing on the ground surface. Methods for monitoring other plant groups are currently under consideration (e.g. fleshy fungi, epiphytic lichens and mosses). Other variables related to species behaviour or ecosystem function such as periodicity of flowering, rates of decay, photosynthetic surface, and reproductive potential (eg. number of flowering shoots, date of flowering, quantity of seeds set, seed viability, annual seedling density, etc.), will also be prepared.

To monitor long-term[2] changes in plant biodiversity in different ecosystems, permanently marked sample areas are essential. The square plot format has been adopted as an Ecological Monitoring and Assessment Network (EMAN) standard. Permanent plots are recommended for use in plant communities where there are no obvious vegetation gradients. Where vegetation gradients are obvious, permanent transects are recommended.

With the increased use of satellite data, ground-truthing is essential to interpret the data. Permanent monitoring plots that collect reliable data can act as standard reference points for the interpretation of changes observed by satellite, i.e., they become permanent ground-truthing stations.

Methods are described for monitoring plant diversity change over time in the various strata of those plant communities that make up Canadian terrestrial ecosystems. Plot sizes for different vegetation strata are recommended, and plot layout and numbers are suggested. EMAN recognizes that local circumstances and interests will dictate specific applications.

Researchers with specific time-limited projects have legitimate reasons for choosing the methods they use. EMAN invites these researchers to consider using the sizes and shapes of the sample plots recommended here, if they are appropriate for their purposes. The data collected from short-term research studies using these standards could provide valuable information for long-term monitoring programs and the interpretation of their data.

Reference throughout the text is made to the "Responsible Group". This is the term used for the group who have the responsibility for overall decision-making and coordination of all monitoring and research at any monitoring, field, or research station. In this capacity, the Responsible Group also has the responsibility to ensure that: 1) all people working in the monitoring program(s) properly record and archive their data; 2) data are subject to quality assessment and quality control; and 3) metadata (information about the data) standards are upheld. This should be done so that future users of the data are not frustrated by not knowing where or why the data were collected in the first place. In addition, the Responsible Group should ensure that plans for periodic reviews of the objectives, progress, and results of the monitoring program(s) are built into the decision-making process.

Before starting a long-term monitoring program, and specifically before laying out permanent plots, the Responsible Group should:

a) complete and record the long-term rationale, objectives and experimental design of the monitoring program

---

[2] *Long-term* in this document is defined as at least 50 years, with an initial planning horizon of at least ten years.

b) ensure that data management systems and archiving arrangements are in place
c) visit all candidate stands and select those suitable for the proposed plots - necessarily a subjective process
d) obtain the necessary authority and permits for undertaking the proposed monitoring program in the selected stands
e) undertake the preliminary stand appraisal(s), and prepare a preliminary plant inventory, together with voucher specimens as appropriate.

Above all, the Responsible Group should make sure that people with appropriate expertise are available and involved in all steps. This includes people with statistical and data management expertise.

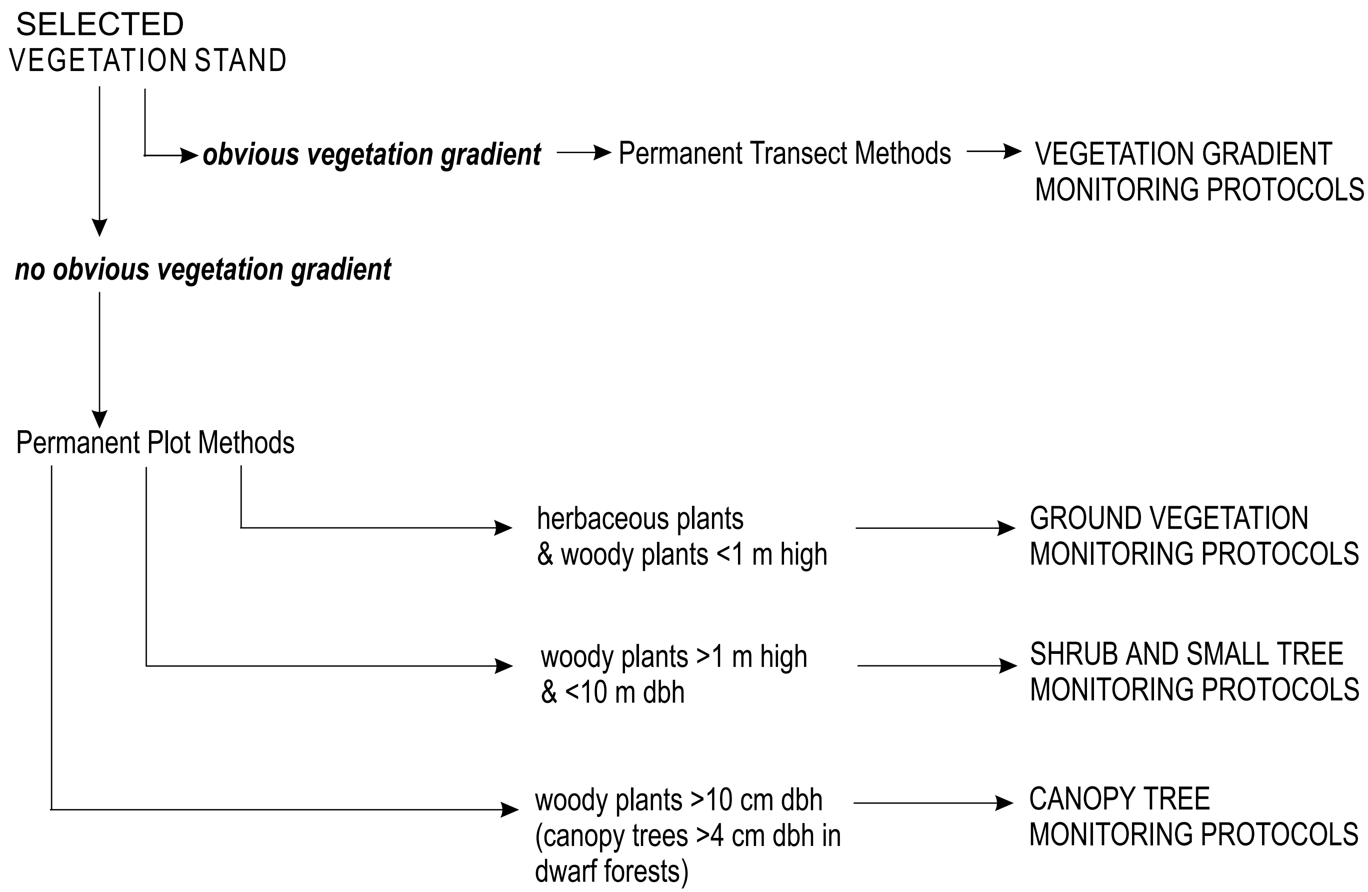
It is also essential that the Responsible Groups in the same ecozone (or ecoregion or ecodistrict) consult and cooperate with one another when establishing biodiversity monitoring programs. They should encourage expertise sharing, and the integration and synthesis of data from individual sites. This will facilitate the scientific interpretations that are applicable to a wider geographic area.

This document gives the rationale and the methodology for establishing the following plot sizes:

! one hundred-by-one hundred metre (1-ha) permanent canopy tree biodiversity monitoring plot
! twenty-by-twenty metre permanent stand-alone canopy tree biodiversity monitoring plot
! five-by-five metre permanent small tree and shrub biodiversity monitoring plot
! one-by-one metre permanent ground vegetation biodiversity monitoring plot
! permanent transects organized as contiguous five-by-five metre plots
! permanent transects organized as contiguous one-by-one metre plots

In addition, the essential and desirable measurements appropriate to each plot size are listed, as are the methods for making these measurements, and the formulae for the initial processing of the data. A flow chart as an aid for selecting the appropriate protocols for the different vegetation strata is to be found overleaf.

TERRESTRIAL VEGETATION BIODIVERSITY MONITORING PROTOCOLS
FLOW CHART



SECTION I

CANOPY-TREE STRATUM BIODIVERSITY MONITORING PROTOCOLS

Table of Contents

Introduction

This section describes the methods recommended for monitoring trees that form the canopy stratum of a forest community. The methods described are recommended for use in stands that have no strong vegetation gradients. Where strong vegetation gradients exist (e.g. at tree line or in proximity to water bodies), permanent transects are recommended for a monitoring program (see Section IV) .

Trees, for the purposes of this document, are defined as normally being at least 10 cm in diameter at breast height (dbh), that is, at 1.3 m above ground level. This is a generally accepted standard in ecological and forestry texts dealing with temperate forests. However, many trees at the edges of their range or in harsh environments do not reach the size defined above, even though they form the canopy of a forest community. See Section II for monitoring small trees that do not form the canopy. This section describes the methods recommended for monitoring trees that form the canopy stratum of a forest community. See Section II for monitoring small trees that do not form the canopy.

Rationale

The long-term monitoring of trees on a permanently marked forest plot gives important information on the structure and composition of a forest; on the condition, growth rates and longevity of the species of trees composing that forest; on changes in species composition or population size that occur over time; and the impacts of environmental change on mature trees, etc. Such long-term monitoring is also essential for the reliable future assessment of current management decisions affecting forest vegetation. Permanent plots that are accurately monitored are also important as potential satellite ground-truthing sites.

One important permanent-plot monitoring program in Canada, for the detection of change in the condition of forest tree species, is the ARNEWS network managed by the Canadian Forest Service (Hall and Addison, 1991). While the objectives of ARNEWS differ from those of EMAN, some of the ARNEWS protocols (D'Eon, Magasi, Lachance and Desrochers, 1994) could be used with those of EMAN. Likewise, many of the methods described in this document could be used in conjunction with ARNEWS plots. Each program would probably benefit from an exchange of results and experience.

Plot[1] Size

For major long-term research and monitoring of forest ecosystems, EMAN recommends two plot or quadrat sizes for monitoring canopy trees: 100 m x 100 m (1-ha) and 20 m x 20 m.

---

[1] *Plot* and *quadrat* are usually synonymous terms for measured areas of vegetation used for sampling. The SI/MAB protocol uses *plot* for the hectare and *quadrat* for the 20 m x 20 m sub-plots. EMAN uses other sizes for sampling, all of which are referred to as *quadrat*s. In this text, *plot* is used for the hectare size and *quadrat* for all other sampling sizes. *Plot* is also used in a general collective sense.

In 1994, EMAN selected the square, one-hectare plot as a standard for monitoring the biological diversity of trees in Canadian forest ecosystems. The one-hectare plot, also known as the SI/MAB plot, is one internationally used standard recommended by the Smithsonian Institution (SI) and the UNESCO Program on Man and the Biosphere (MAB) for monitoring tree biodiversity in tropical forests (Dallmeier 1992).

Subsequently, experience with the hectare plot demonstrated that a second size was needed in Canada. The 20 m x 20 m stand-alone quadrat was selected. The two sizes may substitute for one another as explained below, or may be used together.

i) One-hectare (SI/MAB) plot: Plots of this size may be used where the stands are large enough to accommodate them, the majority of trees making up the canopy are over 10 cm dbh, and the resources are available to establish the plot and undertake the measurements at the recommended time intervals. The use of a one-hectare plot gives a relatively large sample and, therefore, is likely to be reasonably representative of the selected stand with respect to spatial relationships of the species, patchiness, tree fall, species composition, etc. Its use avoids the unintentional bias often introduced by the use of smaller plots, which could exclude gaps or small atypical parts of a forest stand. A disadvantage of the 1-ha plot is that it can be time consuming and expensive.

Data from one large plot in a single stand, while invaluable for a specific site, must be combined with data from other sites to obtain maximum benefit at local, regional, and national scales. It is therefore essential that the Responsible Groups who are using hectare plots within the same ecozone, coordinate their activities and pool their data of the same community type for analysis and interpretation. This will help validate their own results, provide more reliable estimates of change or stability in tree diversity within or across community types in an ecozone, and provide the base for comparisons across ecozones. Over the long term, this approach will help distinguish local effects from regional ones. It is also a powerful tool for bringing public attention to changes occurring over a broad spatial scale.

ii) Twenty by twenty metre stand-alone quadrats: Twenty by twenty metre stand-alone permanent quadrats are relatively inexpensive to establish and allow multiple plots to be set up in a single large stand, or in several neighbouring stands. While quadrats of this size of quadrat may be used in any forest stand, they are particularly recommended in the following situations:

a) tree stands occupying limited areas (e.g. small woodlots, city or narrow valley forests), where a 1-ha plot is too large for the size of the stand;
b) "dwarf" forests with most trees under 10 cm dbh, e.g. in northern taiga or high elevation forests at or near the treeline;
c) dense, young, even aged stands with most trees under 10 cm dbh, e.g. many young coniferous forests; and stands of young aspen. Many of these stands are made up of one or few species, and date from a fire or insect attack.
d) research projects requiring many tree sampling plots to answer specific local and often short-term questions;
e) a permanent hectare plot that has been subjected to fire, clearcut or extensive blowdown, and therefore exhibits massive change. Time and resources may dictate that a limited number of the original 20 m x 20 m quadrats be monitored until the canopy has closed.

Permanent Plot Establishment

This section contains guidance for deciding on the number and arrangement of monitoring plots for forests that have no obvious vegetation gradients (see Section IV for guidance on monitoring communities with obvious vegetation gradients or discontinuities) and the information necessary for surveying 20 m x 20 m stand-alone quadrats and 1-ha plots. The stands to be monitored first have to be selected: this will depend on the stands available and the defined monitoring objectives. Give a name to each stand selected.

Plots established in city forest stands, parks or other areas where the public has unrestricted access, should be as discrete as possible and should be well spaced to reduce the effects of vandalism. In such situations, information should be made available to the public about the objectives and benefits of the program, and opportunities for public participation should be provided.

During the planning process for the establishment of forest monitoring plots, the Responsible Group should decide upon the full scope of its monitoring program. For example, if understorey strata are to be studied using nested quadrats, their locations should be selected before any surveying begins, so that all nested quadrat stakes can be set at the same time as the plot stakes.

One important factor to be considered in the planning process is whether the ground vegetation of the stand is to be monitored and its sensitivity to disturbance by trampling. If it is lush, moss, or lichen-dominated and is to be included in the monitoring program, then proper scheduling of activities, and the separation of ground vegetation plots from the canopy tree plots is crucial to prevent damage (see Section III). For example, the time of the survey of canopy tree plots must be considered to prevent damage to lush ground vegetation (fall or early spring); any plot with lichen-dominated ground layer should be walked on only after rain or a very heavy dew. Attention to this factor during the planning process will increase the likelihood that the changes observed are "real" and not due to the effects of the people collecting the data.

1. How to decide on the number[2] of plots

The number of hectare plots or 20 m x 20 m stand-alone quadrats is often predetermined at any one stand or research site by the time and resources available and, especially in urban areas, the size and shape of stands and the local restrictions respecting their use. The Responsible Group should decide on the number of plots in light of the goals of the monitoring program, statistical advice and the estimated number of species present.

i) One-hectare plots: A single plot is often all that a community volunteer group can manage. Larger research and monitoring sites, including biosphere reserves, should be able to manage at least two plots in each forest type selected.

ii) Twenty-by-twenty metre stand-alone quadrats: The minimum number of 20 m x 20 m stand-alone quadrats in any stand is probably at least five (for northern forests) and approximately ten (for southern forests). A species accumulation curve (see *How to prepare a species accumulation curve*) can be used as a guide in deciding if this number is sufficient for a particular stand. Statistical advice and other monitoring or research objectives may call for more quadrats than determined using the species accumulation curve.

[2] Barbour *et al*., 1999, has a table which suggests a range of numbers of quadrats for monitoring different ecosystems and different strata within those ecosystems. The minimum numbers suggested in this document are derived partly from this table and partly from experience in Canada.

2. How to select the position of the plots

All plots should be randomly distributed in the chosen stand(s) to reduce bias; similarly, the location of a single plot should be selected by a random method. The method described below is one way in which random selection may be achieved. On occasion, plot location(s) in a stand may be selected for specific and subjective purposes. Document the reasons for the location, number and arrangement of plot(s).
In selecting the specific location of each one-hectare plot or 20 m x 20 m stand-alone quadrat, there are several underlying principles that should be observed:

a) In general, plots should be located at a distance from a non-forest stand edge equivalent to at least three times the canopy height. This is to exclude environmental effects (e.g. light penetration, temperature and wind speed differences) due to the proximity of the plot to an edge. This should apply to all hectare plots and, as much as possible, to 20 m x 20 m stand-alone quadrats.
b) Hectare plots should be at least 250 m apart, and 20 m x 20 m quadrats should be at least 50 m apart.
c) In small or irregular stands where the conditions in (a and b above) cannot be met, only 20 m x 20 m stand-alone quadrats (not 1-ha plots) should be used. They should be placed at a distance from the stand edge at least equal to the height of the canopy.
d) In riparian and lacustrine[3] forests where the trees occupy bands 60 - 200 m wide, and the trees are the object of study rather than the vegetation gradient, 20 m x 20 m quadrats should be established - they will be more or less parallel to the water course. When the band is less than 60 m wide, the use of transects is recommended (Section IV).

As an application of these principles:

e) Avoid setting up plots that include atypical (for the stand) major vegetation gradients or sharp ecological discontinuities, e.g. small lake, field, river.
f) Avoid locations where roads or trails run through the plots, unless the impact of the use of trails is the object of the monitoring. In that case, ensure the reason is documented.

One method for randomly selecting plot position is to obtain or prepare a rough chart or map of the stand and overlay it with a grid of an appropriate scale (Figure I.1). Using a table of random numbers (or alternatively, a bag of numbered chips or balls), select one or more cross points (depending on whether a hectare plot or a series of 20 m x 20 m stand-alone quadrats is/are to be established), rejecting any that do not meet the conditions outlined above. Each selected cross point becomes the centre point of a monitoring plot.

[3] Since *riparian* and *lacustrine* vegetation both refer to zones of vegetation bordering respectively rivers and lakes, for convenience, *riparian* will be used in this document to describe these vegetation zones, whether they border a river or a lake.

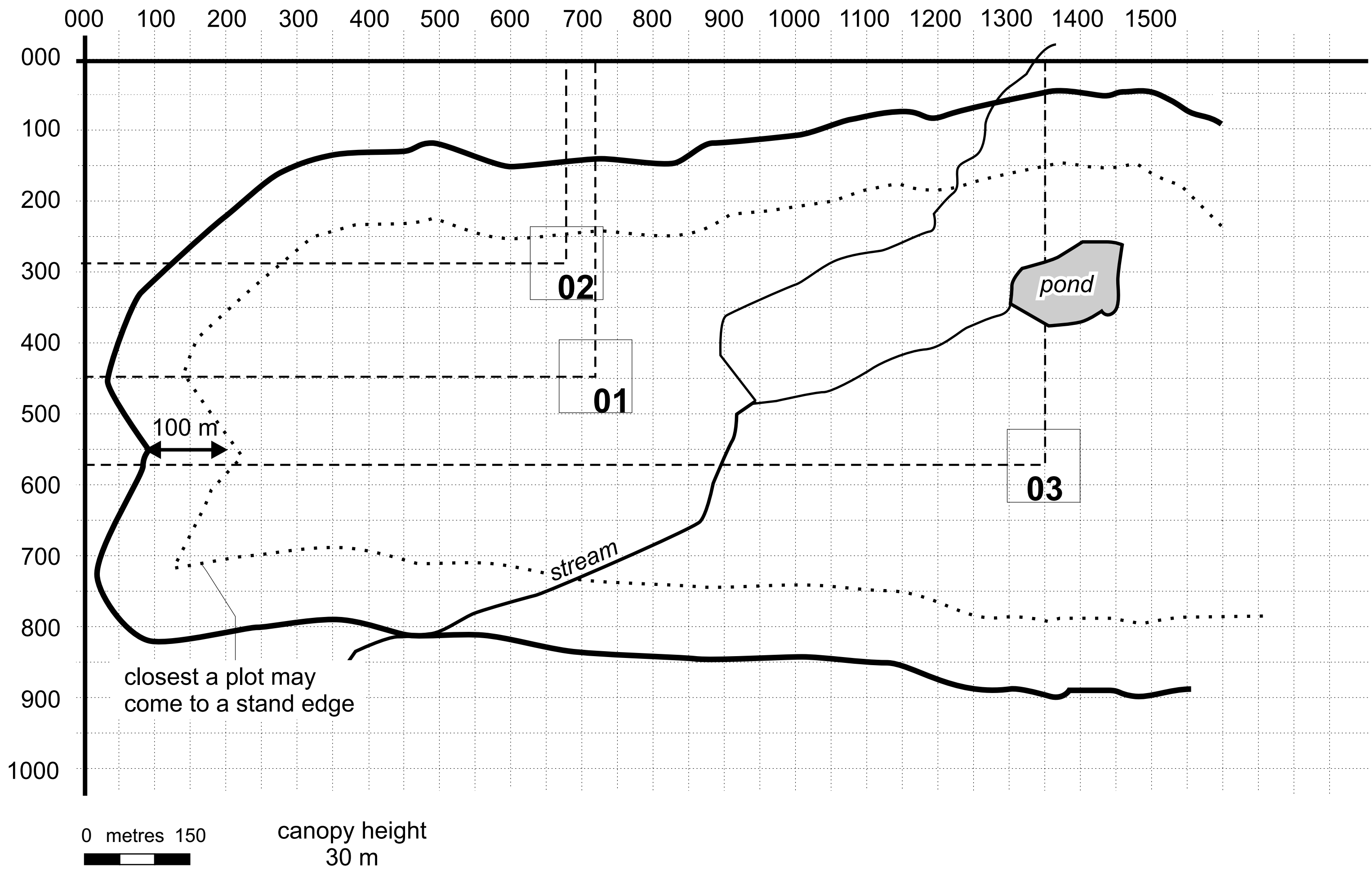


Figure I.1: Rough chart of large selected stand overlaid by a grid of horizontal and vertical lines. Randomly selected coordinates for 01 and 03 would be acceptable, whereas those for 02 would be rejected.

3. How to survey a permanent monitoring plot[4]

Equipment:
- stand chart and list of the randomly selected plot coordinates
- theodolite and tripod
- two steel survey tapes (minimum length 30 m)
- one 2-m telescoping surveying rod (with levelling bubble) that extends to 4 m
- flagging tape
- survey stakes (preferably metal-core plastic), in at least two colours for the 1-ha plot (four of one colour and 32 of the other)
- two heavy mallets
- GPS (global positioning system) instrument with data differentially corrected
- waterproof record book and pencils

Note on stakes: Given the variety of situations in the field, there is considerable room for local initiative in experimenting with different types of stakes depending on what is available. When selecting a stake consideration must be given to its labelling, and the necessity for balance between the need for visibility and the need to be discrete. Stakes must be permanent and sufficiently large so that they can be labelled with the number of each quadrat of which they form a corner. The numbers could be written on the top of the stake or on each side of the stake. If appropriate, an inscribed disc could be attached to the top of the stake.

Team: minimum of three

Season of survey: The preferred time to survey the tree plots is in the fall before any major snow accumulation, when the absence of leaves makes the process much easier. This season will ensure that damage to the ground vegetation is minimal. A second choice would be before the frost is out of the ground in spring. Deciduous trees may be identified when leafless from twig and bark characteristics, so should not prevent spring and fall surveying.

Method: Find the predetermined plot location or previously set centre stake, using the stand chart and the coordinates (Figure I.1). Each plot should be laid out square to the general slope or, if without a visible slope, to the cardinal compass points. Assign a number to each plot or stand-alone quadrat as it is established. For both a 1-ha plot and a 20 m x 20 m stand-alone quadrat, the first part of the method is exactly the same.

To begin the survey, proceed to the preselected point and insert a stake if not already in place (Figure I.2). This stake will be the centre of a 20 m x 20 m sample (either a stand-alone quadrat or quadrat #13 in a hectare plot), and the common point from

---

[4] This method has been adapted from Dallmeier, 1992.

which all four corners of the 20 m x 20 m quadrat are established. Record the latitude and longitude of this stake (hectare plot only). Set up a tripod-mounted theodolite and level it over the centre of the stake using a plumb-bob[5].

Make all measurements to the nearest centimetre.

With the tripod in position, the instrument operator sights along a diagonal bearing to establish the first corner. Make sure in establishing this quadrat that it is properly oriented. Technician A goes down the line with a tape measure a distance of 14.124 m - half the diagonal distance of the 20 m x 20 m quadrat (Figure I.2a). Make any necessary slope corrections (see below) before setting the stake. Technician A holds the surveying rod vertically over the stake at 14.124 m as a target for determining the true bearing. Technician B pushes aside branches or small stems so that the instrument operator has a clear line of site and the vegetation is kept from deflecting the tape. **Survey teams must not cut down trees or shrubs.** Repeat the procedure until four stakes are permanently set. With four stakes in place, a 20 m x 20 m stand-alone quadrat, or the centre quadrat(#13) of a hectare plot is established. In setting the quadrat in this way, any error introduced by moving the theodolite while establishing the first four corners is avoided. This is important in the one-hectare plot to reduce survey errors.

i) For 20 m x 20 m stand-alone quadrats: Before proceeding further, do the check measurements. Set the theodolite over one corner stake, adjust the level and check the distance to the adjacent corners; repeat the check over the diagonally opposite stake. For example, from the A stake check the distance to corners B and D (Figure I.3b), and from the C stake check the distance to corners B and D. Make any necessary adjustments.

Assign the quadrat a unique (identifying) number. Label each corner stake with the quadrat number and corner letter (Figure I.2a), record the latitude and longitude of the A corner stake, and the compass bearing of line A-D (the base reference line - BRL). Continue the survey of quadrats until the number already determined (see *How to decide on the number of plots*) has been established. Identify the species[6] in each quadrat. Prepare a species accumulation curve (see *How to prepare a species*

---

[5] When using the theodolite, avoid taking measurements in close proximity to metal objets such as belt buckles, jewellery, glasses with metal frames, or wrist watches, as they could cause errors in the magnetic readings. It is also important that the tapes are pulled snug to avoid sagging and distortions in measurements. An error of only a few centimetres in initial measurements can result in large errors at the border of a hectare plot.

[6] The identification of the trees is usually possible at any time of the year. Therefore, the species accumulation curve should be done before the surveyors leave. If the species are not identified, the survey will have to be a two-stage process.

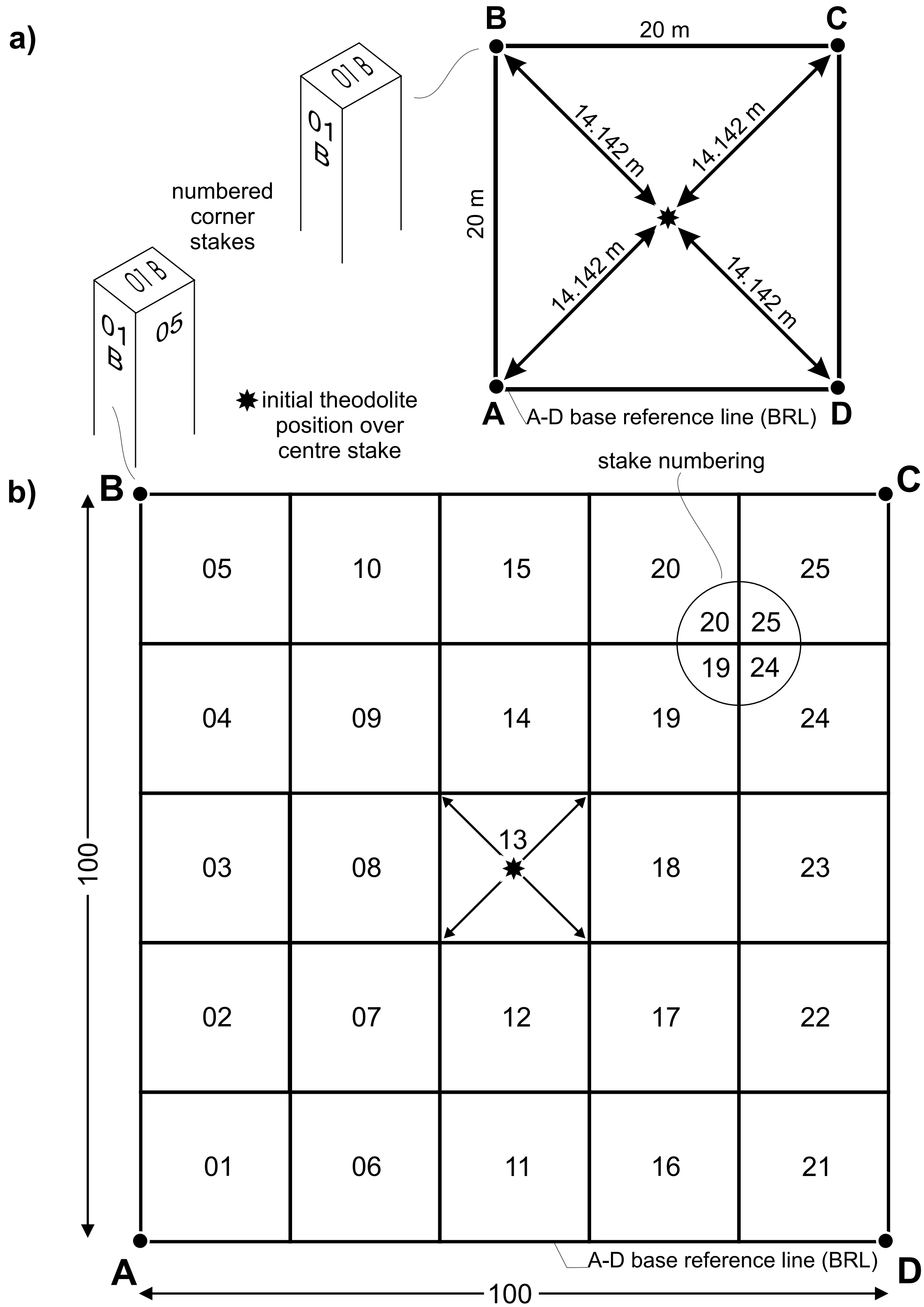


Figure I.2: Plan of the 20 m x 20 m stand-alone and 1-ha tree biodiversity monitoring plots and methods of labelling stakes. (a) Layout for 20 m x 20m stand-alone quadrat, or quadrat #13 of a 1-ha plot. (b) Layout for 1-ha plot (based on Dallmeier, 1992).

accumulation curve) to determine the adequacy of the sample. If the number of quadrats is insufficient, establish additional quadrats (in groups of two) until at least the minimum number is reached.

ii) For a one-hectare plot: From quadrat #13, establish the remaining 20 m x 20 m quadrats, making any needed slope corrections and setting permanent corner stakes. Use the appropriate stake colour (one colour for the four outside corners, and another colour for all other corners). Label the top of each stake with the numbers of the quadrats it touches (Figure I.2b) or place the quadrat number on the appropriate side of stake facing into each quadrat. In addition, label each of the four outside corner stakes with the plot identification number and the corner letter (Figure I.2b). Each time the plot boundary is reached, return to a corner of quadrat #13 and survey in a different direction (Figure I.3). When all four directions to the boundary have been surveyed, survey the remaining quadrat corners. Record the latitude and longitude of the A corner stake, and the compass bearing of line A-D (the base reference line - BRL).

Set each new corner stake as follows (Figure I.3):

a) From a previously set stake, sight along the appropriate bearing and measure 20 metres. If the sight-line is not clear, flagging at 5-m intervals may be helpful.
b) Determine the slope and calculate the slope correction factor.
c) Measure the slope corrected distance and permanently set the new stake. If slopes are steep, it is helpful to set temporary slope-corrected stakes at 5-m or 10-m intervals.

Record in pencil the survey data in a waterproof notebook for later transcription into a permanent record book or electronic file:

- number and coordinates of the starting or set stake
- number and coordinates of the stake being set (or being used as a check)
- slope angle
- slope-corrected distance

Three different bearing measurements must be taken at each stake, the back and check measurements being needed to reduce error accumulation:

a) back measurement (from the set-up point back to the previous stake on the same line)
b) check measurement (from the set-up point to previously established stakes on either side of the current line)
c) new measurement (to set the next stake on the current line)

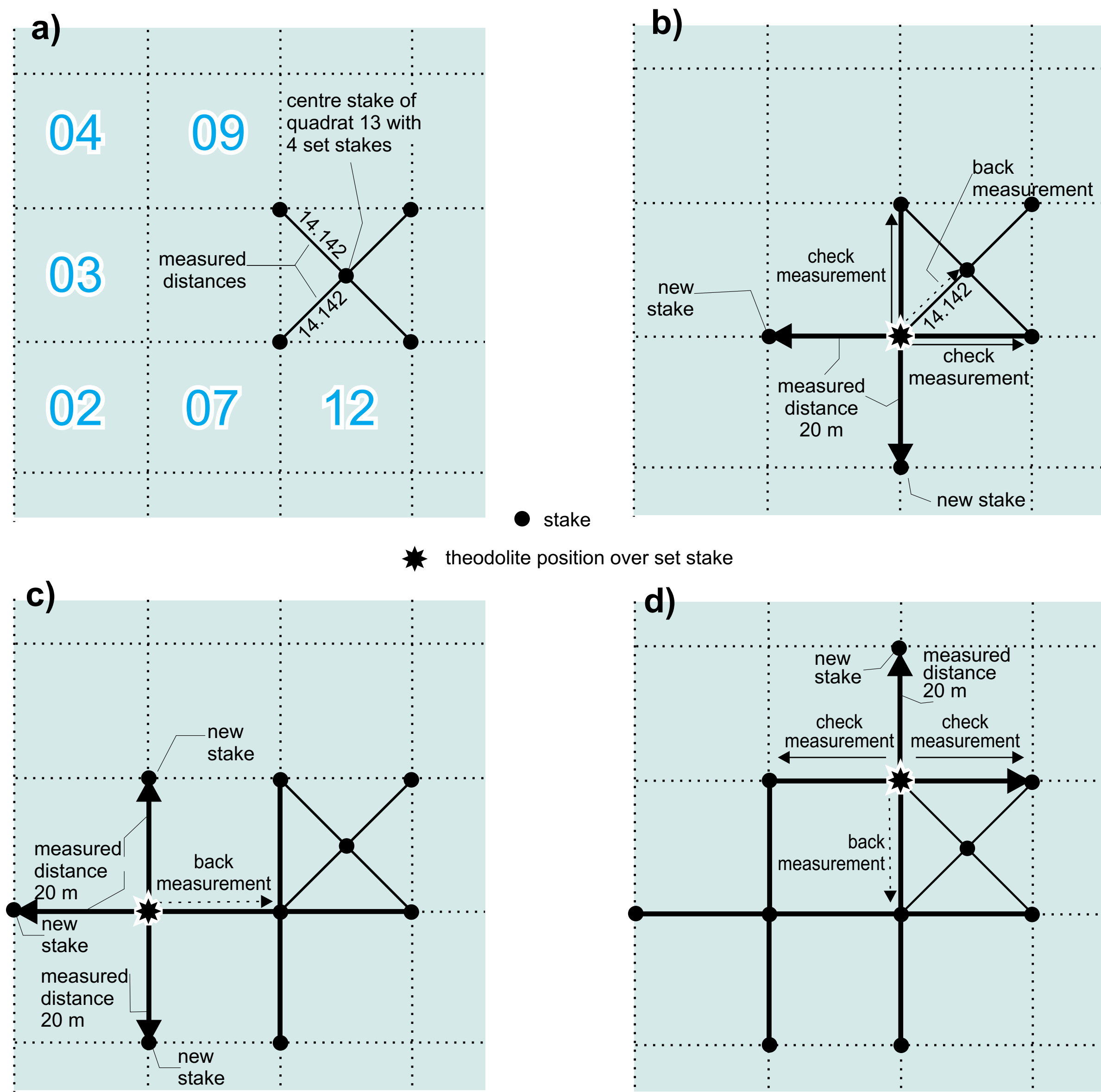


Figure I.3: Plan for setting and checking stakes for the quadrat corners of the one-hectare plot.

a) the centre stake and the four corner stakes of quadrat 13; part of the rest of the plot is shown as dotted lines.

b) theodolite set over the A corner stake of quadrat 13, from which: two new corners are measured and stakes set - the A corner of quadrats 08 and 12; check measurements are made to corners B and D of quadrat 13; and one back measurement made to the centre stake of quadrat 13.

c) theodolite set up over the A corner stake of quadrat 08, from which: three new corners are measured and stakes set - the A corner of quadrats 03, 07 and 09; and the back measurement made to the A corner of quadrat 13.

d) theodolite set over the B corner stake of quadrat 13, from which: one new corner is measured and stake set - the C corner of quadrat 09; the check measurements are made to the A corner of quadrat 09 and the C corner of quadrat 13; and the back measurement made to the A corner of quadrat 13.

4. How to make a slope correction [7] [8]

On uneven or sloping terrain, the 20-m distance between quadrat corner stakes must be adjusted to account for slope. The purpose of this correction is to ensure that each quadrat contains 400 m^2, regardless of the plot topography. This is also necessary when mapping and presenting the result as if the topography were flat (planar mapping). As shown in Figure I.4, the difference between two the corner stakes situated on a slope is always greater than the corresponding horizontal distance.

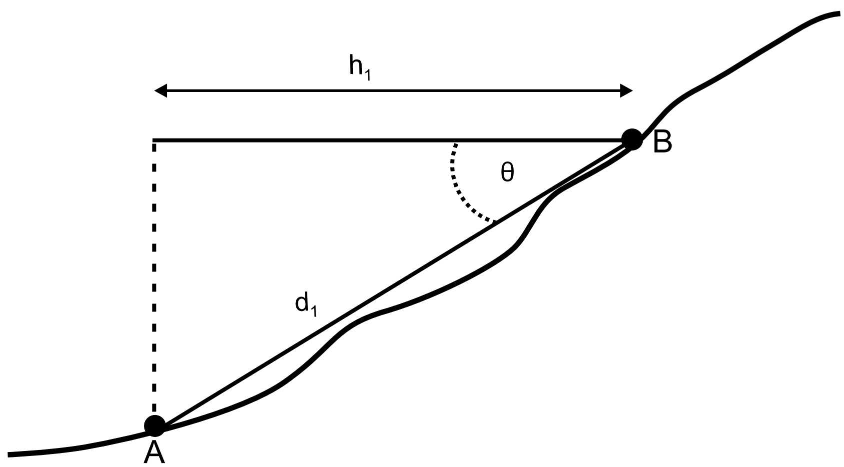


Figure I.4: Slope correction. The distance between two points measured along a slope is always greater than the corresponding horizontal distance. On sloping ground, the 20 m interval between stakes must therefore be extended by a factor corresponding to the degree of slope. (h_1 horizontal distance, d_1 corrected distance, angle theta *(*θ) from the horizontal between A and B)

As the map is derived from horizontal distances between stakes, the 20-m interval between corner stakes on sloping ground must be increased by a distance related to the degree of slope.

The corrected distance (d_1) between stakes on sloping ground is determined as follows:

Step 1. Measure approximately 20 m from the set stake (A) along the bearing to the new stake (B)

Step 2. Measure the angle theta (θ) from stake A to stake B using the theodolite or Clinometer

[7] This method is after Dallmeier, Cominsky and Mistry, in preparation

[8] While the following discussion focuses on slope corrections in relation to establishing corner stakes, the same procedure is used to obtain slope-corrected measurements when mapping trees.

Step 3. Calculate d_1 by one of two methods:

i) Table 1 method

$$d_1 = \frac{h_1}{\text{cosine } (\theta)}$$

ii) Table 2 method but only if h_1 = 20m

Step 4. Measure the corrected distance (d_1) along the bearing and reposition Stake B.

Step 5. Remeasure the angle (θ) from stake A to stake B

Step 6. If the angle has changed from the initial measurement (Step 2), repeat Steps 3, 4 and 5 until there is no change in the angle.

Example: If h_1 = 20 m and θ = 22.5°,
then *cos* (cosine) θ (22.5°) = 0.924 and d_1 = 21.684 m)

Measure to the closest centimetre. For accuracy, the final placement of all corner stakes should be made with the aid of a plumb-bob.

In determining the angle of slope, it is important that the measurement be taken along a line of sight parallel to the average slope of the ground, that is, the height of the instrument should be equal to the height of the target. Since the measurement begins at the eye level of the surveyor, it should end at an equal height on either the surveying rod or the body of the technician.

Two step method for slope correction: When the location of the next corner is out of sight of the theodolite operator, such as when the crest of a steep hill falls along the line between two adjacent corners, a two step procedure is used. The procedure is essentially the same as that outlined above, except that the 20 m distance is measured in two (or more) parts. Measure from stake A to the crest of the hill (stake A_1) and from stake A_1 to stake B to determine the approximate distances between the stakes. To determine the corrected distances (d_1, d_2) follow the Steps 1 - 6 above and use Step 3 ii (Table 1 and the formula) for the calculations (Figure I.5). The distances d_1 and d_2 should total exactly 20 m. Permanently set and label all intermediate stakes (i.e. stake A_1 in this example) as well as the corner stakes (i.e.stakes A and B).

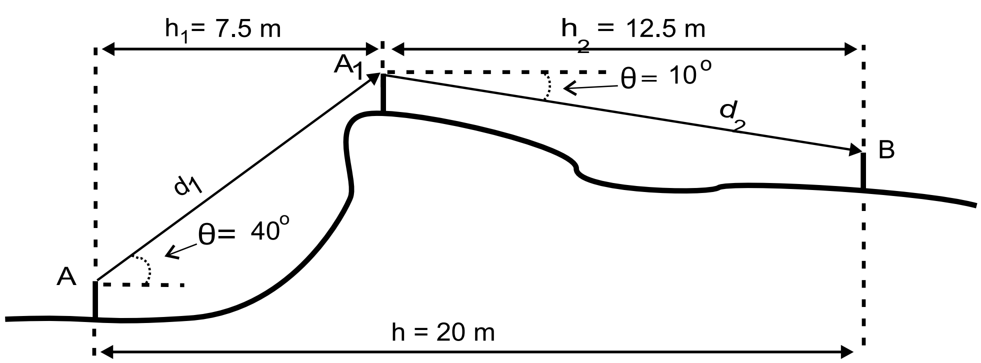


Figure I.5: Two-step method for determining slope correction. For example, from stake A to stake A_1: h_1 = 7.5 m, θ = 40°, cosine = 0.766 and therefore d_1 = 9.778; from stake A_1 to stake B: h_2 = 12.5 m, θ= 10°, cosine = 0.985 and d_2 = 12.693.

TABLE 1: Cosine table (correction factor for slope). Divide the horizontal distance by the factor for the specific angle

	Degree (units)																			
Degree (tens)	**0**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**	**5.5**	**6**	**6.5**	**7**	**7.5**	**8**	**8.5**	**9**	**9.5**
0	1	1	1	1	0.999	0.999	0.999	0.998	0.998	0.997	0.996	0.995	0.995	0.994	0.993	0.991	0.99	0.989	0.988	0.986
10	0.985	0.983	0.982	0.98	0.978	0.976	0.974	0.972	0.97	0.968	0.966	0.964	0.961	0.959	0.956	0.954	0.951	0.948	0.946	0.943
20	0.94	0.937	0.934	0.93	0.927	0.924	0.921	0.917	0.914	0.91	0.906	0.903	0.899	0.895	0.891	0.887	0.883	0.879	0.875	0.87
30	0.866	0.862	0.857	0.853	0.848	0.843	0.839	0.834	0.829	0.824	0.819	0.814	0.809	0.804	0.799	0.793	0.788	0.783	0.777	0.772
40	0.766	0.76	0.755	0.749	0.743	0.737	0.731	0.725	0.719	0.713	0.707	0.701	0.695	0.688	0.682	0.676	0.669	0.663	0.656	0.649
50	0.643	0.636	0.629	0.623	0.616	0.609	0.602	0.595	0.588	0.581	0.574	0.566	0.559	0.552	0.545	0.537	0.53	0.522	0.515	0.508
60	0.5	0.492	0.485	0.477	0.469	0.462	0.454	0.446	0.438	0.431	0.423	0.415	0.407	0.399	0.391	0.383	0.375	0.367	0.358	0.35
70	0.342	0.334	0.326	0.317	0.309	0.301	0.292	0.284	0.276	0.267	0.259	0.25	0.242	0.233	0.225	0.216	0.208	0.199	0.191	0.182

TABLE 2: Corrected distance for a horizontal distance of 20m. Find the specific angle and read off the corrected distance

	Degree (units)																			
Degree (tens)	**0**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**	**5.5**	**6**	**6.5**	**7**	**7.5**	**8**	**8.5**	**9**	**9.5**
0	20	20.001	20.003	20.007	20.012	20.019	20.027	20.037	20.049	20.062	20.076	20.093	20.11	20.129	20.15	20.173	20.197	20.222	20.249	20.278
10	20.309	20.341	20.374	20.41	20.447	20.486	20.526	20.568	20.612	20.658	20.706	20.755	20.806	20.859	20.914	20.971	21.029	21.09	21.152	21.217
20	21.284	21.352	21.423	21.496	21.571	21.648	21.727	21.809	21.893	21.979	22.068	22.159	22.252	22.348	22.447	22.548	22.651	22.758	22.867	22.979
30	23.094	23.212	23.333	23.457	23.584	23.714	23.847	23.984	24.124	24.268	24.415	24.567	24.721	24.88	25.043	25.209	25.38	25.556	25.735	25.919
40	26.108	26.302	26.5	26.704	26.913	27.127	27.347	27.572	27.803	28.041	28.284	28.534	28.791	29.055	29.326	29.604	29.89	30.183	30.485	30.795
50	31.114	31.443	31.78	32.128	32.485	32.854	33.233	33.623	34.026	34.441	34.869	35.31	35.766	36.236	36.722	37.223	37.742	38.278	38.832	39.406
60	40	40.615	41.253	41.915	42.601	43.314	44.054	44.823	45.623	46.456	47.324	48.228	49.172	50.157	51.186	52.263	53.389	54.57	55.809	57.109
70	58.476	59.915	61.431	63.031	64.721	66.51	68.406	70.419	72.559	74.84	77.274	79.879	82.671	85.673	88.908	92.405	96.195	100.317	104.817	109.748

5. How to prepare a species accumulation curve

A species accumulation curve (Figure I.6) is a useful tool for helping determine the number of quadrats needed to sample a single stratum of a plant community. The accumulated number of species (i.e. the number of new species found in each successive quadrat added to the total already found) is plotted on the Y axis against the quadrats (in the order tallied) on the X axis. When the points are joined, the curve characteristically rises abruptly because many new species are added with each new quadrat; it then levels off as fewer species are added with each additional quadrat.

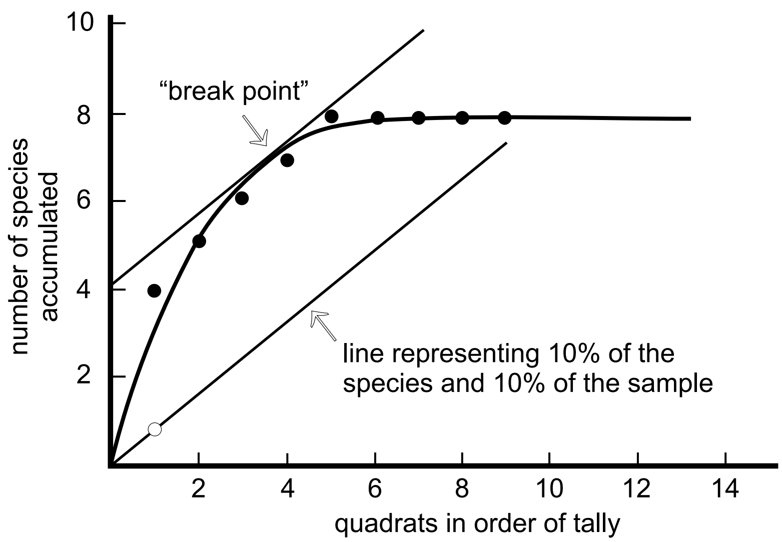


Figure I.6: Preparation of a species accumulation curve for determining the minimum number of quadrats to sample a stratum of vegetation

As added effort yields fewer new species, the need for data about additional species must be weighed against the effort required to get those data. Sampling is sufficient when no, or very few, species are added with each successive quadrat; that is sometime after the curve starts to flatten. Sample size (minimum number of quadrats) may be estimated with reference to the area ("break point") where flattening starts.
.
The break point may be estimated by the "10% rule" i.e. when 10% increase in area yields less than 10% new species. To locate the break point, draw a line from the zero point through the point representing 10% of the species and 10% of the sample area and extend it; draw a second line parallel to the first touching the curve - this is the break point. (Adapted from Oosting, 1956; see also Barbour *et al*., 1999.)

For canopy trees, the recommended minimum number of 20 m x 20 m stand-alone quadrats is three over the break point. Tally ten (for southern forests) or five (for northern forests) stand-alones before preparing a species accumulation curve (stand size may limit the number of samples in some southern forests to five). If below the minimum number, tally two to five more quadrats, prepare a new curve, and repeat until the minimum number is reached.

Record Keeping

Listed below are the essential plot information and baseline data that should be recorded, the measurement schedules that should be followed, and the report contents. The methods are described in *Data/information collecting methods*.

Meticulous record keeping is essential. This applies not only to the variables that are measured in the monitoring program, but also to the descriptions of the location of the plot, the decisions made and the actions taken. The value of the monitoring program will be only as good as the level of informative detail kept about the plots, the accuracy of the data collected, and the systematic application of quality control and quality assurance measures. Ensure that all plot information and raw data are properly archived. EMAN recommends the use of Metamaker software for all electronically stored data (see <www.nbii.gov/tools/metamaker/metamaker.html>).

After the base data have been processed (see *Data compilation and Processing*), a report on the state of the stand should be prepared, followed every five years thereafter by a new report. The first report should contain the goals, objectives, rationale, all the essential information, and the baseline data. The five-year reports should update the original report and give the details of new decisions; and report on the results of remeasurements and discuss their significance. It should pay special attention to the original goals, objectives and rationale of the plant biodiversity monitoring program. Any recommendations for modifying the approach or the variables to be measured during the next period should be clearly articulated, recorded and included in each report. All reports should be archived in electronic and hard-copy forms

Essential information

! name of stand and number of plots or stand-alone quadrats
! map of stand showing the plot location(s), their relationship to any prominent feature, and the route to find the plot or plot area
! latitude and longitude of one-hectare plot centre stake
! latitude and longitude and elevation of stake A, quadrat 01
! compass bearing of Line A-D - the base reference line (BRL)
! number of each plot or stand-alone quadrat
! plan of hectare plot with all quadrats numbered
! average stand height and canopy depth
! written description of access route to stand and to the plot(s)

Baseline tree data

It is essential that the following data be collected and recorded:

! tag number and species of all living and standing trees 10 cm dbh and over (in "dwarf forests", 4 cm dbh and over)
! location of all numbered trees (plotted on a map)
! dbh of all numbered trees
! condition of all numbered trees

It is desirable that the following data be collected and recorded:

- ! height of all numbered trees
- ! height to lowest living branch of all numbered trees
- ! age of stand (determined from off-plot trees)
- ! photographs from standard positions at standard times and dates
- ! degree of canopy closure (by quadrat)

Protocols for photographs and canopy closure have not yet been prepared.

Minimum checking/measurement schedule

Every five years or as necessary the stands should be remeasured. If they are subject to severe weather, fire, or other extreme event, the quadrats should be remeasured and supporting information recorded as soon after the event as it is safe. The following activities should be undertaken and the results recorded:

- ! check that all corner stakes are in place and replace if necessary
- ! remeasure dbh of all numbered trees (replace missing numbers/tags)
- ! number, identify, measure dbh and determine location of all small trees that have reached 10 cm dbh or 4 cm dbh, as appropriate
- ! note the changes in condition of all numbered trees (note tag number and species of the trees that have fallen or died)
- ! orientation of numbered trees that have fallen
- ! core and age any numbered tree that has died
- ! prepare and check a new map for each 20 m x 20 m quadrat
- ! rephotograph (if part of baseline data)
- ! remeasure degree of canopy closure (if part of baseline data)
- ! update the report on the state of the stand

Every ten years, the height of tagged trees and the height to lowest living branch should be made if these measurements are part of the baseline data.

State of the stand report

The outline below applies specifically to a canopy-tree monitoring program. When the program also includes shrubs and small trees, and/or ground vegetation, the information about these results should also be included.
Suggested outline for a baseline report:

- ! overall goals and objectives of the site monitoring program
- ! specific goals and objectives of the plant biodiversity monitoring program
- ! general description of the stand(s) selected for monitoring (e.g. size, location, age, and history)
- ! decisions and rationale for selecting the methods, scheduling, etc.
- ! essential plot information
- ! detailed description of the stand, based on the collected data

Data/Information Collecting Methods

Directions are given for making the measurements or gathering the information that is listed under *Record Keeping*. At the end of this Section is a model field data sheet that monitoring groups may find useful.

Note: To reduce the impact of observers on the forest floor vegetation when ground vegetation quadrats are to be nested within the plots, it is advisable to select and flag the quadrat locations and collect data before collecting tree data (see Section III).

1. How to identify trees

Equipment:
- ! tree identification manual and preliminary species list for the stand
- ! plastic bags or plant press
- ! labelled fresh or dried specimens for reference

Team: two people

Trees must be correctly identified to species. To facilitate identification in the field, it is advisable that the Responsible Group organize a workshop to familiarize the observers with the species they are likely to encounter[9]. Since errors in species identification can occur even among trained observers, an observer who has any doubt whatsoever should collect a specimen for expert identification. This specimen should be a small branch at least 40 cm long with the leaves attached and, if possible, with attached flowers or fruit/cones. A piece of the bark may be useful, but it should never be cut from a live tree. In spring or fall when a tree is leafless, identification is normally possible using twig and bark characteristics. Confirmation of the identification using leaves, flowers or fruit/cones, can be made the following season.

Each specimen should be labelled with the tree's identification number, placed in a plant press, or if the storage is temporary, in a plastic bag which is kept in the shade. Make sure that groups of plants given the same temporary identification are really the same species.

Always have a manual in the field for making identifications. *Trees in Canada* by John Laird Farrar (1995) is recommended for tree identification in conjunction with the recommended nomenclatural standard (see bibliography for recommendations), and field guides to the local floras and species lists. For each plant, record the latin binomial i.e. the scientific name, the authority for the name (e.g. white birch should be listed as *Betula papyrifera* Marsh.), and the manual used for identifications.

For information on making herbarium/voucher specimens, see *Making Plant Collections* (Haber, E. *Guide to Monitoring Exotic and Invasive Plants*, Appendix 3), web address <http://www.cciw.ca/eman-temp/research/exotic/append3.htm>.

---

[9] Participants in a workshop should be made aware of any rare species or species listed as endangered, threatened or vulnerable by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC - internet address <http://www.cosewic.gc.ca/COSEWIC/Default.cfm>) that they may encounter, and warned against harming them.

2. How to number/tag a tree

Before starting any measurements, tie string to the stakes of the surveyed plot to facilitate orientation during tagging and mapping and to make quadrat boundaries clear. Remove the string when all measurements have been taken. The numbering, identifying, and dbh measuring activities may all be done by the same team.

Equipment:
- lead-free tree paint (e.g. Nelson Tube Marker) or
- tree tags to be secured by grafting tape, commercial electrical cable ties, spiral UV resistant plastic cord, or (least recommended) steel or galvanized nails
- metric dbh tape
- field data sheets and pencils

Team: two people

Method: Starting at a 20 m x 20 m quadrat corner, proceed in a clockwise spiral from the periphery to the centre of the quadrat, and number each live and dead tree 10 cm dbh and over (or 4 cm dbh in dwarf forests). Use the dbh tape to determine doubtful diameters. Use paint to number the tree or attach a tag to it, making sure all numbers/tags face in the same direction. Record each tree measured, by number and species. See Figure I.7 for tree numbering system. When a tree is multiple-stemmed and the branches separate below 1.3 m, number/tag and measure each stem that is 10 cm dbh (or 4 cm dbh in dwarf forests) or more.

When a tree is partly in one or more quadrats, tag (and record) it only in that quadrat where at least half of the stem is located. If the tree is on an outside line, only tag and measure it if at least half the stem is inside the quadrat, otherwise ignore it.

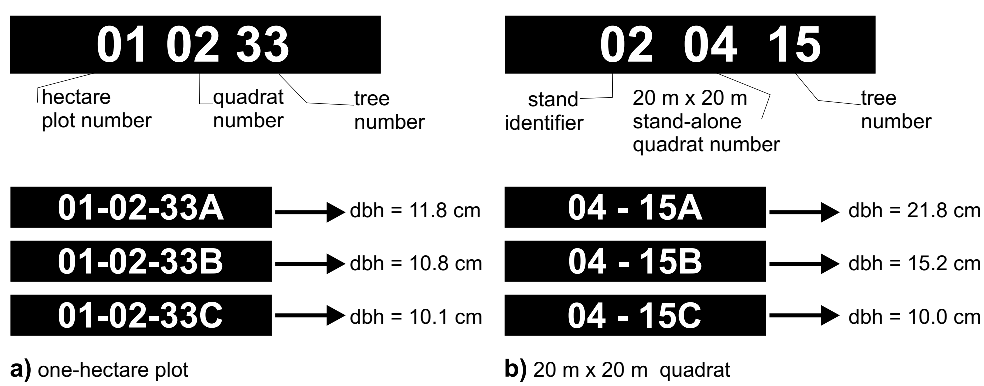


Figure I.7: Tag numbering system for trees on (a) 1-ha plot, and (b) 20 m x 20 m stand-alone plots. When numbering multiple-stemmed trees, the largest stem is always the "A" stem.

3. How to measure diameter at breast height (dbh)

These measurements are taken to evaluate the growth of trees and to determine the area of the stand occupied by each species.

Equipment:
- metric dbh tape
- red or blue lead-free paint (e.g. Nelson Tube Marker)
- data sheets and pencils

Team: two people

Method: Mark each tagged tree with a small daub of environmentally friendly paint at 1.3 m above the ground. This is a permanent mark to ensure that all dbh measurements will be taken at the same place. Make sure the tape is taut and correctly placed around the tree at right angles to the stem axis (Figure I.8) and not over an atypical part of the stem. Many trees are irregular in form (e.g. leaning, branch at 1.3 m, windswept, buttressed etc.) and therefore require special handling when measuring the dbh (Figure I.8). If the dbh is not taken at 1.3 m, record the height at which it is taken. Measure and record separately the dbh of branches which originate below 1.3 m.

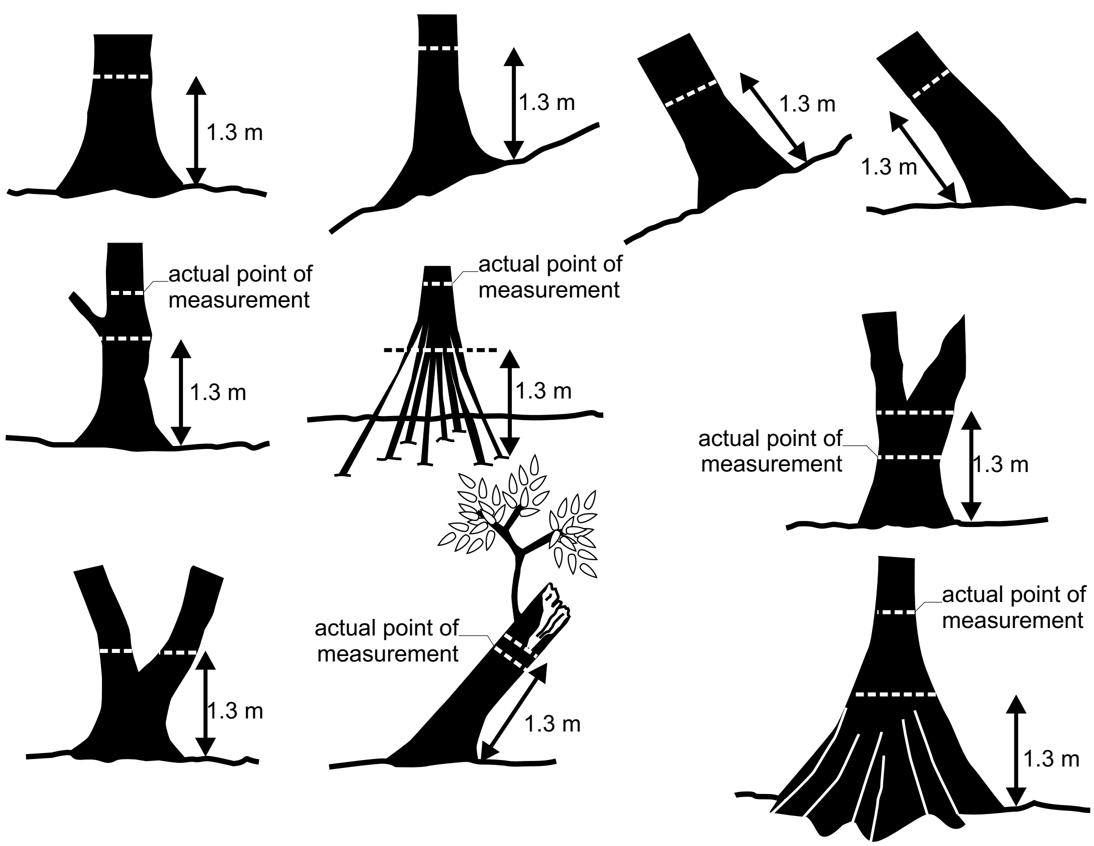


Figure I.8: Measuring positions for dbh (after Dallmeier, 1992). Single dotted line shows the measurement position - if because of a fault two dotted lines are shown, the correct position is labelled.

4. How to map trees [10]

Equipment:
- sonar range finder (1 sender, 2 receivers) and one steel survey tape (30 m) or
- two steel survey tapes (30 m)
- BIOMON software (available through the EMAN office)
- data sheets and pencils

Team: four people (1 sender, 2 receivers, 1 recorder)

Note: If the plot is on sloping land, then distance measurements must be corrected for slope (see *How to Make a Slope Correction*).

Method: The mapping crew follows the tagging crew. In each quadrat, every numbered tree is mapped in relation to two adjacent, precisely located quadrat corner stakes. Each quadrat is bounded by four lines, the one parallel with and closest to the BRL (A-D) is Line 1 (Figure I.9). In a 1-ha plot for example, Line 1 of quadrat #13 goes from corner 13A to 13D, Line 2 from corner 13A to 13B, Line 3 from corner 13B to 13C and Line 4 from corner from 13C to 13D. Getting these lines correctly identified is essential for the BIOMON mapping software.

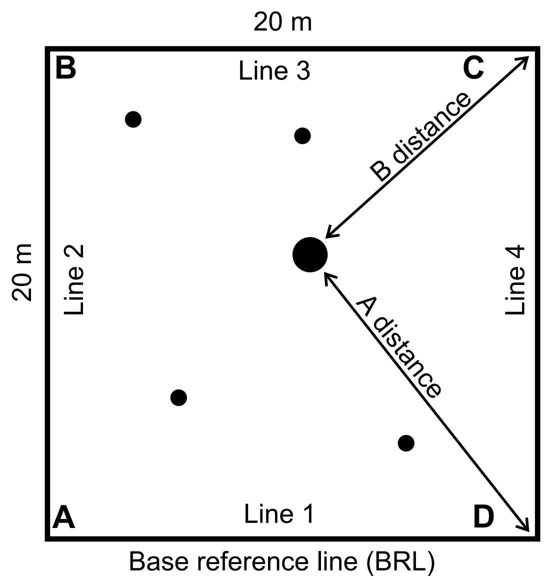


Figure I.9: Set-up for mapping trees

The "sender", if using a sonar range finder, locates the tree to be mapped and calls out the tag number for the recorder. Each "receiver" stands at one of two adjacent corner stakes along Line 1, 2, 3, or 4 of the quadrat to be mapped. From the sender standing

[10] Method adapted from Dallmeier, 1992

with his/her back to the tree, the receiver at the corner to the right of the sender measures the "A distance" to the tree, and the person at the corner to the left, the "B distance". The receiving instrument must be at the same height above the ground as the sending instrument. Questionable distances should be checked with a tape.

If a sonar range finder is not available, all the A and B distances can be measured by steel survey tape, using the same procedure.

Measurements are made to the nearest centimetre. Receivers may have to change their positions, depending on the view lines to the tree. The sum of the A and B distances (that is, the distances from the tree to the two adjacent corners) must be equal to or greater than 20 m. On the data sheet, record the tree number, the A distance, the B distance, and the line number (1, 2, 3, or 4).

How to fail: The two most common errors in mapping are switching A and B distances and incorrectly recording the line number.

Map generation: Enter the data into the computer using the BIOMON software. This program calculates by triangulation the X and Y coordinates of the tree (taking into account the dbh) and generates a map of each quadrat showing the exact location of each tree. Verify the maps in the field. Correct any mistakes by remeasuring the trees, regenerating the maps and rechecking the results.

If preferred, the trees could be mapped directly in the field using the plane table or similar survey technique.

5. How to recognize tree condition

Equipment:
- illustrations of tree condition
- field data sheets and pencils

Team: two people - usually the tagging or dbh team

Method: Note the condition or status of all tagged trees using the illustrations in Figure I.10 for guidance. Record observations on the data sheet using the following symbols:

- standing alive (AS)
- broken alive (AB)
- leaning alive (AL)
- fallen/prone alive (AF)
- standing alive dead top (AD)
- standing dead (DS)
- broken dead (DB)
- leaning dead (DL)
- fallen/prone dead (DF)

Do not record any fallen/prone dead trees when the initial measurements are taken. At each subsequent remeasurement period, record the condition of all tagged trees (alive or dead) that have fallen since the first data were collected. In addition, measure the length, diameter and orientation of all tagged fallen dead trees. These measurements are important over the long term because of the role that dead and decaying trees play in the life of other species and in ecosystem function.

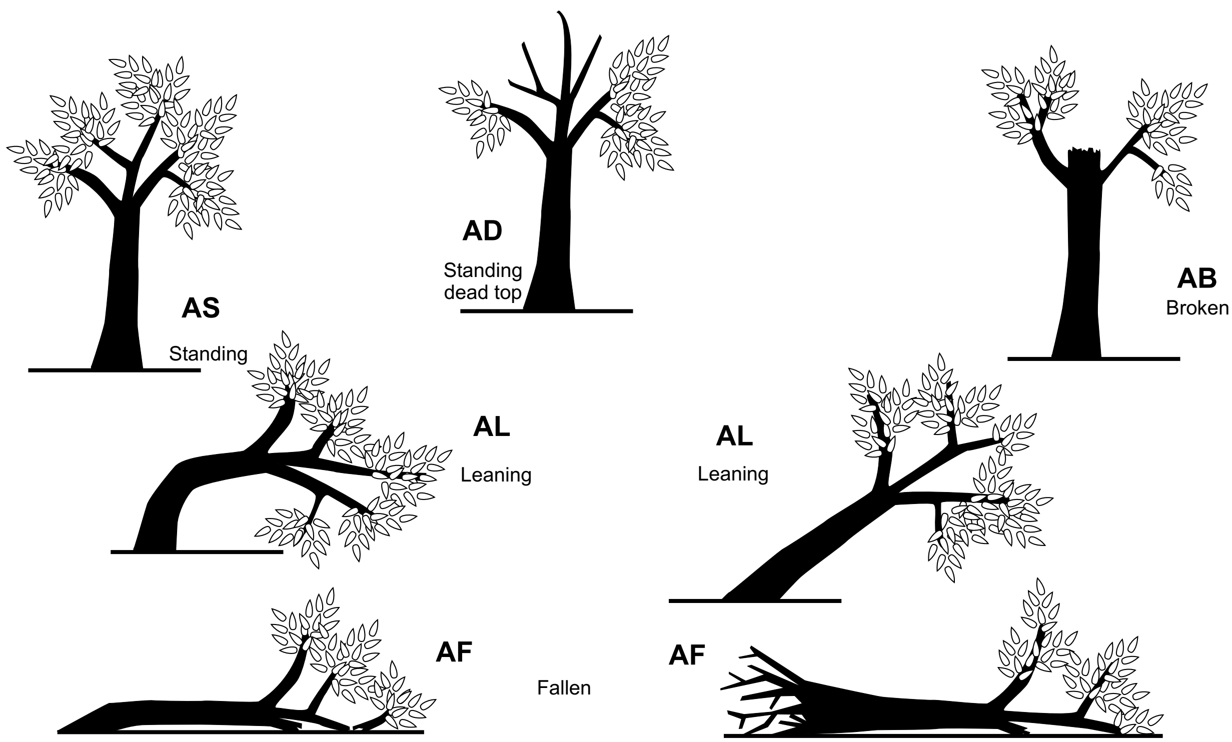


Figure I.10: Illustrations of tree condition (after Dallmeier, 1992)

6. How to measure tree height

It is important to record the heights of individual trees in immature forests because they are measures of the rate of tree growth. The height of an individual tree in mature deciduous forests is often difficult to obtain. For this reason, at least the average tree height and canopy depth of a mature stand should be determined.

Measure the length, diameter and orientation of all tagged trees that fall down between measurement periods.

Equipment:
- ! clinometer (e.g. Haga level)
- ! 30-m steel survey tape
- ! compass
- ! one 2-m surveying rod (with levelling bubble)
- ! data sheets and pencils

Team: two people

Method:
From a measured distance (such as 20 m) from the base of a tagged tree, record the readings (Figure I.11a, b, c, d) for the top and base of the tree, and the horizontal line from the eye-level of the observer to the tree stem, or equivalent below the base of the tree. Record the eye-level height of the observer and whether the base of the tree is above, the same, or below the eye-level of the observer. In addition, take the reading for the lowest live branch. Calculate the height and canopy depth of each tree.

To measure the average canopy height of a stand, from a convenient location and from a measured distance, take the readings for determining the average height and depth of the stand canopy. Record the heights of emergent species, but exclude them when calculating the average height of the stand canopy.

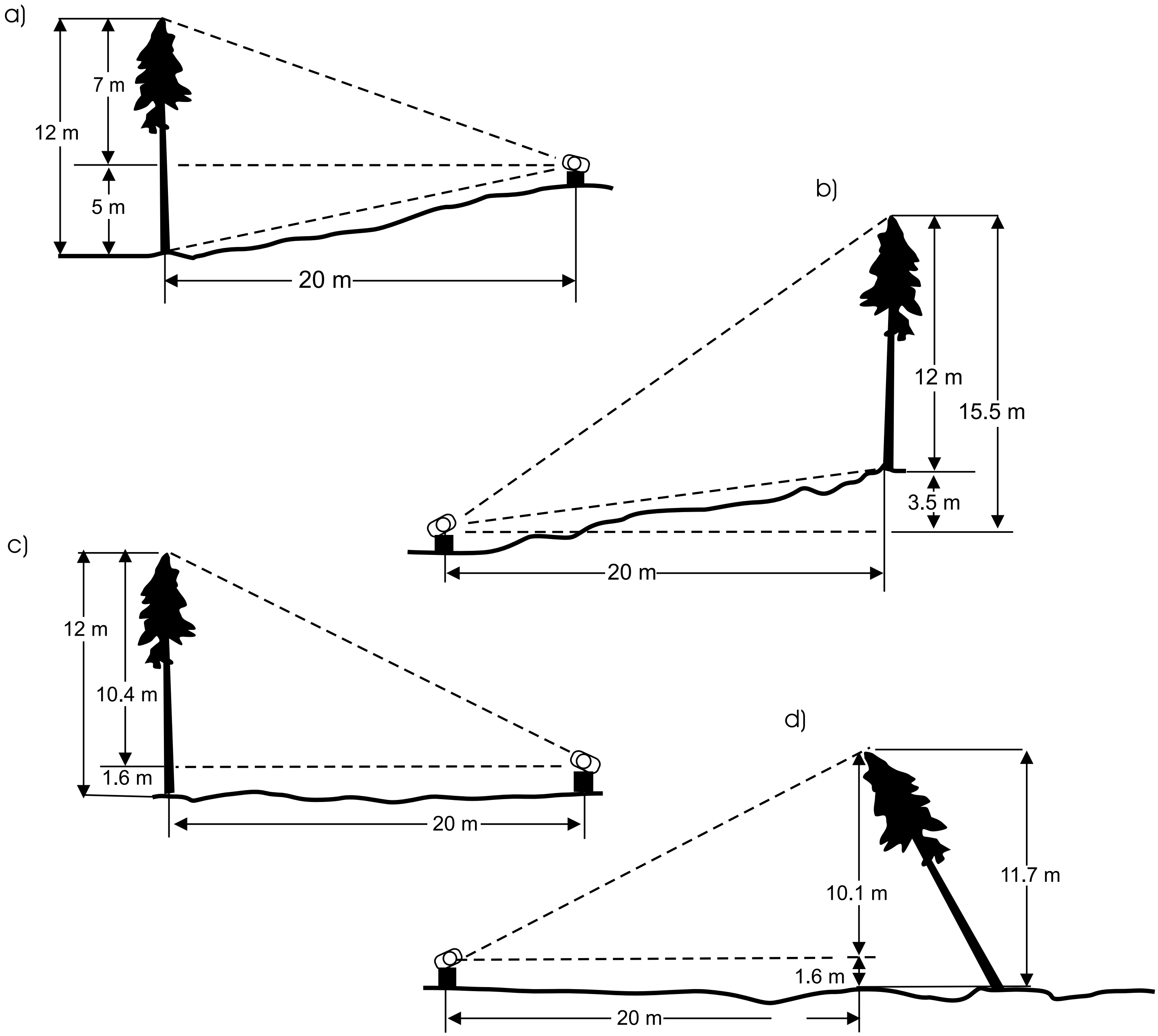


Figure I.11: Measurement of the height of a tree. The height of the tree (12 m or 11.7 m for the leaning tree) is determined by:

a) adding the two measurements above and below the horizontal reading.

b) subtracting the distance from the base of the tree to the horizontal, from the total.

c) adding the height of the instrument above the ground to the distance above the horizontal line.

d) adding the height of the instrument above the ground to the distance from the top of the tree to the horizontal line directly beneath the highest point (use a survey rod as a target).

7. How to determine the age of a tree

Equipment:
- increment borer
- milk shake drinking straws and masking tape
- felt marker to label straws
- metric dbh tape
- field notebook and pencils

Team: two people

Method: Identify the species of trees that together represent the largest and most common canopy trees on the hectare plot. From the stand surrounding the plot, select five specimens of each species for age determination making sure that they mirror the range of sizes on the plot, and record their dbh. **Do not take cores of the trees on the plot.** The Responsible Group should decide whether the cored trees are tagged or marked in some way for future reference - a valuable action which allows for resampling. To give accurate ring widths, take the core on the north-facing side of the tree (if deformed core the stem outside the deformed area) and at right angles to the stem axis. If the tree has a definite lean, core from the upper side. Take the core at 30 cm above the ground - just above the swelling (butt swell) where the roots originate. Record the stem position of each core. Cores from the stem base will give a minimum age closer to the real age than from breast height (provided that the stem is solid) and are best for dendrochronological studies.

Insert the bit of the increment borer in the handle and remove the extractor. Punch the bit through the bark and turn it gently until the end is beyond the centre of the tree. Insert the extractor, lifting it slightly to make sure it goes under the core, and then back off the borer about one turn to break contact between the core and the tree tissue. The notch on the extractor should be up so that if the core breaks, it will still rest in the extractor. Pull out the extractor with the core. (Adapted from Phillips,1959.) **Immediately remove the borer to prevent it becoming "frozen" in the tree.**

Place the core in a milk shake drinking straw, close securely with masking tape, label (species, date, location and dbh) and store in a safe place, preferably in a refrigerator if the cores are wet or full of sap (or freezer if ring widths are also to be measured), until the counting can be done. If a refrigerator is not available for wet cores, mount (see below) as soon as possible to avoid fungal attack. After counting, store the cores for future reference, they are part of the voucher specimens and may be used for further study.

Coniferous trees are generally easier than deciduous trees to bore and their rings easier to count - often with a 10 x hand lens. Cores from diffuse-porous deciduous species must be mounted (glued) into wooden grooves (core trays), and sanded successively with finer and finer grades of wet-or-dry sandpaper (grades recommended are # 80, 150, 250, 320, 400, 600) backed with a pencil eraser (Dr Gerard Courtin, personal communication). Count the rings using a dissecting microscope. For accurate counting, all species should be mounted, sanded and counted under a microscope.

Data Compilation and Processing

The instructions set out below are for the initial analyses of the data from the canopy tree monitoring plots. The work may be done using BIOMON or spread sheet software. Appended to this Section is a model summary data sheet that monitoring groups may find useful.

Prepare a master species list (alphabetically by family and scientific name) for all trees 10 cm dbh and higher (4 cm dbh for dwarf forests) in the stand. Highlight those species which are found in the sample plots. The sample area will be either a multiple of 10,000 m^2 for 1-ha plots or of 400 m^2 for 20 m x 20 m stand-alone quadrats. Use dead-tree data only where specifically requested and record separately.

Using the formulae, calculate for each species separately (live individuals only), first the abundance, basal area, density, and dominance; and then the frequency, relative frequency, relative density, relative dominance and importance value. In addition, calculate the total basal area of all dead standing or leaning trees.

Abundance: total number of individuals of each species in the total area of the sample. When preparing summary tables, list species in order of abundance starting with the most abundant. Always use the scientific names in the tables.

Basal area: cross-section area of tree stems. Using conversion tables, calculate the basal area for each individual from the dbh measurements, then determine the total basal area for each species.

Density: average number of individuals of a species on a unit area basis

$$D = \frac{\text{number of individuals in the sample}}{\text{total area of sample } (m^2)}$$

Relative Density: density of one species relative to all species

$$RD = \frac{\text{number of individuals of a species in the sample}}{\text{total number of individuals of all species in the sample}} \times 100$$

Dominance: area a species occupies in a stand (for trees use basal area) on a unit area basis

$$Dom = \frac{\text{basal area of individual species in the sample } (m^2)}{\text{total area of the sample } (m^2)}$$

Relative Dominance: area a species occupies in a stand (for trees use basal area) as a percentage of the total area occupied by all species

$$\text{RDom} = \frac{\textbf{basal area of a species } (m^2)}{\textbf{total basal area of all species } (m^2)} \times 100$$

Frequency[11],[12]: distribution of a species through a stand, i.e. percentage of plots in the sample area in which a given species occurs

$$\text{F} = \frac{\textbf{number of plots in which a species occurs}}{\textbf{total number of plots in sample}} \times 100$$

Relative Frequency[13]: distribution of one species relative to all species

$$\text{RF} = \frac{\textbf{frequency of a species in the sample}}{\textbf{total frequency of all species in the sample}} \times 100$$

Importance Value[14]: an index made up of Relative Density, Relative Dominance and Relative Frequency that profiles the structural role of a species in a stand. It is useful for making comparisons among stands in reference to species composition and stand structure.

IV = Relative Density + Relative Dominance + Relative Frequency

---

[11] When only a single 1-ha plot (SI/MAB plot) is established, the Frequency of each species is always 100%. The calculation of Frequency using the 20 m x 20 m quadrats of the one-hectare plot is invalid because the plot size is one hectare and thus the sample size is one.

[12] Frequency and Relative Frequency can only be calculated, compared and pooled when data are taken from plots that are the same size and shape.

[13] When only a single 1-ha plot is established, the Relative Frequency of each tree species will be the same; the actual value will depend on the number of species in the plot.

[14] When comparing or pooling Importance Values from different stands, all values must be based on plots that are the same size and shape.

CANOPY-TREE SAMPLE: FIELD DATA SHEET (1-ha. plot or 20 m x 20 m stand-alone quadrats). Stand name... Date...................................

Stand location (lat. & long.) ....Hectare plot and quadrat nº.............................**OR** Stand-alone quadrat nº............... Av. stand height...................................

Identification manual.................................... Observer(s)..

Tag #	Species name	Number of stems	dbh (cm)	Line (1,2,3,4)	A distance (m)	B distance (m)	Height (m)	Condition	Notes

CANOPY-TREE SAMPLE: SUMMARY SHEET. Stand name... Date...

Stand location (lat. & long.)... Number of 1-ha plots .... **OR** Number of 20 m x 20 m stand-alone quadrats ....

Sample area (m^2).................. Average canopy height .... Data processor(s)...

Species name	Abundance	Density	Basal Area	Dominance	Frequency	Relative Density	Relative Frequency	Relative Dominance	Importance Value	Notes

SECTION II

SHRUB AND SMALL-TREE STRATUM
BIODIVERSITY MONITORING PROTOCOLS

Table of Contents

Introduction

Woody species over one metre in height and under 10 cm dbh are dealt with together in this section. Monitoring methods for woody species less than one metre in height are to be found in Section III. The methods described are recommended for use in stands that have no strong vegetation gradients. Where strong vegetation gradients exist (e.g. at tree line or in proximity to water bodies), permanent transects are recommended for a monitoring program (see Section IV).

Definitions

The definitions used in this document for shrubs and small trees is one of convenience because the categories of "shrub" and "small tree" may be difficult to differentiate. In addition, a species may, according to its stage of development, be classified sequentially as a seedling, sapling, small tree, and canopy tree.

Shrubs: defined in this document as usually multi-stemmed woody plants less than 4 cm dbh with most of the stems originating at or near the ground. Saplings under 4 cm dbh will be measured with the shrubs in the shrub and small tree stratum. Shrubs are usually present in forests, they dominate in heath communities, they may form the canopy in riparian[1] strips in the ecotone between forests and alpine or arctic tundra, and in bogs or other high-water-table communities. Shrubs may also be found scattered in large or small clumps in grassland communities.

Small trees: defined in this document as usually single-stemmed, woody plants 4 cm dbh and less than 10 cm dbh. Therefore large saplings and some tall single-stemmed shrubs will be measured with small trees in the shrub and small tree stratum. In addition, where they are present, vines (e.g. grape vines) would be included with small trees, even though their leaves are in the canopy stratum. Some species, especially those that sucker readily (e.g. white birch and red maple), may have more than one stem. Small trees that tolerate shade usually form part of the understorey of a forest and depend on the canopy for survival. Those that do not tolerate shade often form the early stages of forest regeneration after fire, blow-down or harvest. Small trees may also be found in groups or scattered in grassland communities. Tree species at the northern edge of their range or close to their altitudinal limit may be classified as small trees or as shrubs. Such trees may alter their form under long-term climate change.

When small trees form the canopy of extensive "dwarf" forests or dense forests or form large patches in non-forest communities, they should be treated according to the methods described in Section I.

[1] Since *riparian* and *lacustrine* vegetation both refer to zones of vegetation bordering respectively rivers and lakes, for convenience, *riparian* will be used in this document to describe these vegetation zones, whether they border a river or a lake.

Rationale

In forest communities, the monitoring of small trees and shrubs will give information on the rates of growth and mortality of saplings, and replacement rates of canopy species. Monitoring will also provide data about the influence of the canopy on the rates of recruitment of seedlings into the understorey, will provide data on species confined to the lower forest strata, and will give hints about how the structure of the upper forest strata is likely to change in the future. In non-forest communities, shrub and small tree monitoring data should give insight into the dynamics of woody vegetation patches. The behaviour of some invasive plant species may also be tracked. While detailed plant data are essential when monitoring animal biodiversity, shrub and small-tree data are particularly important when monitoring or managing valued wildlife species whether in non-forest or forest communities.

Plot[2] Size

A 5 m x 5 m quadrat is recommended for most situations but, for densely packed shrubs, 2 m x 2 m quadrats may be suitable. Decisions about the size of the quadrat should be made by the Responsible Group and the reasons for the decision recorded. Select one size of quadrat only for this vegetation stratum to ensure comparability.

Numerous small quadrats for monitoring small trees and shrubs (given their size and distribution) will give greater representation of the ecosystem and more reliable data than few large plots For this stratum, small plots are more efficient than large in terms of time and resources, and given the size of the plants, there is less chance of missing individuals on a small sample plot.

[2] *Plot* and *quadrat* are usually synonymous terms for measured areas of vegetation used in sampling. In this document *plot* is used as a general term (and for the 1-ha sampling size) while *quadrat* is used for all other sampling sizes.

Permanent Plot Establishment

Once the stands for monitoring have been selected, and the size of quadrat has been determined, there are still a number of important decisions that have to be taken before quadrats can be established in the field. These include the minimum number of quadrats required for efficient and effective monitoring, how they are to be arranged in the selected stand(s), and how their locations are to be determined. The decisions have to be taken in light of the other research and monitoring activities that may be on-going in the same stand and the scheduling needs of the observers undertaking these activities.

1. How to decide on the number[3] of quadrats

In general, the minimum number of quadrats to make an appropriate sample is probably at least ten for 5 m x 5 m quadrats and probably at least twenty for 2 m x 2 m quadrats. In both cases the number could be much higher. Preparation of a species accumulation curve (see *How to prepare a species accumulation curve*) is helpful in determining the minimum number of quadrats required. The exact number will also depend on:

- the size of the stand being sampled
- the spatial distribution of the shrubs and small trees in the stand
- statistical advice that may call for a higher number of quadrats
- whether or not the small-tree and shrub monitoring is associated with a one-hectare canopy-tree monitoring plot

[3] Barbour *et al*., 1999, has a table which suggests a range of numbers of quadrats for monitoring different ecosystems and different strata within those ecosystems. The minimum numbers suggested in this document are derived partly from this table and partly from experience in Canada.

2. How to determine the quadrat arrangement

Quadrat arrangement for shrub and small-tree monitoring will differ with the type of plant community being monitored. In forest ecosystems, either nested or stand-alone quadrats are recommended (depending on the specific situation), while in non-forest communities, only stand-alone quadrats are recommended.

i) FOREST ECOSYSTEMS

It is assumed that the shrubs and small trees in forest ecosystems will be monitored in conjunction with the canopy-tree monitoring. An important and early decision that the Responsible Group must make is whether the shrub and small-tree quadrats are to be nested or are to be set up as stand-alones. The decision will depend on the forest type. In very humid or very wet forests, or forests with a lichen-dominated ground layer, it is preferable that the small-tree and shrub quadrats be set up as stand-alones outside any plot(s), because trampling can be very damaging to the ground and dense shrub vegetation. Where forests are drier (e.g. located on sandy or stony substrates) and are without lush ground vegetation or a dense shrub layer, the shrub and small-tree quadrats may be nested in the one-hectare plot or 20 m x 20 m stand-alone quadrats.

Any plot with lichen-dominated ground layer should be walked on only after rain or a heavy dew.

The 5 m x 5 m (or 2 m x 2 m) shrub and small-tree quadrats may be arranged in one of three ways. They are:

a) randomly distributed stand-alones outside the hectare plot
b) nested in randomly selected corners of randomly selected quadrats of a hectare plot
c) nested in one or more randomly selected corners of the 20 m x 20 m stand-alone quadrats

Selection of the specific quadrat locations must be by a random selection method, e.g. the use of a table of random numbers or a bag of numbered chips or balls.

For situation (a), stand-alone 5 m x 5 m quadrats should be located within a 10-m band (excluding corners) surrounding the hectare plot (Figure II.1). This band should be established outside a 2-m access corridor that also surrounds the hectare plot. Use a rough sketch map overlaid by the extensions of the quadrat lines as a reference to select the specific locations. Ensure that the 5 m x 5 m quadrats are at least 15 m apart and are in the same community type as the hectare plot. Use a compass and tapes to find the specific points.

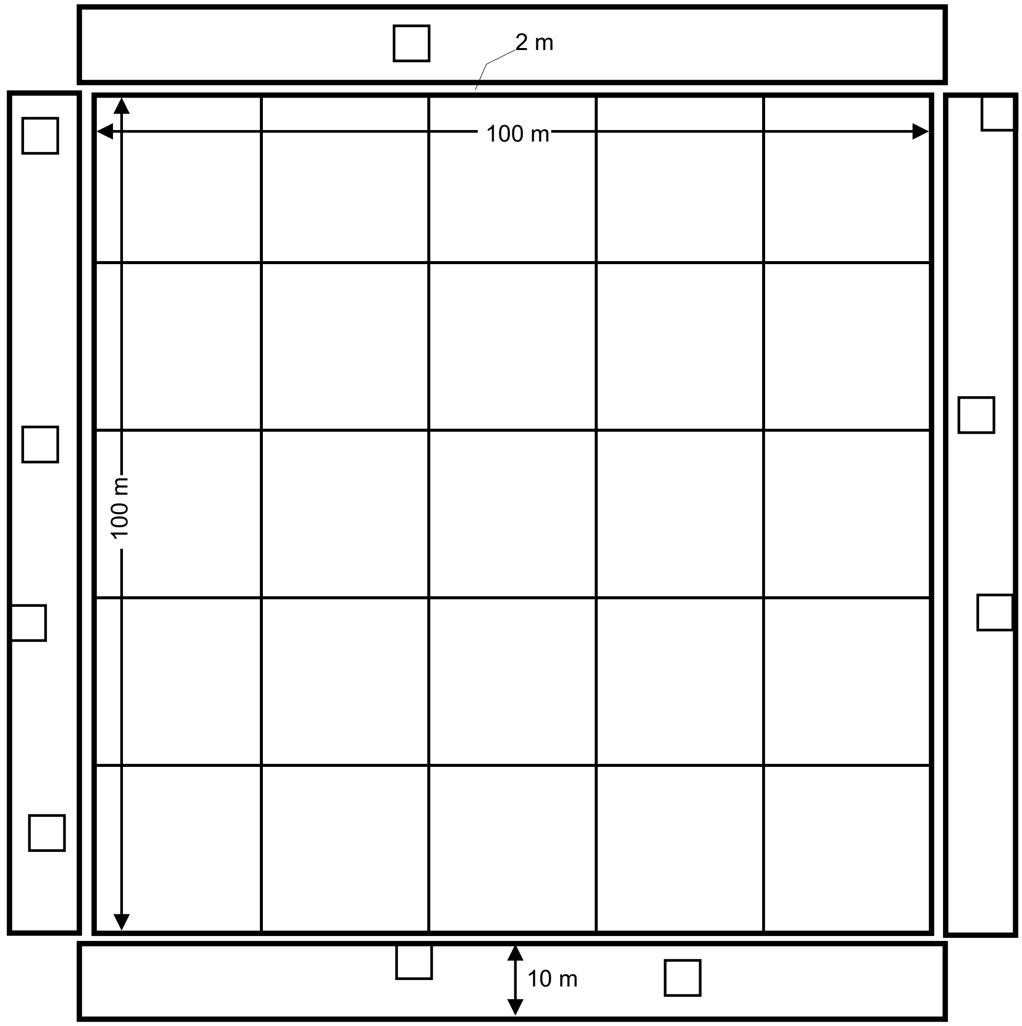


Figure II.1: Hectare plot surrounded by 2-m access corridor and 10-m band containing ten 5 m x 5 m quadrats in randomly selected positions

For situations (b) and (c), nest 5 m x 5 m quadrats in a hectare plot or in 20 m x 20 m stand-alones (Figures II.2 and II.3). First, randomly select the 20 m x 20 m quadrats, then in a separate operation, randomly select a corner of the chosen quadrats. Reject the location of any 5 m x 5 m quadrat that is not a minimum of 15 m from another of the same size (i.e. they must not be in adjacent corners).

If through the use of the species accumulation curve more 5 m x 5 m quadrats are required than the total number of 20 m x 20 m stand-alone quadrats, select diagonally opposite corners to ensure that the 5 m x 5 m quadrats are 15 m apart.

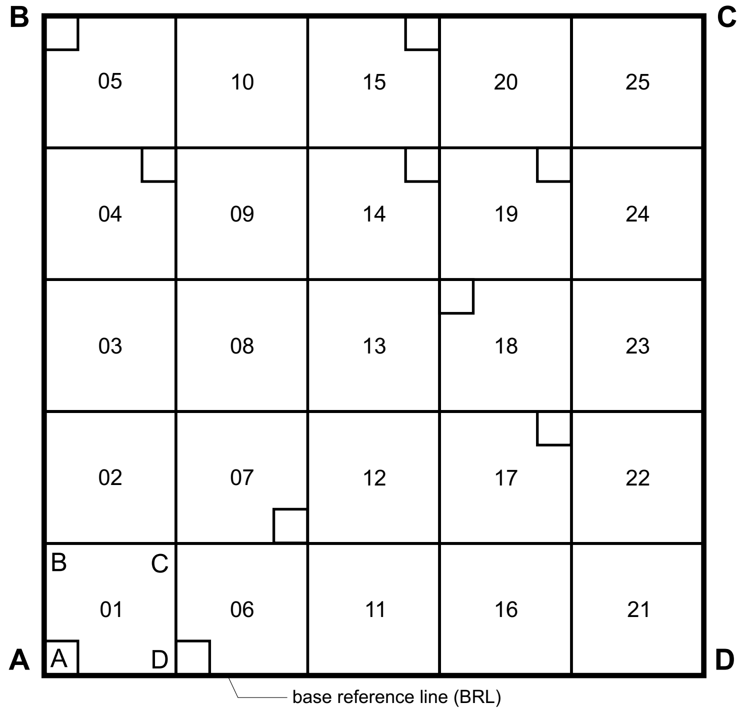


Figure II.2: Plan of a 1-ha plot showing the positions of 5 m x 5 m quadrats nested in ten randomly selected 20 m x 20 m quadrats. (Randomly selected quadrats: 07, 14, 06, 04, 15, 01, 19, 17, 18, 05; randomly selected corners: D, C, A, C, C, A, C, C, B, B.)

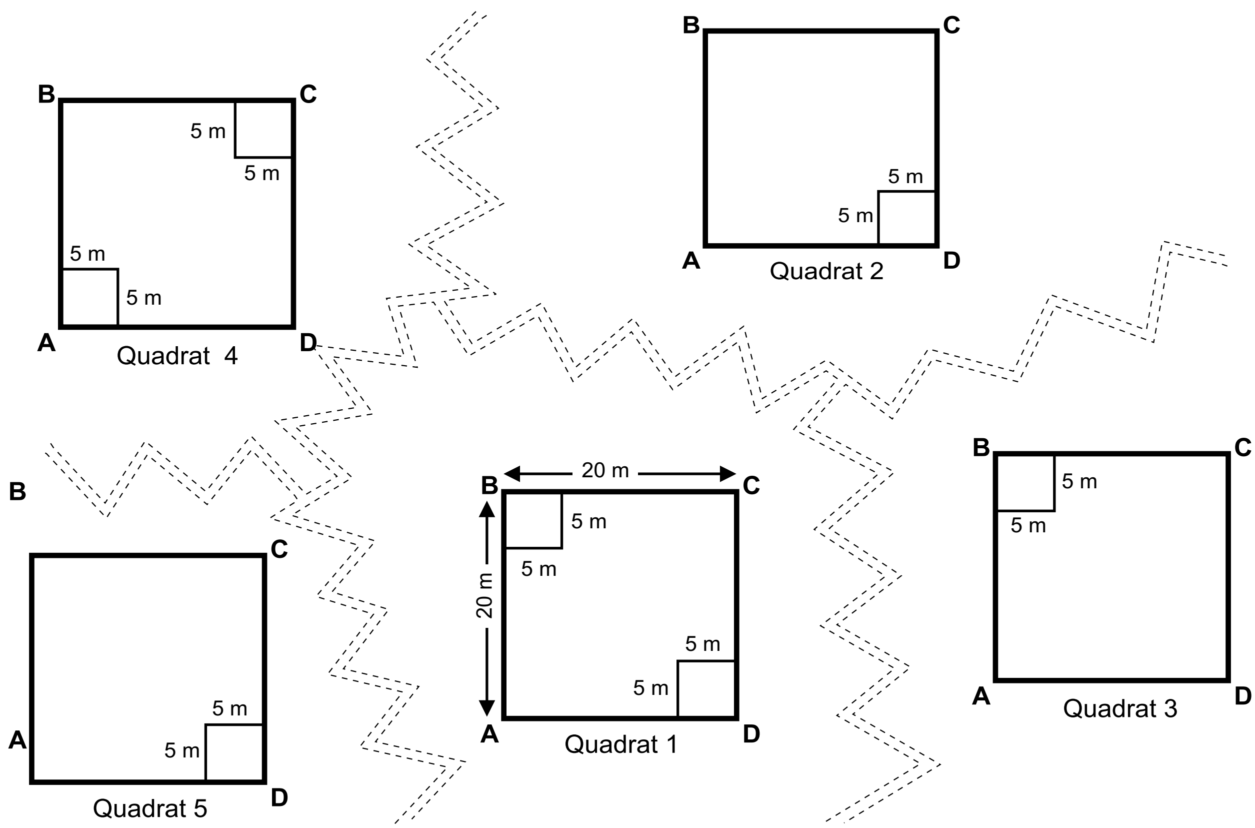


Figure II.3: Layout for 5 m x 5 m quadrats nested in randomly selected corners of stand-alone 20 m x 20 m quadrats. The figure is not drawn to scale: since the 20 m x 20 m quadrats are all more than 50 m apart, the jagged lines represent the missing land area.

ii) NON-FOREST ECOSYSTEMS

Select the community where the monitoring is to take place. To determine the quadrat locations within the community, use a random selection method while observing the following general principles:

a) Locate quadrats at a distance from the stand edge equivalent to at least three times the height of the canopy of the shrubs or small trees being measured;
b) Where this is not possible because the stands are small or irregular, the quadrats must be placed at a distance at least equivalent to the height of the canopy from the stand edge;
c) Ensure that quadrats are at least 15 m apart.

On a rough chart drawn to scale of each selected stand, overlay a square grid at a scale appropriate to the map. As an example, for a grassland ecosystem of about eight hectares with stands of shrubs and small trees, draw a grid 400 m long by 200 m wide (or other proportions depending on the shape of the stand) and assign three-digit numbers to the grid lines of the X and Y axes (Figure II.4).

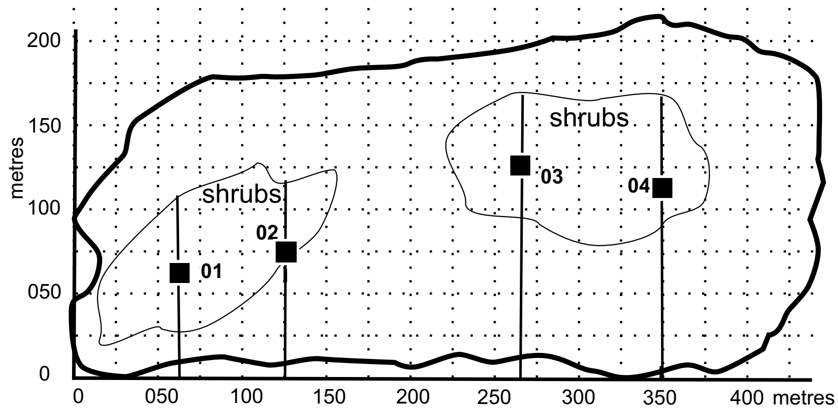


Figure II.4: Rough chart of a grassland stand with two patches of shrubs and small trees, overlaid with a grid. The locations of 4 randomly selected 5 m x 5 m stand-alone quadrats (not to scale) are shown. 01, 03, and 04, would be accepted, and 02 rejected.

From a table of random numbers based on the lengths of the X and Y axes (or alternatively from a bag of numbered chips or balls), select and record the 10 cross points on the grid that satisfy the conditions outlined above. Each cross point becomes the centre point of a quadrat.

Once the quadrat locations have been selected, use a compass and tapes to find the specific point(s) in the stand and drive in a stake for reference purposes.

3. How to survey/establish shrub and small-tree monitoring quadrats

Directions are given for 5 m x 5 m quadrats, but they apply equally well to 2 m x 2 m quadrats. Where there are differences, they are noted in the appropriate place.

Season of survey : The preferred time to survey quadrats in forest ecosystems is in the fall before any major snow accumulation when the absence of leaves makes the work easier. This period also ensures that damage to the ground vegetation by the technicians is kept to a minimum. In most non-forest ecosystems the season of survey is less critical.

i) STAND-ALONE QUADRATS

Equipment:
- list of stake locations marking quadrat centres
- theodolite and tripod
- two steel surveying tapes (minimum length 10 m)
- flagging tape
- one 2-m telescoping surveying rod (with levelling bubble) that extends to 4 m
- survey stakes, preferably metal-core plastic, especially if they are to be driven completely into the ground
- two mallets
- GPS (global positioning system) instrument with data differentially corrected
- waterproof record book and pencils

Team: minimum of three

Method: Position the theodolite[4] over the previously set centre stake to start the survey. With the tripod in position and properly level, the instrument operator sites along a diagonal bearing to establish the first corner. Make sure in establishing the quadrat that it is properly oriented, and "square" to the main slope of the land or, if flat, oriented "square" to the cardinal compass points. Technician A goes down the line with a tape measure to reach a horizontal distance of 3.535 m - half the diagonal distance between the opposite corners of the 5 m x 5 m quadrat. (The diagonal measurement of 2 m x 2 m quadrats is 2.83 m.) Make all measurements to the nearest centimetre.

Technician A holds a surveying rod vertically over the 3.535-m mark as a target for the instrument operator to determine the true bearing. Technician B pushes aside branches or small stems as necessary so that the instrument operator has a clear line of site and the vegetation is kept from deflecting the tape. **Survey teams must not cut or remove**

[4] When using the theodolite, it is important to avoid taking measurements in close proximity to metal objets such as belt buckles, jewellery, glasses with metal frames, or wrist watches, as they could cause errors in the magnetic readings. It is also important that the tapes are pulled snug to avoid sagging and distortions in measurements.

branches. In the same way, set the other three stakes. With the setting of these four stakes, a 5 m x 5 m stand-alone plot is established. Mark each corner stake with the quadrat number and the appropriate corner letter (Figure II.5). Line A-D is the base reference line (BRL).

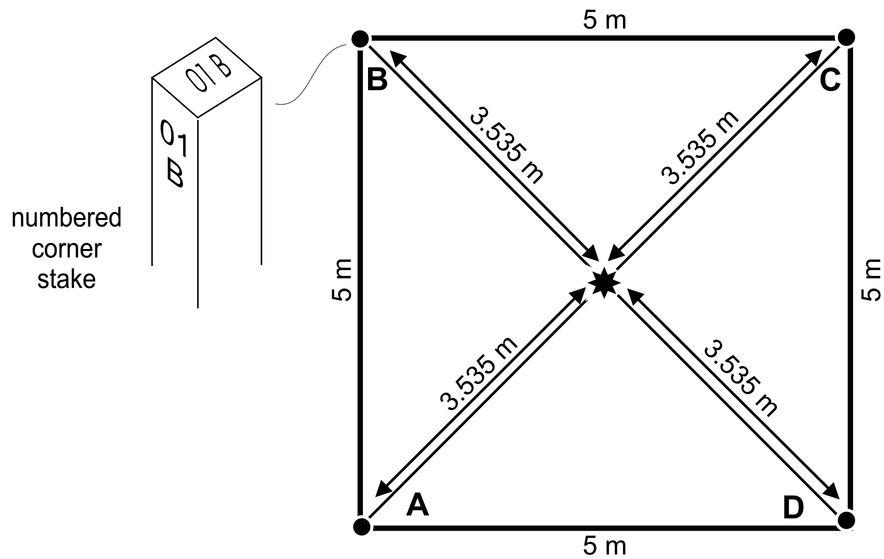


Figure II.5: Plan for setting up a 5 m x 5 m stand-alone quadrat. Numbering system for stakes is illustrated.

Continue to survey the quadrats until at least ten, or the preselected, larger number have been established. Identify the shrub and small-tree species in each quadrat and prepare a species accumulation curve (see *How to prepare a species accumulation curve*) to confirm that sufficient quadrats have been established. If insufficient, select another three to five positions, survey the plots, identify the species and include the additional species (if any) in the species accumulation curve. Continue until at least the minimum number of quadrats suggested by the graph has been established.

For reference purposes, record the latitude and longitude of some outstanding feature in the stand and the compass bearing of the A-D line of each quadrat. Prepare a plan of the layout of the quadrats in relation to the reference feature, and a written description of the route to find them.

ii) NESTED QUADRATS

The method below describes the setting of stakes 5 m from the 20 m x 20 m quadrat corners, using tapes and compass. This method can be used for either 20 m x 20 m stand-alones or on selected 20 m x 20 m quadrats of the one-hectare plot. If a theodolite is available, it could, of course, be used to set the 5-m stakes.

Equipment:

- list of pre-selected quadrat locations
- two steel surveying tapes (minimum length 10-m)
- flagging tape
- one 2-m telescoping surveying rod (with levelling bubble) that extends to 4 m
- string (60 m, plus 20 m for each quadrat)
- survey stakes, preferably metal-core plastic, especially if they are to be driven completely into the ground
- two mallets
- waterproof record book and pencils

Team: minimum of three

Method: From the selected corner stake, stretch strings to attach to the two adjacent corner stakes of the 20 m x 20 m quadrat. To ensure that the angle between the strings is a right angle, measure and mark 60 cm along one arm, and 80 cm along the other arm. The distance between the two marks should measure exactly 100 cm. (This demonstrates the use of the theorem of Pythagoras, i.e. $A^2 + B^2 = C^2$). Measure 5 m from the selected corner along each of the strings and insert a temporary stake (Figure II.6).

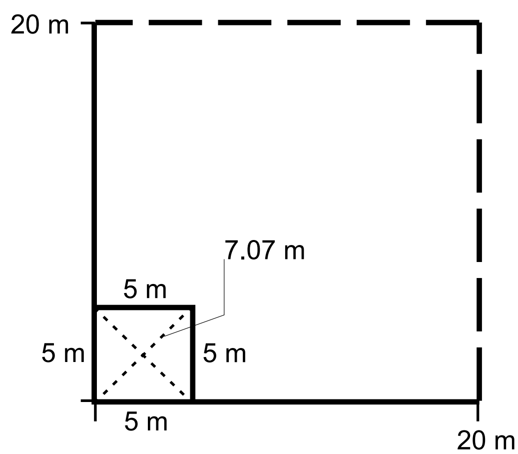


Figure II.6: Plan for setting up a 5 m x 5 m quadrat nested in a 20 m x 20 m quadrat

Establish a right angle at each of the temporary stakes, and measure 5 m from each to establish the fourth corner. Verify that the diagonal distances measure 7.07 m, and adjust the temporary stakes as necessary. For ease in data collection, outline the 5 m x 5 m quadrat with string.

Once the permanent positions are established, label the stakes with the quadrat number and corner letter. Leave the string in place until the shrub and small-tree data have been collected and then remove.

Continue to survey the quadrats until ten (or a predetermined larger number required for specific local needs, e.g. the result of statistical advice), have been established. Identify the species in each one. Prepare a species accumulation curve to determine the adequacy of the sample. If ten quadrats are insufficient, randomly select three to five additional corners, establish the quadrats, identify the species and prepare a new species accumulation curve. Continue until at least the suggested minimum number has been established.

4. How to prepare a species accumulation curve

A species accumulation curve (Figure II.7) is a useful tool for helping determine the number of quadrats needed to sample a single stratum of a plant community. The accumulated number of species (i.e. the number of new species found in each successive quadrat added to the total already found) is plotted on the Y axis against the quadrats (in the order tallied) on the X axis. When the points are joined, the curve characteristically rises abruptly because many new species are added with each new quadrat; it then levels off as fewer species are added with each additional quadrat.

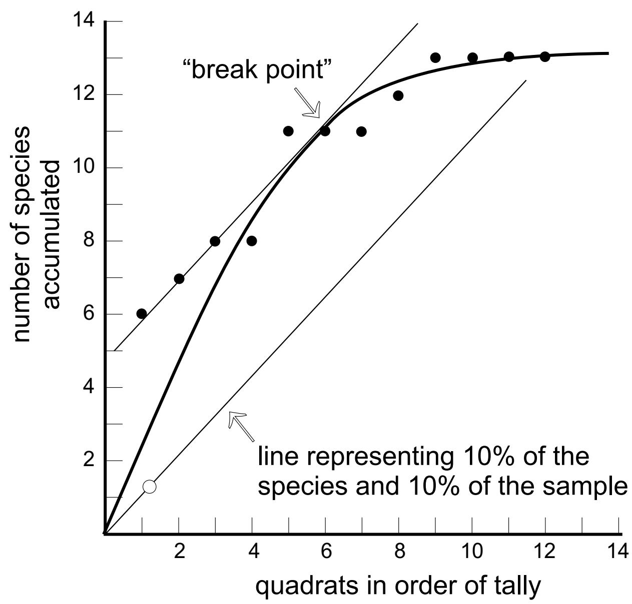


Figure II.7: Preparation of a species accumulation curve for determining the minimum number of quadrats to sample a stratum of vegetation

As added effort yields fewer new species, the need for data about additional species must be weighed against the effort required to get that data. Sampling is sufficient when no or very few species are added with each successive quadrat, that is sometime after the curve starts to flatten. Sample size (minimum number of quadrats), may be estimated with reference to the area ("break point") where flattening starts.

.

The break point may be estimated by the "10% rule" i.e. when 10% increase in area yields less than 10% new species. To locate the break point, draw a line from the zero point through the point representing 10% of the species and 10% of the sample area and extend it; draw a second line parallel to the first touching the curve - this is the break point. (Adapted from Oosting, 1956; see also Barbour *et al.,* 1999.)

For shrubs and small trees, the minimum number of quadrats is five over the break point. Tally ten 5 x 5 m quadrats (or twenty 2 m x 2 m quadrats) before preparing a species accumulation curve. If below the minimum number, tally three to five more quadrats, and prepare a new curve. Continue until the minimum number is reached.

Record Keeping

Listed below are the essential plot information and baseline data that should be recorded, the measurement schedules that should be followed, and the report contents. The methods are described in *Data/information collecting methods*.

Meticulous record keeping is essential. This applies not only to the variables that are measured in the monitoring program, but also to the descriptions of the location of the plot, the decisions made and the actions taken. The value of the monitoring program will be only as good as the level of informative detail kept about the plots, the accuracy of the data collected, and the systematic application of quality control and quality assurance measures. Ensure that all plot information and raw data are properly archived. EMAN recommends the use of Metamaker software for all electronically stored data (see <www.nbii.gov/tools/metamaker/metamaker.html>).

After the base data have been processed (see *Data Compilation and Processing*), a report on the state of the stand should be prepared, followed every five years thereafter by a new report. The first report should contain the goals, objectives, rationale, all the essential information, and the baseline data. The five-year reports should update the original report and give the details of new decisions; and report on the results of remeasurements and discuss their significance. It should pay special attention to the original goals, objectives and rationale of the plant biodiversity monitoring program. Any recommendations for modifying the approach or the variables to be measured during the next period should be clearly articulated, recorded and included in each report. All reports should be archived in electronic and hard-copy forms

Essential information

- name of stand and number of quadrats
- plan of stand with all quadrats located and numbered
- written description of access route to the stand

stand-alones:

- latitude, longitude and elevation of each quadrat (if independent of a one-hectare plot) and position in relation to any reference feature of the stand
- compass bearing of each base reference line (Line A-D)

or

- latitude, longitude, and number of the associated one-hectare plot
- compass bearing of each base reference line (Line A-D) - if different from the 1-ha plot

nested quadrats:

- identification numbers of the 1-ha plots where the nested quadrats are established, and the position (20 m x 20 m reference corner) of the 5 m x 5 m quadrats

Baseline data

It is essential that the following data be collected and recorded:

all species ≥4 cm dbh

- tag numbers, species names, and dbh
- condition of all individuals tagged
- height, and height to lowest living branch of all tagged individuals
- map of all tagged individuals

all species <4 cm dbh and ≥1 m tall[5]

- tag numbers and species names
- map of all tagged individuals

It is desirable that the following data be collected and recorded:

- height and canopy width[6] of all tagged small trees (especially important in ecosystems with scattered small trees)
- photographs from standard positions at standard times
- degree of canopy closure (if applicable)

Photography and canopy closure protocols have not yet been prepared.

Minimum checking/measurement schedule

At least every 5 years the stands should be remeasured. If the stand in which the quadrats are located is subject to severe weather, fire, or other extreme event, the quadrats should be remeasured and supporting information recorded as soon after the event as it is safe. The following activities should be undertaken and the results recorded:

all quadrats and all species

- recheck all corner stakes and replace as necessary
- note the changes in status of all tagged shrubs and small trees (record the tag number of those that have died)
- replace missing tags/numbers
- prepare and check a new map for each quadrat
- remeasure canopy closure (if applicable)
- rephotograph (if part of baseline data)

---

[5] When it is not possible to separate individual shrubs from one another (most likely in shrub-dominated ecosystems), record the number of clumps of each woody species.

[6] For small trees over 1.3 m in height, dbh measurements taken with carpenter's calipers, may be substituted for canopy width measurements.

all species ≥4 cm dbh

- remeasure dbh of all tagged small trees
- note tag number, species and dbh of all small trees that have reached 4 cm dbh
- remeasure height of tagged individuals and height to lowest living branch

all species <4 cm dbh and ≥1 m tall

- remeasure height and canopy width of all tagged individuals
- tag, number, identify, measure height and canopy width and map all species that have reached minimum measurements

State of the stand report

This outline applies specifically to a stand in which the small trees and shrubs are the dominant vegetation type. When the program also includes monitoring the ground vegetation, the information about these results should also be included.

Suggested outline for a baseline stand report:

- overall goals and objectives of the site monitoring program
- specific goals and objectives of the plant biodiversity monitoring program
- general description of the stand(s) selected for monitoring (e.g. size, location, age, and history)
- decisions and rationale for selecting methods, scheduling, etc.
- essential plot information
- detailed description of the stand, based on the results of the data collection

When the monitoring of shrubs and small trees is part of a forest monitoring program, then the report on this stratum will form part of the overall report on the state of the stand. In this case, only the following need be addressed:

- decisions and rationale for selecting methods, scheduling, etc.
- essential plot information
- detailed description of the shrub and small tree stratum, based on the collected and analyzed data

Data/Information Collecting Methods

Directions are given for making the measurements or gathering the information listed under *Record Keeping*. At the end of this Section is a model shrub and small tree field data sheet that monitoring groups may find useful.

1. How to tag a shrub or small tree

Before starting any measurements, tie string to the stakes of the selected quadrat to make its boundaries clear and facilitate orientation during tagging and mapping. Remove the string when all measurements have been taken.

Equipment:
- tree tags
- dbh tape (metric)
- grafting tape, commercial electrical cable ties, or plastic coated wire
- flagging tape
- field data sheets and pencils

Team: two people

Method: Tag all woody individuals over one metre in height and 4 cm dbh or above (Figure II.8). In the case of individuals on a quadrat line, tag if 50 % is inside the quadrat, otherwise ignore. Attach the tag to a branch using one of the ties mentioned above (for shrubs, consider using a piece of flagging tape to highlight the tag's position). Record the tag number and species of each individual tagged. When a small tree is multiple-stemmed and the branches separate below 1.3 m, number/tag and measure each stem that is 4 cm dbh or more. Add the letters A, B, etc after the tree number on the tag, with the largest diameter stem being A.

When shrubs are in dense clumps and the individuals are impossible to distinguish, note this on the data sheet and treat the clump as an individual. Tag the clump and, if necessary, flag one or more branches to identify it.

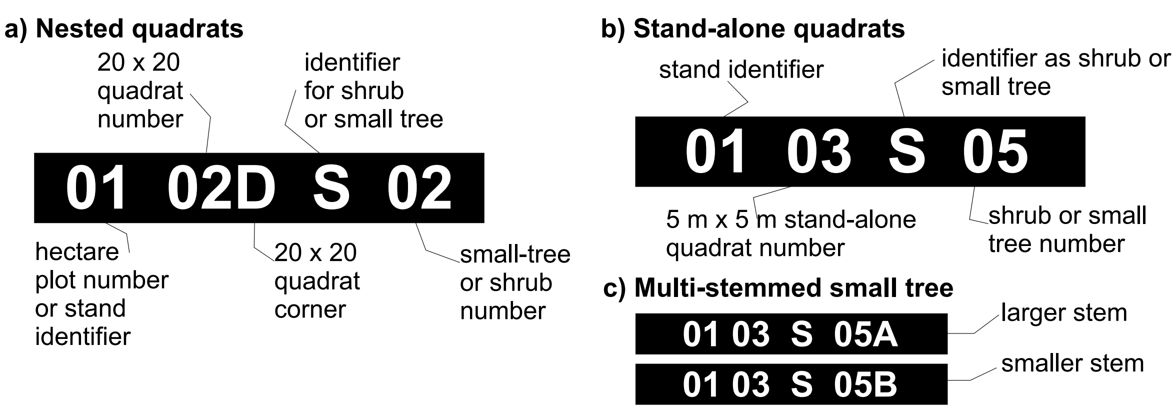


Figure II.8: Tag numbering system for shrubs and small trees in a) nested quadrats and b) stand-alone quadrats; c) illustrates numbering for multiple stems of a single tree - the largest stem is always "A".

2. How to identify plants

Equipment:
- ! manuals, species list for the stand
- ! plastic bags or plant press
- ! labelled fresh or dried specimens for reference

Team: two people

All plants must be correctly identified to species. To facilitate identification in the field, it is that advisable that the Responsible Group organize a workshop to familiarize the observers with the species they are likely to encounter[7]. As errors in species identification are found even among trained observers, any observer who has any doubt whatsoever should collect a specimen for expert identification[8]. The specimen must be at least 40 cm long with the leaves attached, and if possible, with attached flowers or fruit. Each specimen should be labelled with an identification number relating it to the unknown species in the quadrat. Never take a specimen from the quadrat; choose one of the same species from outside the quadrat. Place the specimen in a plant press (bend it into a "v" or "z" shape if it is too large for the press sheets) or, if the storage is temporary, in a plastic bag which is kept in the shade. Make sure that any group of individual plants given the same temporary identification are really the same species.

Always have a manual in the field for making identifications. *Trees in Canada* by John Laird Farrar (1955) is recommended for the identification of small trees (and some of the larger shrubs) in conjunction with the manual recommended as the nomenclatural standard (see bibliography), species lists, and field guides to the local flora. For each plant, record the latin binomial (i.e. scientific name), authority for the scientific name (e.g. pussy willow should be listed as *Salix discolor Muhl.*), and the manual used for identifications.

For information on making herbarium/voucher specimens, see *Making Plant Collections* (Haber, E. *Guide to Monitoring Exotic and Invasive Plants*, Appendix 3). Internet address <http://www.cciw.ca/eman-temp/research/protocols/exotic/append3.htm>.

---

[7] Participants in a workshop should be made aware of any rare or species listed as endangered, threatened or vulnerable by the Committee on the Status of endangered wildlife in Canada (COSEWIC - web address <http://www.cosewic.gc.ca/COSEWIC/Default.cfm>) they may encounter and warned against harming them.

[8] If an observer has reason to believe that an unknown plant is rare or COSEWIC-listed, it should not be collected. Three options are possible for identifying the plant: a) bring an expert to the field; (b) take a photograph; or (c) make a sketch of its salient features. Accompany the last two with a good written description of the habitat.

3. How to measure diameter at breast height (dbh)

This measurement is taken to measure growth of small trees over time and to determine the basal area occupied by each species. Normally, only small trees or shrubs that are at least 4 cm dbh are measured, but if time and resources permit, diameters of small trees <4 cm dbh and $\geq$ 1.3 m in height could be measured using small calipers instead of diameter tapes (in which case, cover may not be measured).

Equipment:
- metric dbh tape (and small metal calipers if used)
- blue non-lead paint (e.g. Nelson Tube Marker)
- data sheets and pencils

Team: two people

Method: Mark each small tree with a small daub of environmentally friendly paint at 1.3 m above the ground.This is a permanent mark to ensure that all dbh remeasurements are taken at the same place. Make sure the tape is correctly placed around the tree at right angles to the direction of growth (Figure II.9) and not over an atypical part of the stem. Many small trees may be irregular in form or position and therefore require special handling in measuring the dbh. When the dbh is not taken at 1.3 m, record the height at which it is taken.

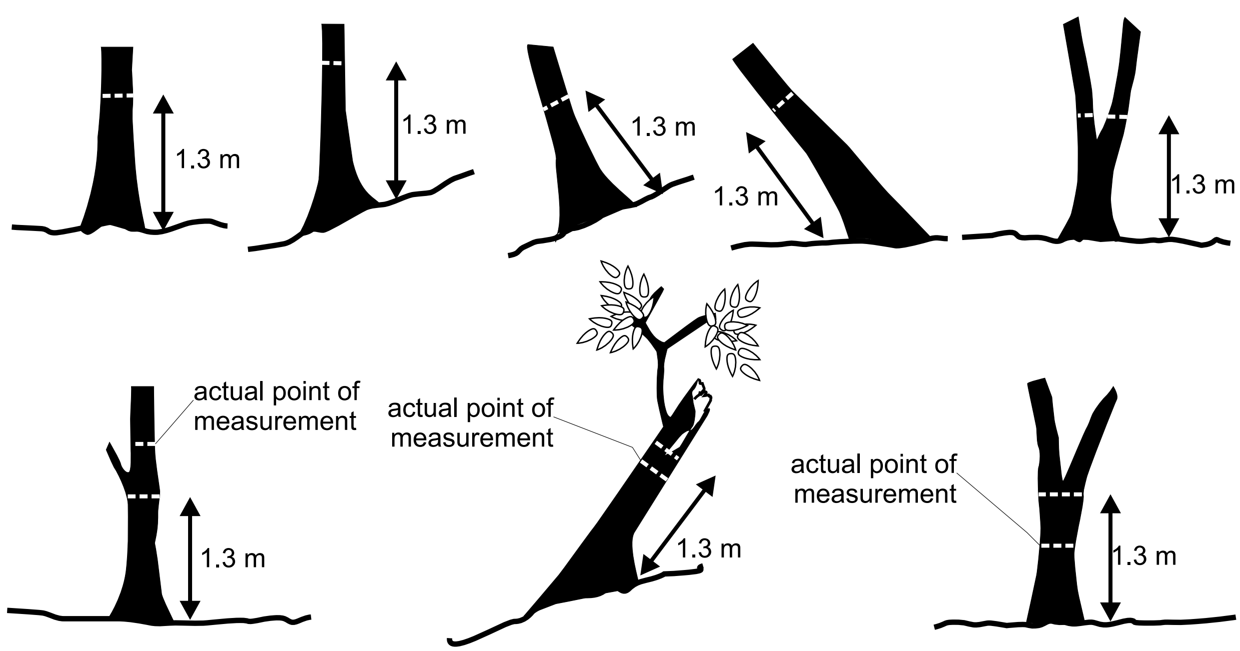


Figure II.9: Measuring positions of dbh (after Dallmeier, 1992). Single dotted line shows the measurement position - if because of a fault two dotted lines are shown, the correct position is labelled.

4. How to map shrubs and small trees

Equipment:
- one steel survey tape (minimum length 10 m)
- 2-m telescoping surveying rod (with levelling bubble)
- Compass
- data sheets and pencils

Team: three people

Method: Each tagged woody species is mapped in relation to two adjacent, precisely located, corner stakes of the quadrat in which it is found (Figure II.10).

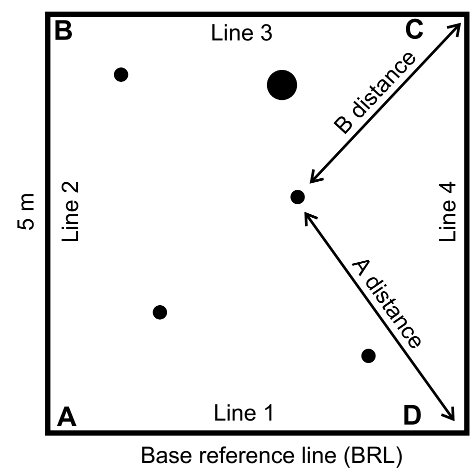


Figure II.10 : Set-up for mapping shrubs and small trees

One team member, holding one end of the survey tape, stands at the tagged tree that is to be mapped. With the second team member holding the other end of the tape, measurements are taken from the tree to two adjacent corners of the quadrat, for example, to the C corner and to the D corner, which are at either end of Line 4. The tape must be kept taut, with each end at the same height above the ground. The naming of these distances is from the point of view of the person standing at the tree: to his/her right is the "A distance" (i.e. the distance from the tree to the D corner); and to his/her left is the "B distance" (i.e. the distance from the tree to the C corner). The third team member records the tag number, the A and B distances and the line number. (Note that the sum of the A distance and the B distance must be equal to or greater than 5 m.) Alternatively, the lines could be recorded as A-B, B-C etc., and the measurements expressed as distances from the tagged tree to the specific corners.

How to fail: The two most common errors in mapping are switching A and B distances and incorrectly recording the line number.

Map generation: In forest ecosystems where a one-hectare plot or single 20 m x 20 m stand-alone quadrats have been established, use the maps generated by the BIOMON software and the measurements taken in the field to add the small trees and shrubs. Use the completed quadrat maps to verify in the field the position of each small tree and shrub and correct any mistake by remeasuring the distances, redoing the maps and rechecking the results.

If preferred, the shrubs and small trees could be mapped directly in the field using the plane table or similar survey technique.

5. How to recognize small-tree condition

Equipment:
- illustrations of small tree condition
- field data sheets and pencils

Team: two people - usually the tagging or dbh team

Method: Note the condition (or status) of all tagged trees using the illustrations in Figure II.11 for guidance. Record observations using the following symbols:

- standing alive (AS)
- broken alive (AB)
- leaning alive (AL)
- fallen/prone alive (AF)
- standing alive, dead top (AD)
- standing dead (DS)
- broken dead (DB)
- leaning dead (DL)
- fallen dead (DF)

Do not record any fallen/prone dead individuals when taking the initial measurements. At each subsequent remeasurement, record the condition of all tagged individuals (alive and dead) including those that have fallen since the baseline data were collected.

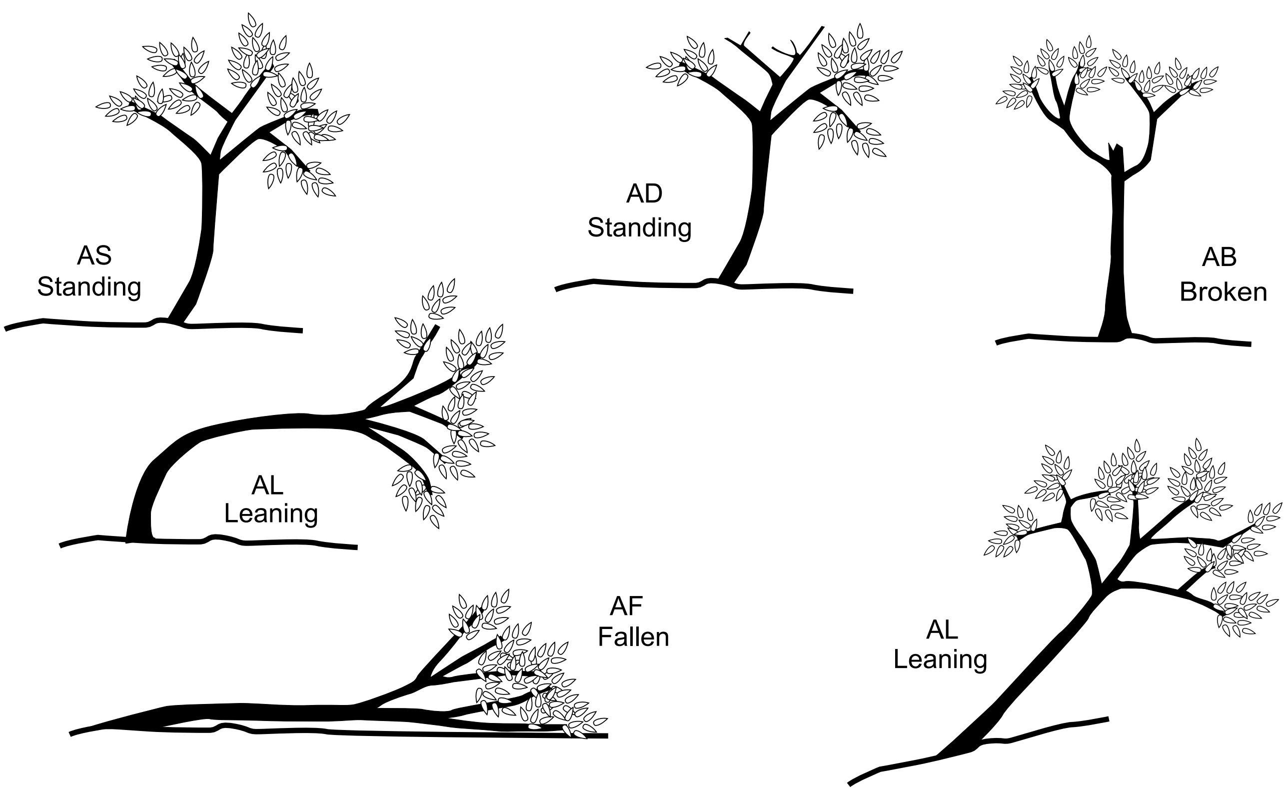


Figure II.11: Illustrations of small tree condition (after Dallmeier, 1992)

6. How to measure shrub and small-tree heights

Equipment:
- telescoping survey rod (with levelling bubble) for trees <2 m
- clinometer (Haga level is suggested) for trees $\geq$2 m
- steel survey tape (minimum length 10 m)
- Compass
- field data sheets and pencils

Team: two people

Note: If individual height measurements are not taken, it would be useful to determine the average height of the stand and the depth of the canopy of the shrub dominated communities, and of groups of small trees in non-forest communities. These canopy heights and depths can be determined using one of the methods below.

Methods: Measure the heights of both living and dead individuals.

Telescoping survey rod: One person holds the telescoping rod against the tree or in the centre of a shrub (Figure II.12) and the other person records the height. At the same time, record the height of the lowest live branch if over 1 m above the ground level. These two figures will determine the canopy depth.

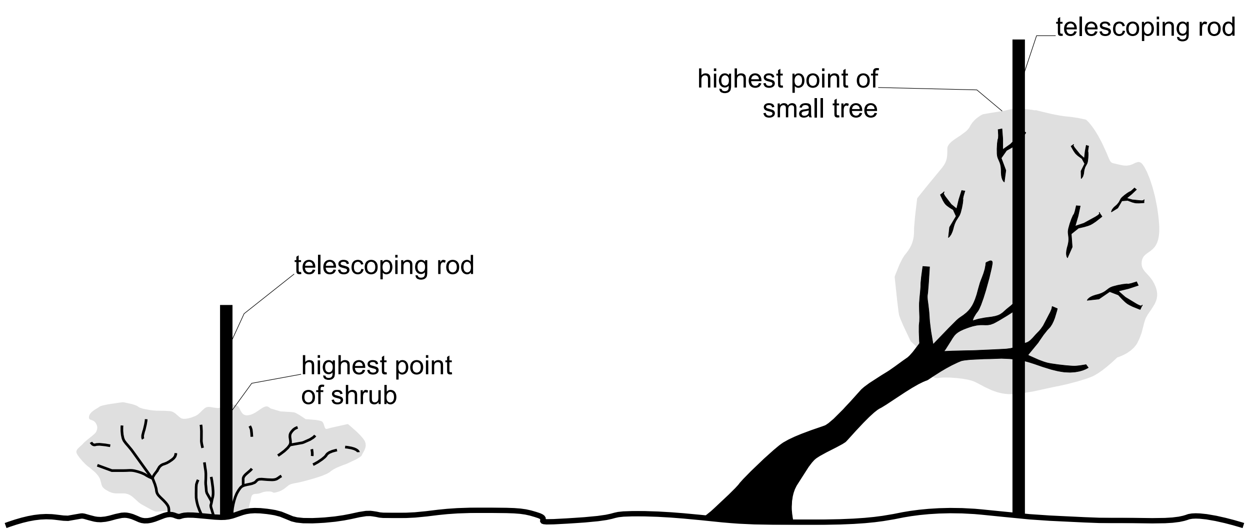


Figure II.12: Measurement of small-tree or shrub heights using a telescoping survey rod

Clinometer: From a measured distance (such as 10 m) from the base of the tree, record the readings (Figure II.13) for the top and base of the tree, and the horizontal line from the eye-level of the observer to the tree stem, or equivalent below the base of the tree. Record the eye-level height of the observer and whether the base of the tree is above, the same, or below the eye-level of the observer. In addition, take the reading for the lowest live branch. Calculate the height and canopy depth of each tree.

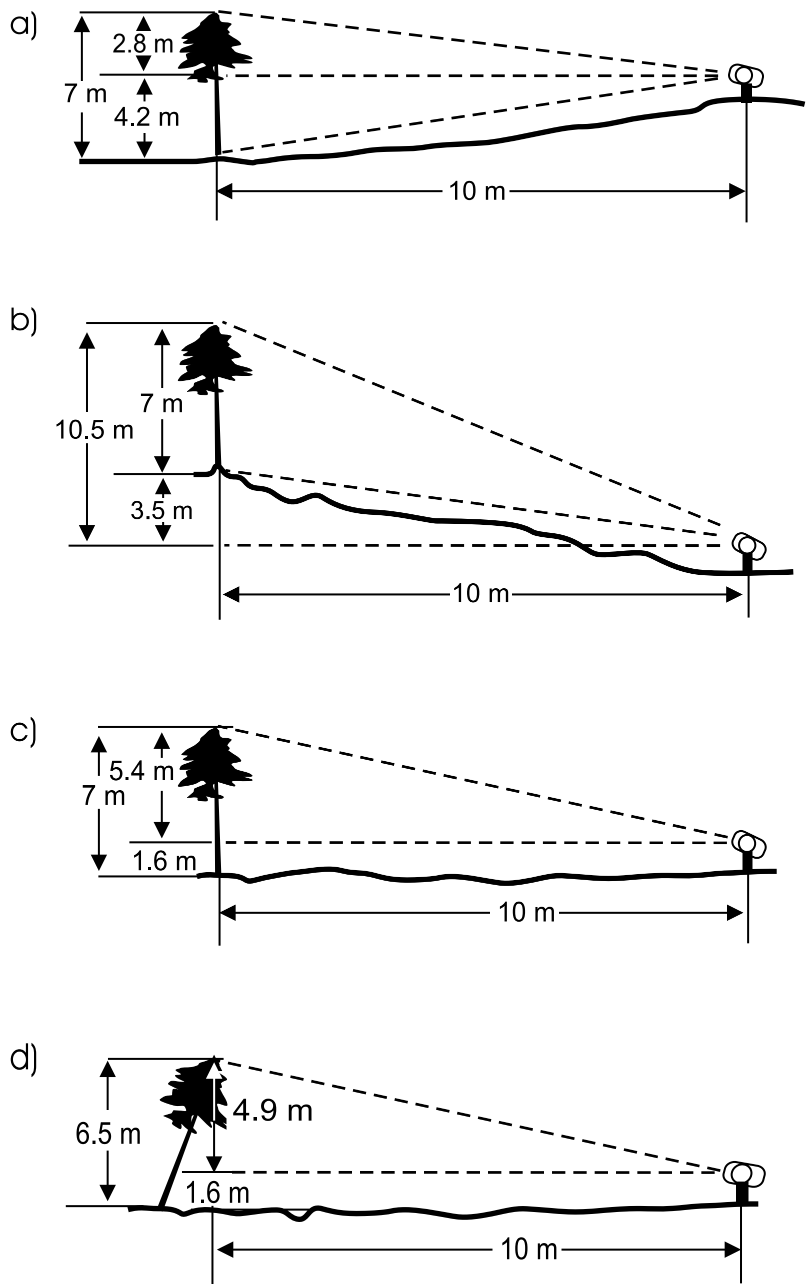


Figure II.13: Measurement of the height of a small tree. The height of the small tree (7.0 m for a, b, and c, and 6.5 m for d) is determined by:

a) adding the two measurements above and below the horizontal reading

b) subtracting the distance from the base of the tree to the horizontal, from the total

c) adding the height of the instrument above the ground to the distance above the horizontal line

d) adding the height of the instrument above the ground to the distance between the top of the tree and the point on the horizontal line directly beneath (use a survey rod as a target)

7. How to measure canopy width

Normally, the measurement of canopy width is taken only on species under 4 cm dbh. If the dbh of trees less than 4 cm is measured, there may be no need to take canopy width. In some non-forest ecosystems, with infrequent, widely spaced trees over 4 cm dbh, canopy width of small trees may be an important variable to record, especially in relation to other biota being monitored in the same ecosystem. The Responsible Group must decide whether the canopy width in this situation should be recorded.

Equipment:
- steel measuring tape (minimum length 10 m)
- Compass
- data sheet and pencils

Team: two people

Method: One person holds the tape at the stem of the sapling or small tree, or holds a rod in the centre of the shrub (Figure II.14). The other draws out the tape to the drip-line of the canopy and measures the distance, which is recorded. For shrubs and saplings, take four measurements at the cardinal points of the compass; for trees, take eight measurements at 45° intervals, starting with the north.

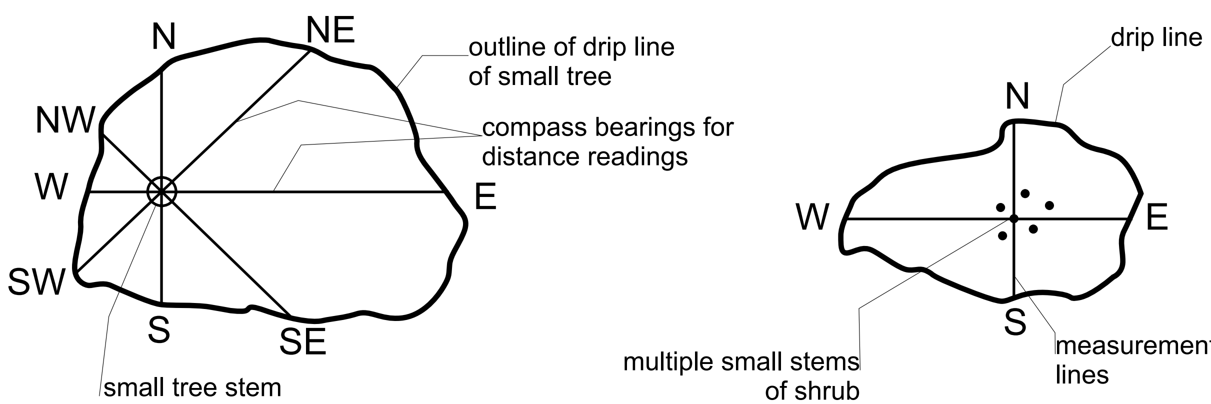


Figure II.14: Measurement of shrub and small-tree canopy width

Data Compilation and Processing

The instructions and formulae set out below are for the initial analyses of the data from the shrub and small tree monitoring plots. Appended to this section is a model data summary sheet that monitoring groups may find useful.

Prepare a species list (alphabetically by family and scientific name) for the shrub and small tree stratum of the stand being monitored. Note which of the species in the list are actually present in the quadrats that comprise the sample. The area of the sample will be a multiple of 25 m^2 for 5 m x 5 m quadrats. Use dead tree data only where specifically requested and record separately.

Because of the size differences among the individuals present in the shrub and small-tree stratum, two different methods are used for determining the area a plant occupies: cover (determined from canopy widths), and basal area (determined from dbh). Because of this, the data has be divided into two groups: individuals with dbh measurements and individuals with canopy width measurements. Using the formulae listed below make the following calculations:

a) total area sampled (e.g. ten 5 m x 5 m quadrats equals 250 m^2)
b) for each species within each group, calculate: abundance, density, dominance, frequency, relative density, relative dominance, relative frequency and importance value
c) for the group with dbh measurements, use basal area for the determination of dominance; for the group with canopy-width measurements, use cover for the determination of dominance.

Abundance: total number of individuals of each species in the total area of the sample. When preparing summary tables, list species in order of abundance starting with the most abundant. Always use the scientific names in the tables.

Basal area: cross-section area of woody plant stems. Using conversion tables, calculate the basal area from dbh figures for each individual and the total basal area for each species.

Cover: area occupied by individuals of a species. Calculate the cover of an individual (the area of the canopy when projected on the ground) from canopy-width measurements and then determine the total cover for each species.

Density: average number of individuals of a species on a unit area basis

$$D = \frac{\text{number of individuals in the sample}}{\text{total area of the sample } (m^2)}$$

Relative Density: density of one species relative to all species

$$RD = \frac{\text{number of individuals of a species in sample}}{\text{total number of individuals of all species in the sample}} \times 100$$

Dominance: area a species occupies on a unit area basis. It is determined by using **either** basal area **or** cover.

$$Dom = \frac{\text{area occupied by a species in the sample } (m^2)}{\text{total area of the sample } (m^2)}$$

Relative Dominance: area a species occupies relative to the total area occupied by all species in a sample. It is determined by using **either** basal area **or** cover.

$$RDom = \frac{\text{area occupied by a species in the sample } (m^2)}{\text{area occupied by all species in the sample } (m^2)} \times 100$$

Frequency[9]: distribution of a species through a stand, that is the percentage of quadrats in the sample in which a species occurs

$$F = \frac{\text{number of quadrats in which a species occurs}}{\text{total number of quadrats in sample}} \times 100$$

Relative Frequency: distribution of one species in a stand relative to all species

$$RF = \frac{\text{frequency of a species in the sample}}{\text{total frequency of all species in the sample}} \times 100$$

Importance Value[10]: an index made up of Relative Density, Relative Dominance and Relative Frequency that describes the structural role of a species in a stand. It is also useful for making comparisons among stands in reference to species composition and stand structure

IV = Relative Density + Relative Dominance + Relative Frequency

---

[9] Frequency and Relative Frequency can only be calculated, and compared and pooled when data are from quadrats that are of the same size and shape.

[10] When comparing or pooling Importance Values from different stands, all values must be based on quadrats that are the same size and shape.

SHRUB AND SMALL-TREE SAMPLE: FIELD DATA SHEET. Stand name...Community Type...

Date........................... Stand location (lat. & long).. Quadrat size...................... Quadrat (nested or stand-alone) nº..................................

Identification Manual .... Observer(s)...

Tag #	Species name	Number of stems	Line (A, B, C, D)	A Distance (m)	B Distance (m)	Canopy Width **OR** dbh (m)	Height (m)	Condition	Notes

SHRUB AND SMALL-TREE SAMPLE: SUMMARY SHEET. Stand name.. Community type..

Stand location (lat. & long.)... Quadrat size.................. Number of quadrats in sample .... Sample area(m^2).................................

Date........................ Data processor(s)..

Species name	Abundance	Density	Frequency	Basal Area **OR** Cover	Dominance	Relative Density	Relative Frequency	Relative Dominance	Importance Value	Notes

SECTION III

GROUND VEGETATION BIODIVERSITY MONITORING PROTOCOLS

Table of Contents

Introduction

For the purposes of this document, ground layer vegetation (defined as comprising mosses, lichens and fungi growing on the ground, together with small trailing and rosette plants) and field layer vegetation (defined as comprising all herbaceous vegetation regardless of height, and all woody plants under 1 m in height) are combined for convenience. The methods described here are for use in conjunction with those already described in Sections I and II for canopy tree and shrub and small tree strata in forest and non-forest communities, or on their own where appropriate.

Rationale

The purposes of monitoring ground vegetation vary according to the interests of the Responsible Groups implementing a biodiversity monitoring program. All species except epiphytes germinate in the ground vegetation layer, spending what is probably the most vulnerable part of their life cycle in this stratum. Species found only in the ground vegetation stratum usually have a shorter lifespan and different survival tactics than those that eventually occupy other strata.

Ground vegetation species are finely tuned to their environment. The large numbers of species and individuals will yield a rich data base for analysis of their dynamics in response to environmental changes. Shifts in the concentration of airborne pollutants, increased in UV-B radiation, and the variability of temperature and moisture regimes are among the environmental changes that may impact the species. Long-term monitoring of ground vegetation species should help differentiate between short-term natural cyclic population variation, and longer term vegetation shifts driven by environmental change. Faster results on population change are more likely to be achieved from monitoring the ground vegetation stratum than from monitoring other vegetation strata. Phenological observations can also contribute to documenting climate cycles and long term change.

Monitoring rare plant species, most of which are herbaceous, is important for determining population stability. It is also within this stratum that the movement of invasive species can most easily be tracked. Ground vegetation is also important as food and habitat for animal (vertebrate and invertebrate) species. Information from monitoring this stratum is vital for land management decisions.

i) FOREST ECOSYSTEMS

The composition and structure of the forest floor vegetation may vary depending on canopy cover (which determines the amount of light reaching the forest floor), the season of the year, and substrate and moisture variation. Species making up the ground vegetation include seedlings of canopy trees or the species that are likely to replace the canopy trees as a result of succession.

In Canada, more attention has been focused on the canopy-tree stratum than on the ground vegetation stratum with the result that there is little long-term information about the population dynamics of canopy-tree species when occupying this stratum. Monitoring will yield information about the rate of germination, growth and development of these seedlings, and their interactions with the species that make up the understorey strata, resulting in clues about the long-term development of the stand being studied.

ii) NON-FOREST ECOSYSTEMS

Herbaceous plants that are found in non-forest ecosystems, because of their relatively short life spans and rapid maturation rates, are expected to respond more rapidly to environmental change than those found in forest ecosystems. Full exposure puts ground vegetation species under direct risk from changes in climate, moisture regime, UV-B radiation, acid rain, etc. Information, derived from accurate, standard methods documenting the reactions of herbaceous species to such exposure, could provide a useful early warning system about the changes that are also affecting herbaceous species in forests, but are occurring at a slower rate, because of the filtering action of the canopy cover.

The long-lived plants of arctic and alpine tundra are also important to monitor especially since environmental changes appear to be most extreme at high latitudes and altitudes. The International Tundra Experiment (ITEX) protocols, which may be used in conjunction with those described here, are recommended for use in monitoring the impact of environmental change on individual species (for the description of the methods see <http://www.dpc.dk/About_us/NSN/ITEXManual.html>). This is an international program dedicated to understanding the effects of global climate change on tundra ecosystems.

Plot[1] Size

The recommended quadrat size for monitoring ground vegetation is 1 m x 1 m. In some ecosystems (e.g. dense grassland, meadow) where the individuals are small, numerous and densely packed, smaller quadrats (e.g. 50 cm x 50 cm, or 25 cm x 25 cm) may be more appropriate. Although the directions in this document are based on the use of 1 m x 1 m quadrats, they may be easily adapted for smaller sizes. One size of quadrat should be chosen for a particular monitoring program because data from different sized quadrats cannot be combined and must be processed separately.

Permanent Plot Establishment

Since an intensive ground vegetation monitoring program necessitates several visits per year, scheduling must allow for this without interfering with the activities of others. The Responsible Group should keep scheduling and monitoring needs in mind when discussing the arrangement of 1 m x 1 m quadrats, especially if they are to be nested in plots where other vegetation strata are being monitored. When 1 m x 1 m quadrats are nested in larger quadrats, it is important that they not be placed in corners because of the damage that can be caused by data collectors.

1. How to decide on the number[2] of quadrats

The number of quadrats necessary to adequately sample the ground vegetation of a particular ecosystem is probably less than 50 for most parts of Canada. Since the number of vascular plant species decreases with an increase in both latitude and altitude, the minimum number of quadrats will be lower in northern Canada than in southern Canada. The number of 1 m x 1 m quadrats needed will depend in part on statistical advice, the number of species, and the time and resources available. The number for smaller-sized quadrats will usually be greater than for 1 m x 1 m quadrats. Set up and count the accumulated species on a minimum of 20 1 m x 1 m quadrats before preparing a species accumulation curve. Establish additional quadrats as necessary.

---

[1] *Plot* and *quadrat* are usually synonymous terms for measured areas of vegetation used in sampling. In this document, *plot* is used as a general term (and for the 1-ha sampling size) while *quadrat* is used for all other sampling sizes.

[2] Barbour *et al*., 1999, has a table which suggests a range of numbers of quadrats for monitoring different ecosystems and different strata within those ecosystems. The minimum numbers suggested in this document are derived partly from this table and partly from experience in Canada.

2. How to determine the arrangement of quadrats

The 1 m x 1 m quadrats may be set up as stand-alones in any situation and may also be nested in larger quadrats. What follows here is a description of different arrangements which a Responsible Group may consider depending on the objectives of the monitoring program and the community type being monitored.

One by one metre quadrats may be arranged as follows:

a) stand-alones randomly distributed in any community type from tundra to forests
b) nested in 5 m x 5 m stand-alone quadrats
c) nested in 20 m x 20 m stand-alone quadrats
d) stand-alones used associated with 1-ha plots
e) nested inside a hectare plot but only on well drained substrates with sparse ground vegetation - not recommended by EMAN

The arrangement of 1 m x 1 m quadrats must be considered very carefully when the planning the full monitoring program - not only when planning the plant monitoring program - because of the damage that data collectors can unwittingly cause. **The more activities requiring data collectors to be regularly in a limited area (e.g. a 1-ha plot), the more likely it is that the changes observed will be due to the combined impact of the data collectors.** The impact of a schedule of multiple data collection visits annually to a limited area (e.g. a 1-ha plot) requiring multiple data gatherers will bring about changes in the structure and composition of the ground vegetation. Some of the changes will be path creation, soil compaction, disappearance of some herbaceous and other plant species, disruption of the habitat of small vertebrate or invertebrate species, etc). The changes will be particularly rapid or even immediate in ense, very humid or very wet plant communities, or on dry lichen dominated communities. If care is taken by limiting the number of people and numbers of annual visits to a specific limited area, probably not much harm is done (except on dry lichen-dominated ground cover). **Any stand with lichen-dominated ground vegetation should be walked on only after rain or when still wet after a heavy dew.**

EMAN strongly recommends against nesting ground vegetation quadrats inside a 1-ha plot because of these concerns (unless visitor impact is an objective of the monitoring program). One exception could be for forest stands on sandy or stony substrates, with a sparse shrub layer, and limited lush or lichen ground vegetation. In such situations 1 m x 1 m quadrats may be established on the hectare plot if the monitoring is restricted, and schedule limited to single annual visits. When statistical advice suggests that more than the minimum number of 1 m x 1 m quadrats recommended here, stand-alone are preferable and to nested quadrats. Whatever the decision regarding stand-alone or nested quadrats, the decision should be recorded and the reasons given.

To reduce trampling and other effects associated with corner stakes, EMAN recommends that all nested quadrats be established along the sides of the quadrats in which they are nested and not in the corners.

a) Stand-alone 1 m x 1 m quadrats: Select the community where the monitoring is to take place. To determine the quadrat locations within the community, use a random selection method. One method is to prepare a rough map of the of the area to be monitored and draw a line along one side (Figure III.1). Randomly select two or more points along this line for setting stakes (base stakes). Randomly select locations along a line perpendicular to the original line starting from the base stake (Figure III.1a). Another method is to preselect (using a random selection method) two or more points in the stand. From these points where the base stakes are placed, quadrat locations can be determined by randomly selecting points on a compass star centred on the point (Figure III.1b). In selecting the specific locations, ensure that all quadrats are at least 5 m apart.

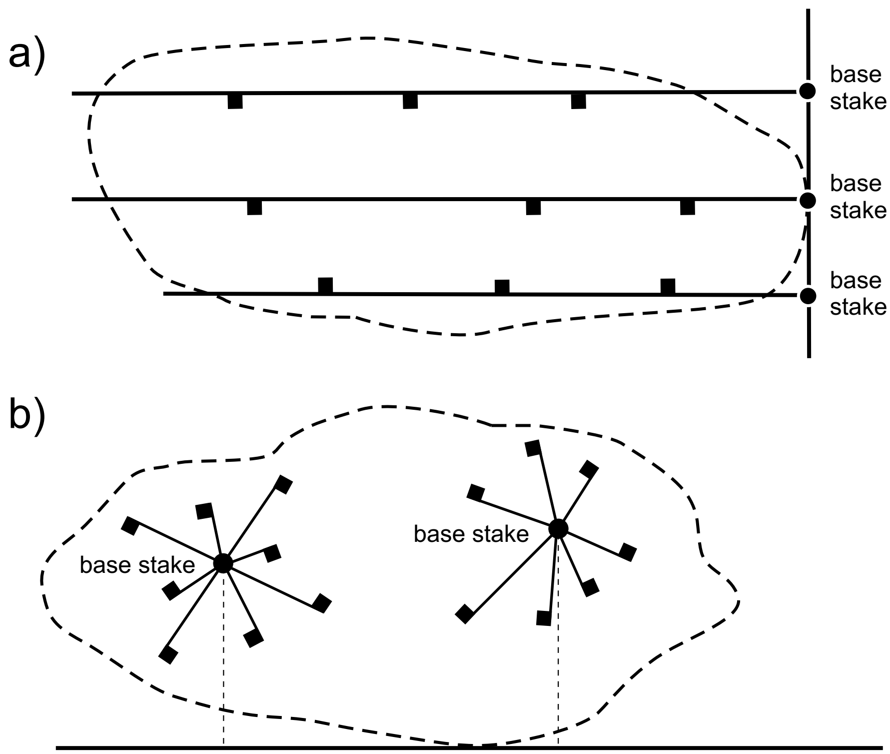


Figure III.1: Two plans for placing 1 m x 1 m stand-alone quadrats in a grassland community. a) Three randomly selected lines crossing the community from base stakes, with randomly selected 1 m x 1 m stand-alone quadrats; b) Two randomly selected locations for base stakes from which randomly-distributed arms of random lengths radiate, with a stand-alone 1 m x 1 m quadrat at its tip.

Using a table of random numbers, or a bag of numbered chips or balls, draw numbers to select points along the line. Each point represents the location of one corner of a quadrat. The decision as to whether the quadrat is to go to the left or right of the line should be pre-determined before going into the field. Set at least 2 stakes at each selected point and drive in flush with the ground (use metal-core plastic or stainless steel stakes).

A series of lines could be established in this way with a permanent stake (base stake) being placed at the origin of each line or the centre of the compass star arrangement.

b) Quadrats nested in 5 m x 5 m stand-alone quadrats: Position the 1 m x 1 m quadrats two metres (Figure III.2) from a corner of the 5 m x 5 m quadrats. Because 1 m x 1 m quadrats are nested in 5 m x 5 m quadrats, opportunities for randomization will be limited, especially when the ground vegetation is rich in species. Presence of tree stems may further limit the number of quadrats or influence their placement. More than one nested quadrat will mean that they are less than the recommended 5 m apart.

When the shrub and small tree sample size is ten 5 m x 5 m quadrats then each one will have two nested 1 m x 1 m quadrats. Randomly select a line (A-D, A-B, B-C, C-D) of each 5 m x 5 m quadrat for the location first quadrat 1 m x 1 m; the second will be established on the opposite side. When the shrub and sample size is more than ten 5 m x 5 m quadrats, select a line from each one, and then randomly select which quadrats will have a second 1 m x 1 m quadrat, if necessary.

If more than 20 quadrats are required and there are ten 5 m x 5 m quadrats, then a third and perhaps a fourth 1 m x 1 m quadrat (Figure III.2) could be established in each 5 m x 5 m quadrat. Alternatively, the required additional number could be established as stand-alones in the same plant community. Such a procedure would give statistically more reliable data. Tally the new quadrats in groups of five.

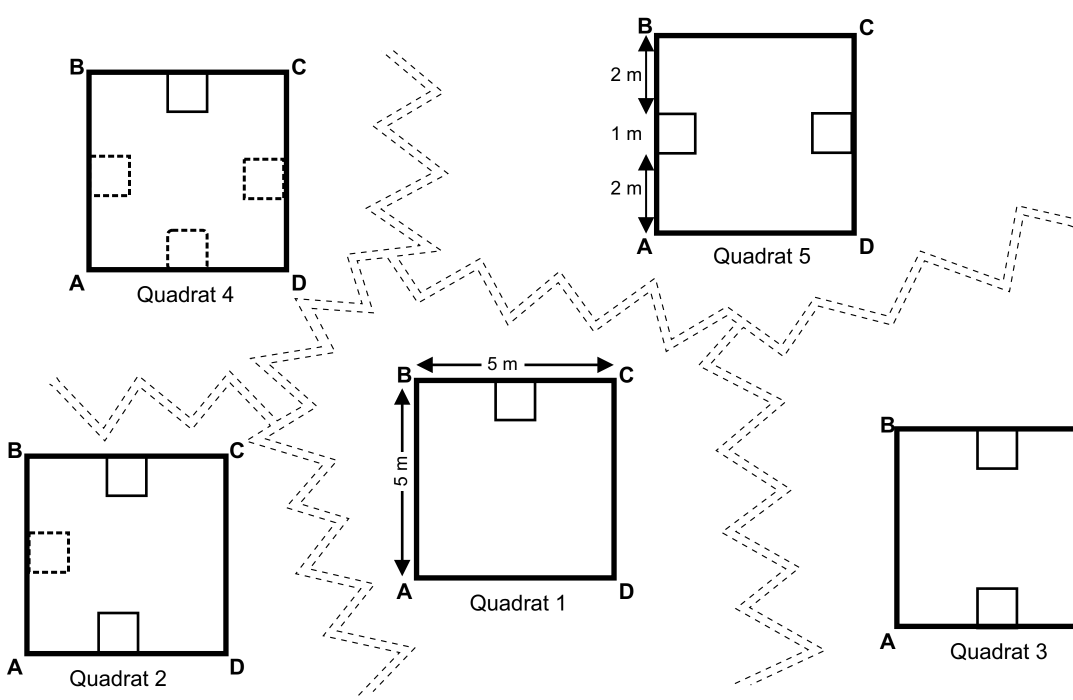


Figure III.2: Layout of 1 m x 1 m quadrats nested in randomly distributed 5 m x 5 m stand-alone quadrats. The figure is not drawn to scale: since the quadrats are all more than 15 m apart, the jagged

c) Quadrats nested in 20 m x 20 m stand-alone quadrats. Select the 20 m x 20 m quadrats by a random selection method (random numbers or bag of numbered beans). In a second process, randomly select the line (A-D, A-B, B-C, C-D) for the 1 m x 1 m quadrats. Set up four (or fewer if obstructed by tree stems) 1 m x1 m quadrats between the stakes set at 5 m from each corner of the 20 m x 20 mquadrat, leaving a minimum of one metre between each quadrat (Figure III.3). The layout can be done in conjunction with 5 m x 5 m small-tree quadrats, or independent of them.

This arrangement will give four 1 m x 1 m quadrats on one side of a 20 m x 20 m quadrat (if no trees or other obstructions get in the way). Five 20 m x 20 m stand-alone quadrats would give up to twenty 1 m x 1 m quadrats. If necessary, select a second line of the 20 m x 20 m quadrats for additional 1 m x 1 m quadrats.

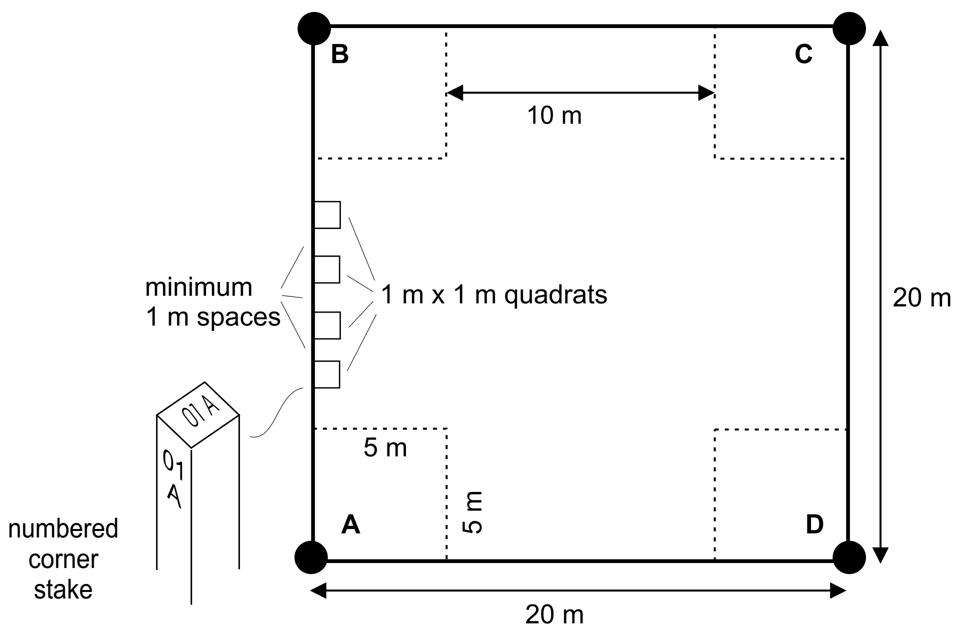


Figure III.3: Layout of 1 m x 1 m quadrats nested in 20 m x 20 m stand-alone quadrats. The 1 m x 1 m quadrat corner stake illustrated would be the A corner of quadrat 01 (the other three quadrats in the series being 02, 03,and 04 respectively

d) Stand-alone and nested quadrats associated with one hectare plot: Establish 1 m x 1 m quadrats as stand-alones or nested in 5 m x 5 m stand-alone quadrats inside a 10-metre band surrounding the hectare plot (Figure III.4). This band should be open at the corners and surround an access corridor at least two metres wide. Make sure that all the 1 m x 1 m quadrats are within the same plant community as the hectare plot. Using the plan and the extensions of the quadrat lines as reference, randomly select the positions of the 1 m x 1 m quadrats. Ensure that the quadrats are at least 5 m apart.

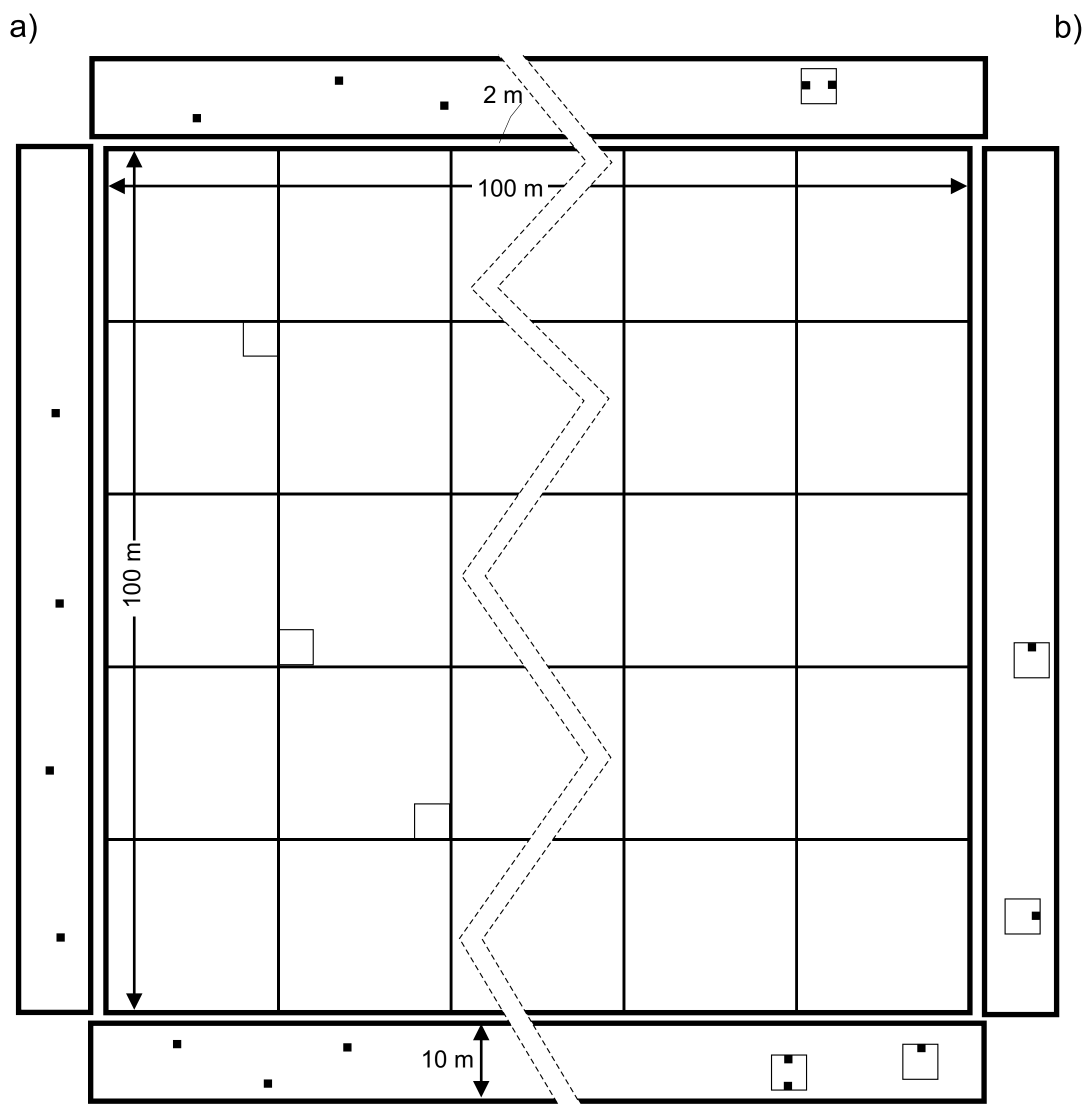


Figure III.4: Layout of 1 m x 1 m quadrats associated with a 1-ha plot.
a) 1 m x 1 m stand-alone quadrats; b) 1 m x 1 m quadrats nested in 5 m x 5 m quadrats

e) Quadrats nested in a one-hectare plot: If possible, 1 m x 1 m quadrats should be staked and flagged, and the data recorded before the trees are numbered and mapped, so that damage to ground vegetation is minimized. If this is impossible, then data collection of the ground vegetation should be delayed for at least a year.

Arrange the quadrats along the two outside borders of quadrats 07, 09, 17, and 19 (Figure III.5). A maximum of four 1 m x 1 m quadrats should be laid out on a side, spaced at least 1 m apart (avoiding tree trunks), and starting no less than 6 m from a corner. Leave a minimum of 1 m between each 1 m x 1 m quadrat. This will give a maximum of thirty-two 1 m x 1 m quadrats in each hectare plot (if no trees or other obstructions get in the way). If this number is insufficient, additional 1 m x 1 m quadrats could be established on the outside borders of quadrats 08, 12, 14 and 18.

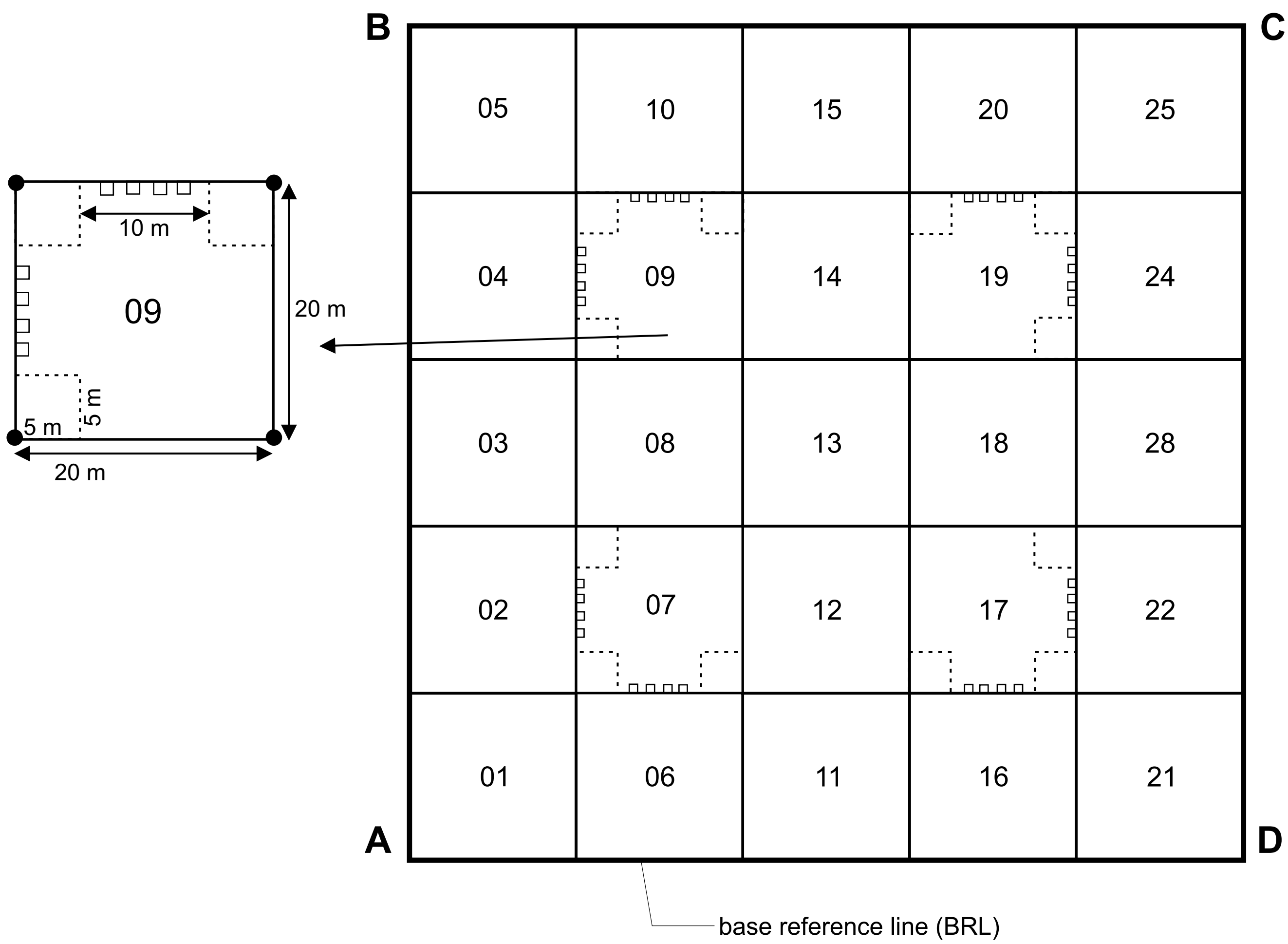


Figure III.5: Layout of 1 m x 1 m quadrats nested in a hectare plot

3. How to survey/establish ground vegetation monitoring quadrats

The 1 m x 1 m quadrats may be established as stand-alones or nested in larger quadrats.

Equipment:
- list of stake locations marking the quadrat A corners
- two steel survey tapes (minimum 10 m)
- compass
- accurately constructed 1 m x 1 m frame
- flagging tape
- survey stakes (preferably a metal-core plastic, especially if they are to be driven completely into the ground
- GPS (Global Positioning System) instrument with data differentially corrected
- water proof record book and pencils

Note: Use of an accurately constructed 1 m x 1 m frame makes delineation of quadrats much more rapid than the use of tapes and compass. The frame is also used for collecting data. The inside measurements of each side of the quadrat frame (may be pvc pipe or wood), should be exactly one metre when assembled. A collapsible frame is useful when there are shrubs or tall herbaceous species present. It is also easier to carry than a non-collapsible one.

Season of survey: Fall is the preferred season in forested ecosystems before snow accumulation and damage to the herbaceous vegetation is minimum. In non-forest ecosystems, the survey can usually be done any time of year when the weather is suitable, provided the ground vegetation is not luxuriant.

Methods

Stand-alone quadrats: Guided by the list of the coordinates of the preselected quadrat locations, use a compass and tapes to locate of the position of the base reference stake for each quadrat. Permanently set the stake at the A corner and label it with the quadrat number and corner letter (Figure III.3). Use an accurately constructed 1 m x 1 m frame to delineate the quadrat area and set corner stakes.

Nested quadrats: The positions of nested quadrats could be selected and stakes set when the larger quadrats (20 m x 20 m or 5 m x 5 m) in which they are to be established are themselves surveyed. If this has not been done, the positions along the sides of the larger quadrat should be measured by metal tapes and the two corners staked that fall on that line. Stake the remaining corners using the 1 m x 1 m frame.

All quadrats: Assign each 1 m x 1 m quadrat a unique number and label its A corner stake. After establishing twenty 1 m x 1 m quadrats and identifying the species, prepare a species accumulation curve (see *How to prepare a species accumulation curve)*. If insufficient quadrats have been established, continue to select locations and establish new quadrats, identify any new species and extend the species accumulation curve until the suggested minimum number has been established, unless statistical considerations call for more.

4. How to prepare a species accumulation curve

A species accumulation curve (Figure III.6) is a useful tool for helping determine the number of quadrats needed to sample a single stratum of a plant community. The accumulated number of species (i.e. the number of new species found in each successive quadrat added to the total already found) is plotted on the Y axis against the quadrats (in the order tallied) on the X axis. When the points are joined, the curve characteristically rises abruptly because many new species are added with each new quadrat; it then levels off as fewer species are added with each additional quadrat.

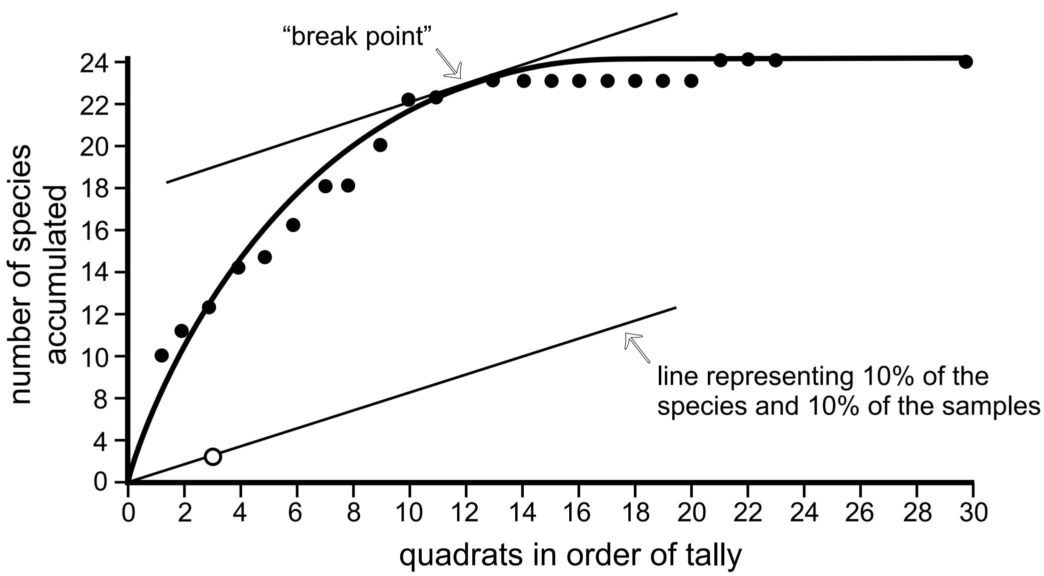


Figure III.6: Preparation of a species accumulation curve for determining the minimum number of quadrats to sample a stratum of vegetation

As added effort yields fewer new species, the need for data about additional species must be weighed against the effort required to get that data. Sampling is sufficient when no or very few species are added with each successive quadrat, that is sometime after the curve starts to flatten. Sample size (minimum number of quadrats) may be estimated with reference to the area ("break point") where flattening starts.

The break point may be estimated by the "10% rule" i.e. when 10% increase in area yields less than 10% new species. To locate the break point, draw a line from the zero point through the point representing 10% of the species and 10% of the sample area and extend it; draw a second line parallel to the first touching the curve - this is the break point. (Adapted from Oosting, 1956; see also Barbour et al, 1999.)

For ground vegetation species, the recommended minimum number of 1 m x 1 m is ten over the break point. Tally twenty (for southern forests) or fifteen (for northern forests) stand-alones before preparing a species accumulation curve. If below the minimum number, tally five to ten more quadrats, prepare a new curve, and repeat until the minimum number is reached.

Record Keeping

Listed below are the essential plot information and baseline data that should be recorded, the measurement schedules that should be followed, and the report contents. The methods are described in *Data/information collecting methods* .

Meticulous record keeping is essential. This applies not only to the variables that are measured in the monitoring program, but also to the descriptions of the location of the plot, the decisions made and the actions taken. The value of the monitoring program will be only as good as the level of informative detail kept about the plots, the accuracy of the data collected, and the systematic application of quality control and quality assurance measures. Ensure that all plot information and raw data are properly archived. EMAN recommends the use of Metamaker software for all electronically stored data (see <www.nbii.gov/tools/metamaker/metamaker.html>).

After the base data have been compiled (see *Data Compilation and Processing*), a report on the state of the stand should be prepared, followed every five years thereafter by a new report. The first report should contain the goals, objectives, rationale, all the essential information, and the baseline data. The five-year reports should update the original report and give the details of new decisions; and report on the results of remeasurements and discuss their significance. It should pay special attention to the original goals, objectives and rationale of the plant biodiversity monitoring program. Any recommendations for modifying the approach or the variables to be measured during the next period should be clearly articulated, recorded and included in this report. All reports should be archived in electronic and hard-copy forms

Essential information

- name of stand and number of quadrats
- plan of monitoring area with all quadrats located and numbered
- (stand-alone quadrats) latitude and longitude and elevation of a prominent feature of the stand where the quadrats are established; latitude and longitude of the base stakes and the compass bearing of each line used for locating the quadrats
- (nested quadrats) the identification numbers of the 5 m x 5 m or 20 m x 20 m quadrats where the 1 m x 1 m quadrats are nested
- written description of access route to the stand(s)

Baseline species data

It is essential that the following data be collected and recorded:

- name and number of individuals of each woody species under 1 m in height (count as one individual those species that form clumps or runners)
- name and number of individuals of each herbaceous species (count as one individual those species that form clumps), no matter what their height

on a minimum of five selected 1 m x 1 m quadrats

- map of area occupied by each individual plant
- tag number of each individual perennial if possible
- height of each individual tree seedling
- photograph of the quadrat (protocols to be prepared)

Minimum checking/measurement schedule

In each of the first two years following quadrat establishment, remap and remeasure those quadrats previously mapped. Every five years or less as necessary the mapped quadrats should be remeasured, remapped and rephotographed, and the species in the unmapped quadrats identified and recounted. These activities should all be undertaken on the same date as the original measurements were taken, or as close as possible to that date. If the stand is subject to severe weather, fire, or other extreme event, all quadrats should be remeasured and supporting information recorded as soon after the event as it is appropriate.

State of the stand report

This outline applies only to those stands where the 1 m x 1 m quadrats are the largest used. Where the ground vegetation is part of a forest, or other plant community monitoring program, for instance, the details of the 1 m x 1 m quadrat monitoring would be included in a single report for the whole stand.

Suggested outline for a baseline stand report:

- overall goals and objectives of the site monitoring program
- specific goals and objectives of the plant biodiversity monitoring program
- general description of the stand(s) selected for monitoring (e.g. size, location, age, and history)
- decisions and rationale for selecting methods, scheduling, etc.
- essential plot information
- detailed description of the stand, based on the results of the data collection

When the ground vegetation is part of a taller plant community monitoring program, then only the following need be addressed:

- decisions and rationale for selecting methods, scheduling, etc.
- essential plot information
- detailed description of the stratum, based on the results of the data collection

Data/Information Collecting Methods

Directions are given for making the measurements or gathering the information listed under Record Keeping. At the end of Section II are model field data sheets that monitoring groups may find useful.

1. How to count and map ground vegetation species

Equipment:
- ! 2 square frames with each inside arm exactly 1 m in length (constructed from wood or pvc pipe), one plain and one gridded in 10-cm squares using thin rods, or capable of supporting a piece of rigid clear plastic scored with a 10-cm-square grid
- ! reference specimens of plants likely to be encountered
- ! waterproof field note book
- ! pantograph and pencils or
- ! squared graph paper and pencils

Team: two people

Season: When counting and mapping ground vegetation, it is essential that the quadrats be visited several times a year to ensure that all species are identified. Record the dates when the measurements were taken or mapping done - they will determine the dates of all future counting or mapping.

To ensure that all species are mapped and identified, the following schedule is suggested for the first two - three years:

a) in late spring or early summer, when spring ephemerals are still visible and most of the other plants have started to grow (but might not be easily identified). At this time, mapping is easiest because growth in height is still slow and the positions of most plants are easily determined.

b) in mid-summer, when most of the plants can be identified (except for the fall bloomers, such as the aster family and many grasses and sedges).

c) in the fall, when the balance of the plants can be identified, and their maximum cover be determined.

During the first two years of monitoring, all perennial species in the plots should have been identified so that their recognition will no longer depend on flowering material. The observers should develop a "feel" for the best time(s) to remeasure so that the greatest number of species are measured at their maximum cover. In most of Canada one visit per year may be sufficient, but where spring ephemerals are present, two visits will be needed (and therefore two sets of data collected which can be combined). It is very important to record the exact date of each visit. The appropriate times in different parts of the country will be dependent on the individual species and the climate zone. A standard schedule is essential.

Observers should always be vigilant in recording the appearance of species new to the quadrats.

Methods

i) Species count: To count the ground vegetation species, surround the quadrat stakes with string or place a 1 m x 1 m wooden frame precisely over the quadrat stakes. A collapsible frame is particularly useful if the herbaceous vegetation is tall. Identify each species rooted within the space, and count the number of individuals of each species that are present. When species cannot be identified, assign a temporary code to each unknown species. When identifications have been made replace the temporary codes with the latin binomials and authorities.

When it is not possible to separate individual low shrubs from one another (most likely in shrub-dominated communities), count the number of clumps and note that clumps, not individuals, have been recorded. Plants that form runners, or trail across the ground surface, create difficulties when counting. It is probably best to count such plants as one individual per quadrat and record how they were handled.

ii) Mapping: Randomly select at least five quadrats from the total number of 1 m x 1 m quadrats established for further detailed study starting with detailed mapping. Set a gridded frame over the quadrat to be mapped. If the vegetation is tall, then legs or other supports will be necessary to bring the frame to a suitable height. In this situation, a string connecting the stakes is necessary to outline the area exactly.

If using a gridded frame, transcribe to scale the outline of the plants in the quadrat on to gridded paper; if using a scored plastic sheet, the outlines of the plants can be traced directly on to tracing paper supported on the plastic. A pantograph is useful, especially in the early summer or when plants are low-growing. Its advantage is that it can transcribe to scale, directly on to paper, the outlines of plants or other details of the quadrat. The maps will be used to calculate the cover (area occupied) of each species.

The decision as to what part of a plant to measure when trying to determine the area a plant occupies can be very difficult. For species such as bunch grasses, measure the base at the ground level. For taller species, record the stem position, and the approximate area the leaves cover when looked at from above. For dense stands of low shrubs, herbaceous species, mosses or lichens, where it is impossible to define an individual, treat that part of the stand that falls within the quadrat as a single clump and note that this has been done.

Tag or otherwise mark each plant that is mapped.

2. How to identify plants

Equipment: ! manuals, local species list
! plastic bags or plant press
! labelled fresh or dried specimens for reference

Team: ! two people

All plants must be correctly identified to species. To facilitate identification in the field, it is that advisable that the Responsible Group organize a workshop to familiarize the observers with the species they are likely to encounter[3]. As errors in species identification are found even among trained observers, any observer who has any doubt whatsoever should collect a specimen for expert identification. If the unknown is woody, it should be at least 40 cm long with the leaves attached, and if possible, with attached flowers or fruit. If it is small or herbaceous, the whole plant is usually collected[4]. Each specimen should be labelled with a notation or number relating it to the unknown species in the quadrat. Never take a plant from the quadrat; choose a specimen of the same species from outside the quadrat. Place the specimen in a plant press (bend it into a "v" or "z" shape if it is too large for the press sheets) or, if the storage is temporary, in a plastic bag which is kept in the shade. Make sure that any group of individual plants given the same temporary identification are really the same species.

Always have a manual in the field for making identifications. A list of recommended manuals (including nomenclatural standards) covering national and regional flora is found in the bibliography. Field guides to the local flora and species lists should always be used in conjunction with these manuals. Always record the latin binomial (i.e. scientific name), authority for the scientific name (e.g. common dandelion should be listed as *Taraxacum officinale* Weber), and the manual used for the identification.

For information on making herbarium/voucher specimens, see *Making Plant Collections* (Haber, E. *Guide to Monitoring Exotic and Invasive Plants*, Appendix 3). Internet address <http://www.cciw.ca/eman-temp/research/protocols/exotic/append3.htm>.

---

[3] Participants in a workshop should be made aware of any rare or species listed as endangered, threatened or vulnerable by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC - web address <http://www.cosewic.gc.ca/COSEWIC/Default.cfm>) that they may encounter and be warned against harming them.

[4] If an observer has reason to believe that an unknown plant is rare or COSEWIC-listed, it should not be collected. Three options are possible for identifying the plant: a) bring an expert to the field; (b) take a photograph; or (c) make a sketch of its salient features. Accompany the last two with a good written description of the habitat and the plant.

3. How to tag or mark ground vegetation species

Permanently marking ground vegetation species is necessary if individuals are to be followed over time. A map alone cannot be relied upon to ensure that individuals present in any one year are the same ones that were present the year before. Marking individual ground vegetation species is difficult and the task leaves considerable room for individual initiative.

Equipment:
- tags and plastic ties
- numbered bird bands
- tongue depressors
- permanent ink markers

Method: Use ties to attach tags to shrubs under 1 m in height. For trailing perennials and tree seedlings, bird bands make useful tags. For plants that have perennial below-ground parts and annual above-ground parts, the position of the individuals must be marked with numbered tongue depressors or similar small stakes.

Mark each tag with the quadrat number and the number of the individual.

Data Compilation and Processing

The instructions and formulae set out below are for the initial analyses of the data from the ground vegetation monitoring plots. Appended to Section III are some model data summary sheets for mapped and unmapped quadrats that monitoring groups may find useful.
Prepare a species list (alphabetically by family and scientific name) for the ground vegetation stratum of the stand. Note which of the species in the list are actually present in the quadrats that comprise the sample. Determine the total area sampled (quadrat area multiplied by the number of quadrats).

Compilation of data from unmapped (or all) quadrats, calculate for each species separately: abundance, density, relative density, frequency, and relative frequency.

Compilation of data from mapped quadrats, calculate for each species separately: abundance, cover, density, dominance, frequency, relative density, relative dominance, relative frequency, and importance value.

Abundance: total number of individuals of each species in the total area sampled. When preparing summary tables, list species in order of abundance starting with the most abundant. Use the scientific names in all the tables.

Cover: area occupied by individuals of a species. It is determined by measuring the area the plant covers when projected on the ground (calculated from the maps).

Density: average number of individuals of a species on a unit area basis

$$D = \frac{\text{number of individuals in the sample}}{\text{total area of the sample } (m^2)}$$

Relative Density: density of one species relative to the density of all species

$$RD = \frac{\text{number of individuals of a species in the sample}}{\text{total number of individuals of all species in the sample}} \times 100$$

Dominance: area a species occupies on a unit area basis. It is determined by using cover, calculated from the maps.

$$Dom = \frac{\text{area occupied by a species in the sample } (m^2)}{\text{total area of the sample } (m^2)}$$

Relative Dominance: area a species occupies relative to the total area occupied by all species (use cover calculated from the maps)

$$RDom = \frac{\text{area occupied by a species in the sample } (m^2)}{\text{total cover of all species in the sample } (m^2)} \times 100$$

Frequency[5]: the distribution of a species through a stand, that is the percentage of quadrats in the sample area in which a given species occurs

$$F = \frac{\text{number of quadrats in which a species occurs}}{\text{total number of quadrats in the sample}} \times 100$$

Relative Frequency: distribution of one species in a sample relative to the distribution of all species

$$RF = \frac{\text{frequency of a species in the sample}}{\text{total frequency of all species in the sample}} \times 100$$

Importance Value[6]: an index made up of Relative Density, Relative Dominance and Relative Frequency which describes the structural role of a species in a stand. It is useful for making comparisons among stands in reference to species composition and stand structure.

IV = Relative Density + Relative Dominance + Relative Frequency

---

[5] Frequency and Relative Frequency can only be calculated, compared or pooled when data are from quadrats that are of the same size and shape.

[6] When comparing or pooling Importance Values from different stands, all values must be based on quadrats that are the same size and shape.

UNMAPPED GROUND VEGETATION SAMPLE: FIELD DATA SHEET. Date..................................

Stand Name .... Location (lat & long).. Quadrat Nº..........................

(Nested in quadrat Nº ....) Quadrat dimensions........................... Community type...

Identification Manual... Observer(s) ....

Species name	Number of stems or clumps	Comments

MAPPED GROUND VEGETATION SAMPLE: FIELD DATA SHEET Date...................... Stand Name ....

Location (lat & long)..Community type... Quadrat size..............................

Quadrat Nº................ (Nested in quadrat Nº...............). Identification manual...

Observer(s) ....**COVER IS DERIVED FROM MAPS**

Tag #	Species name	cover (cm^2)	Comments

UNMAPPED GROUND VEGETATION SAMPLE: SUMMARY SHEET: Stand name .... Date...

Stand location (lat. & long.)....................................... Community type.. N° of quadrats in sample................... Quadrat dimensions...........................

Sample area (m^2)........................... Data processors(s)...

Species	Abundance	Density	Frequency	Relative Density	Relative frequency	Notes

MAPPED GROUND VEGETATION SAMPLE: SUMMARY SHEET. Stand name.. Date..

Stand location (lat. & long.).. Community type.. Number of quadrats in sample ....

Quadrat dimensions .... Sample area (m^2)...................... Data processors(s)..

Species	Abundance	Density	Frequency	Cover	Dominance	Relative Density	Relative Frequency	Relative Dominance	Notes

SECTION IV

VEGETATION GRADIENT BIODIVERSITY MONITORING PROTOCOLS

Table of Contents

Introduction

Permanent transects are used for measuring biodiversity change in areas where the changes from one community type to another are so rapid or abrupt that the area of one or more of the constituent communities are too small to use a method described in Section I, II, or III. The transect type recommended for this situation is essentially a series of quadrats arranged contiguously in a straight line.

Rationale

Rapid change from one community type to another is usually brought about by elevational, moisture or other environmental gradients. Individual species react differentially to environmental gradients and thus create vegetation gradients. Monitoring across these gradients is likely to yield data useful for showing plant response to a variety of environmental changes (especially changes in temperature or moisture regimes that may be largely natural, e.g. climate change; or largely anthropogenic, e.g. engineering activities altering ground water regimes). Information derived from long-term monitoring will help distinguish between cyclic phenomena and long-term change.

A special situation in which transects may be useful is in vegetation corridors through agricultural or urban landscapes, where migrations of animals or plants are being monitored. While not dealt with further in this document, the methods presented here could be easily adapted for such purposes.

Examples of situations where permanent transects are useful:

- presence of altitudinal or moisture or other gradient
- riparian or lacustrine[1] communities of any width where the vegetation zonation is of interest
- grasslands with scattered individuals or small groups of trees and shrubs
- research projects that require transects to answer specific local questions
- abrupt transitions between two plant communities e.g. grassland to forest

Transect Size

The width of any transect will be determined by the types of communities found across the gradient under study. Transects that are at least five metres wide should be used when large trees, small trees, or large shrubs form the dominant community type, while transects that are one metre wide should be used when low-shrub and ground vegetation dominate. There are also circumstances under which transects of other widths may be preferable. For example, when ground vegetation is very dense (e.g. composed largely of grasses or mosses), transects of 50 cm wide may be chosen; or when trees are very scattered, transects 20 m wide may be selected. In montane forests, 20 m x 20 m stand-alone quadrats may be set up as one or more discontinuous transects across the altitudinal gradient. The length of a transect will depend on the

[1] Since *riparian* and *lacustrine* both refer to zones of vegetation bordering bodies of water, for convenience, *riparian* will be used in this document to describe these vegetation zones whether they be found bordering a river or a lake.

monitoring site. A transect extending from one small community to another may be only a few meters long, while one across riparian or altitudinal gradients may be much longer. There may be times when two or more widths are used in different parts of the same gradient depending on the vegetation type.

Permanent Transect Establishment

1. How to decide on the number of transects

Several permanent transects should always be established. The minimum number is probably about three, but the purposes of the monitoring and the area to be covered could increase this number considerably. The minimum number of transects required to monitor small areas of riparian vegetation, a sample of sloping prairie, or treeline dynamics, is probably between three and five. Based on the suggestions of Barber *et al.* 1999, and Canadian experience, ensure that in any sampling program using transects, there are at least ten 5 m x 5 m quadrats for canopy trees, ten 5 m x 5 m quadrats if shrubs dominate, and twenty 1 m x 1 m quadrats. However, monitoring a whole drainage basin would require many more permanent transects, depending on its size and the type(s) of vegetation gradients selected for study. Where several vegetation gradient types are present, classify them and for simplicity, choose one and set up multiple transects, rather than try to cover all types. Statistical advice is essential.

2. How to select transect arrangement and locations

The transects should be oriented at right angles to the gradient and should start and finish well into the ecosystems on either side, unless natural barriers (e.g. cliff bases) determine the starting and finishing points. When riparian systems are under study, the base stake of the transect should be placed at a convenient and easily recognizable boundary, e.g. spring flood level, high-water level, edge of the shrub zone, etc. From this point, the transect could go in both directions: to the water's edge (or preferably below the zone of submerged vegetation in the water body), and, in the opposite direction, through all the different types of vegetation until the transect is well into vegetation where the gradient is no longer obvious (Figure IV.1).

Once the stands have been selected, use a method that reduces inadvertent bias when choosing the specific locations for the transects. The following method is one that could be used. Prepare a rough chart to scale of the selected area(s) and draw a line parallel to a convenient boundary or natural feature, such as a water course (Figure IV.2). The base stake for each transect will be set on this line.

From a table of random numbers or a bag of numbered chips or balls, select points along the line as the starting locations for the transects. Reject any that are not at least 50 m apart (for trees and large shrubs) or 10 m (for herbaceous vegetation and small shrubs), run right angles to the gradient, or because of their orientations are likely to cross each other. Use a compass and measuring tapes to find the specific points in the field, and mark each one with a permanent base reference stake.

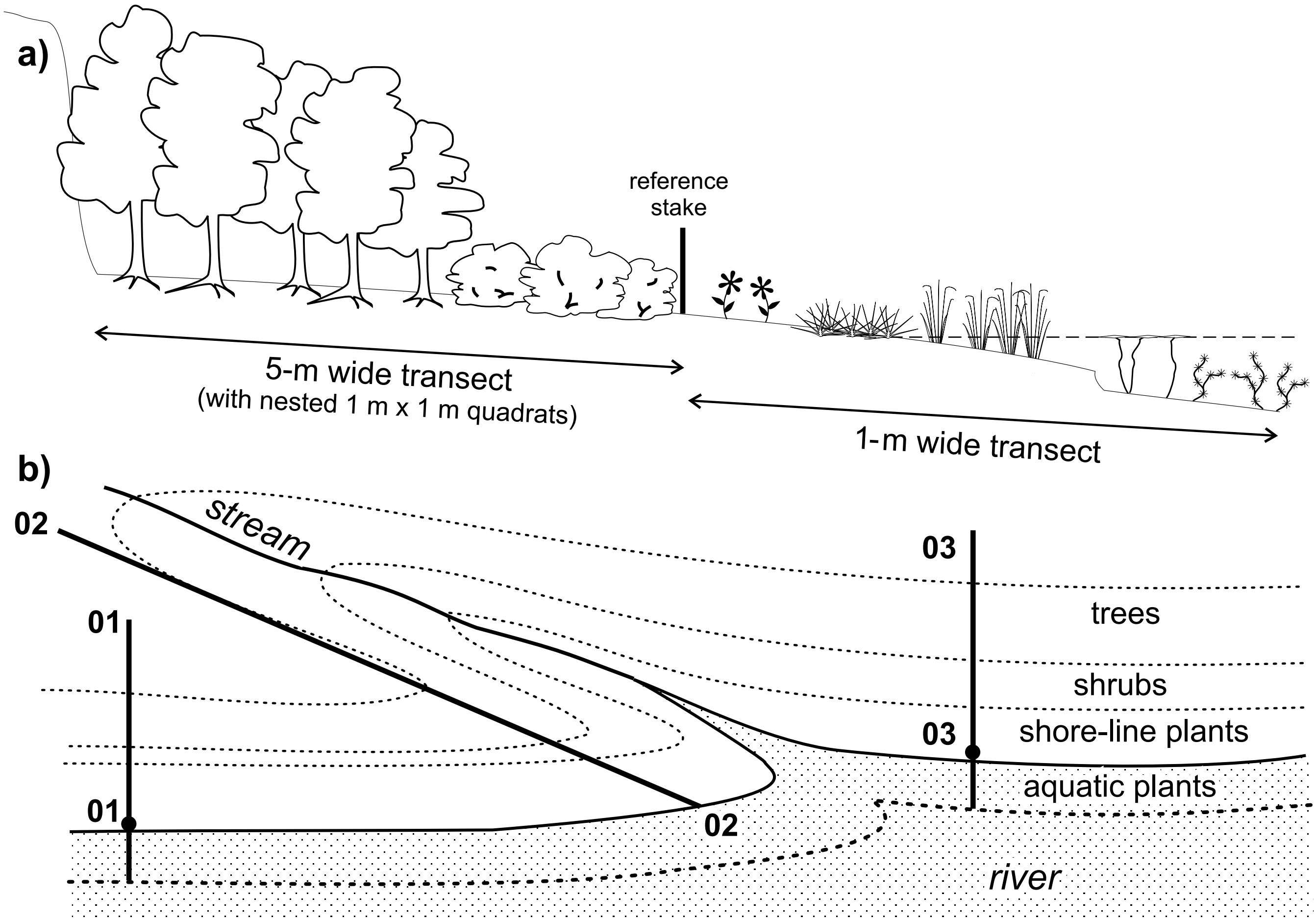


Figure IV.1: Vegetation communities across a riparian gradient where transects may be used. a) gradient in profile with reference stake set; b) gradient in plan with three transect locations selected. 01 and 03 would be accepted, 02 rejected.

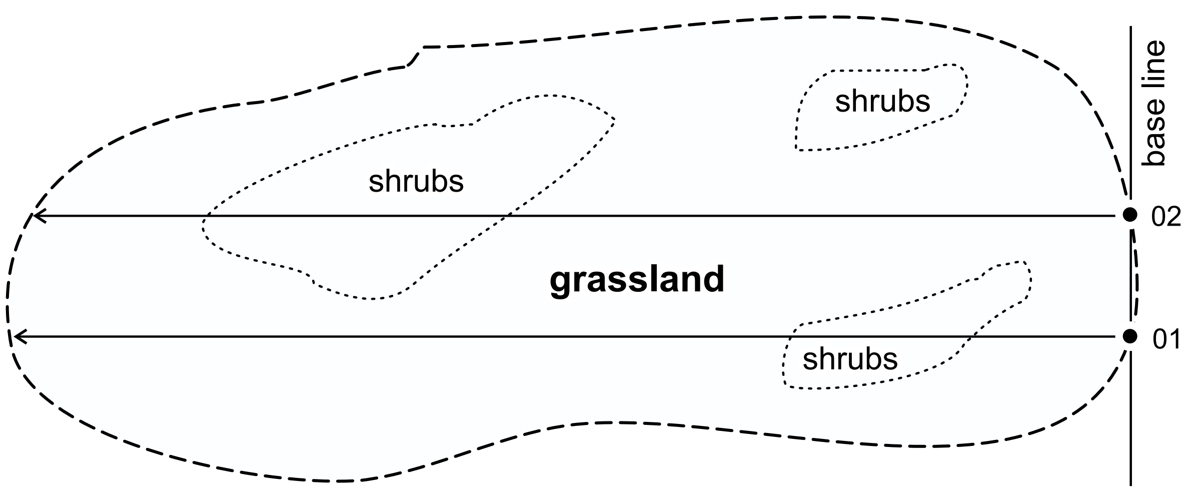


Figure IV.2: Rough chart of selected grassland stand with scattered shrubs overlaid with the base line for transect selection, and two transect locations (01 and 02) selected

3. How to survey a transect

Directions are given for surveying a transect that is five metres wide. Transects of other widths would be established in the same way. See note below on discontinuous and one-metre wide transects.

Equipment:

- list of coordinates for base stake of each transect
- theodolite and tripod
- two steel survey tapes (30 m)
- flagging tape
- one 2-m telescoping surveying rod (with levelling bubble) that extends to 4 m
- two mallets
- survey stakes, preferably metal-core plastic, especially if they are to be driven completely into the ground
- GPS (global positioning system) instrument with data differentially corrected
- waterproof record book and pencils

Team: three people

Season of survey: The preferred time to survey the transects is in the fall before any major snow accumulation, when the absence of leaves makes the process much easier. This season will ensure that damage to the ground vegetation is minimal. Areas subject to flooding should not be surveyed in the spring. Where river shores are the object of study, summer surveying may be appropriate.

Method: Give a name to the stand and a unique number to each transect. Label the base reference stake (which becomes the A corner of the first quadrat of the transect) with the transect number. Use the transect plans (Figure IV.3) as a reference. Transects are laid out more or less at right angles to the base line and oriented so that they lie across the vegetation gradient. They are formed as a series of contiguous quadrats, and it is by quadrat that the transect is established.

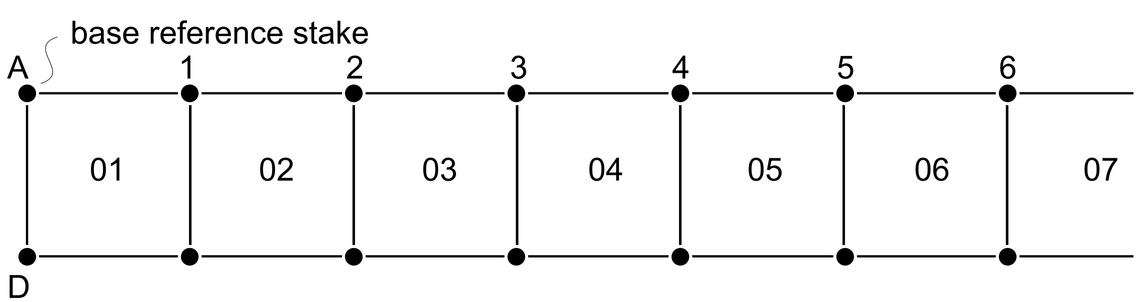


Figure IV.3: Plan of the transect layout. A-D is the base reference line; the quadrats are numbered 01, 02 etc.; the stakes are numbered 1, 2, etc.

To begin the survey, set up a tripod-mounted theodolite[2] over the base reference stake (A corner) and level it using a plumb-bob positioned over the centre of the stake. From this position, three measurements are taken to set the stakes at the remaining corners (B, C, and D) of the first quadrat (Figure IV.4). Make all measurements to the nearest centimetre.

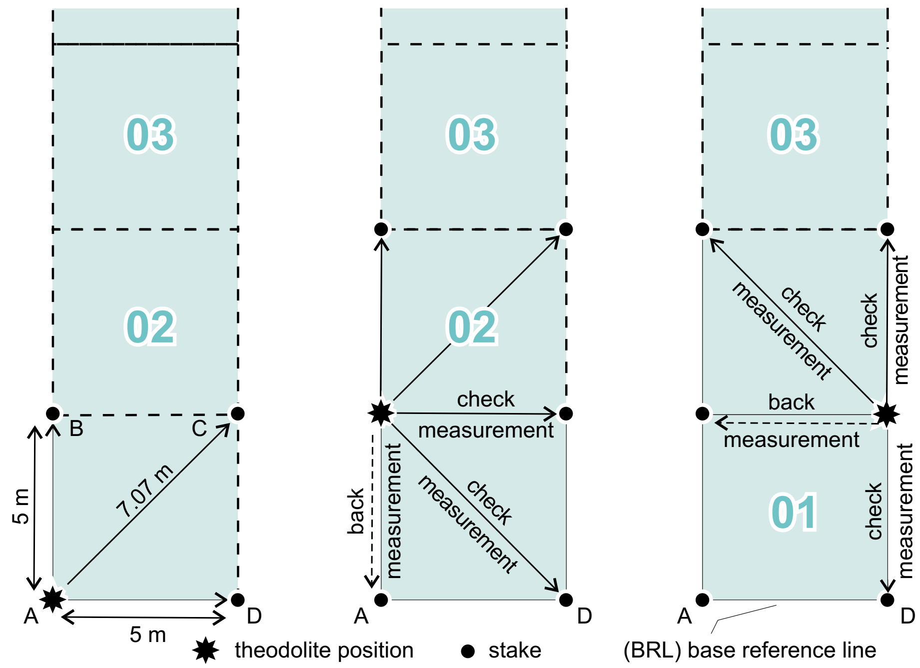


Figure IV.4: Plan for setting and checking stakes for a transect

The instrument operator sites along a bearing that is at right angles to the direction of the transect to establish the base reference line (BRL). Make sure in establishing this line that it is properly oriented, that is, at right angles to the gradient. A team member measures 5 m in the direction of the BRL, and holds a surveying rod vertically over that position as a target to determine the true bearing, and sets the stake (D corner). If the slope is steep (over 15%), a slope correction factor must be added (see *How to make a slope correction*). In the same way, the B corner is set 5 m in the direction of the transect and at right angles to the BRL. The C corner stake is set by siting at a 45 degree angle between corners B and D, and measuring 7.07 m. This forms quadrat #01 on which the rest of the transect is built.

The third team member pushes aside branches or small stems so that the instrument operator has a clear line of site and the vegetation is kept from deflecting the tape.

[2] When using the theodolite, avoid taking measurements in close proximity to metal objets such as belt buckles, jewellery, glasses with metal frames, or wrist watches, as they could cause errors in the magnetic readings. It is also important that the tapes are pulled snug to avoid sagging and distortions in measurements.

Survey teams must not cut down trees or shrubs.

Mark the base A and D corner stakes with the transect number. Record the latitude and longitude of the base reference stake (A stake), the compass bearing of the BRL (i.e. Line A-D), and the compass bearing of the direction of the transect.

From this first 5 m x 5 m quadrat, survey the number of quadrats necessary to create the transect. Each new stake is set from one previously set, by sighting along the appropriate bearing and measuring 5 m (on the transect line) or 7.07 m on the diagonal and making any necessary slope corrections. Alternate from one side of the transect to the other to ensure that all distances are checked.

Each stake should be set as follows (Figure IV.4):

a) from a previously set stake, sight along the appropriate bearing and measure 5 metres (or 7.07 m)
b) determine the slope and calculate the slope correction factor
c) measure the slope corrected distance and permanently set the new stake

To reduce error accumulation after the first quadrat has been surveyed, four different bearing measurements must be taken at each stake:

a) back measurement (from the set-up point back to the previous set stake)
b) check measurement (to previously established stakes)
c) new measurement (to set the next stake on the current line)
d) diagonal measurement to a new stake and/or a previously set stake

Record (in pencil) in a waterproof notebook for later transcription into a permanent record book or electronic file the coordinates of the base reference stake and the coordinates of the last stakes of the transect.

Discontinuous transect: A discontinuous transect is one where measurements are taken at predetermined distances or altitudes (not contiguous quadrats) along a selected bearing. It is useful for monitoring mountain forest communities using 20 m x 20 m quadrats established at predetermined altitudes along a compass bearing. Select the compass bearing and altitudes and use the methods in Section 1 for establishing the quadrats. Discontinuous 1-m wide transects could be used in grassland or tundra communities

1-m-wide transect: To establish a transect that is one metre wide, use the same method for setting the base stake (the A corner stake) as described above. Unless the transect is very long, or very accurate information is required (in which case a meticulous survey such as that described above is required), it is probably sufficient to establish a single line of stakes to mark the transect. This can be done using tapes and compass and setting a permanent and numbered stake every five metres. Mark the corners of each quadrat between the 5-m stakes with additional stakes so that their exact positions can be identified. The 1-m square frame is a useful guide for positioning and measuring the area of the quadrats between permanent stakes.

4. How to make a slope correction[3, 4]

On uneven or sloping terrain, the 5-m distance between quadrat corner stakes must be adjusted to account for slope. The purpose of this correction is to ensure that each quadrat of the transect contains 25 m^2, regardless of the plot topography. This is also necessary when mapping and presenting the result as if the topography were flat (planar mapping). As shown in Figure IV.5, the difference between two the corner stakes situated on a slope is always greater than the corresponding horizontal distance.

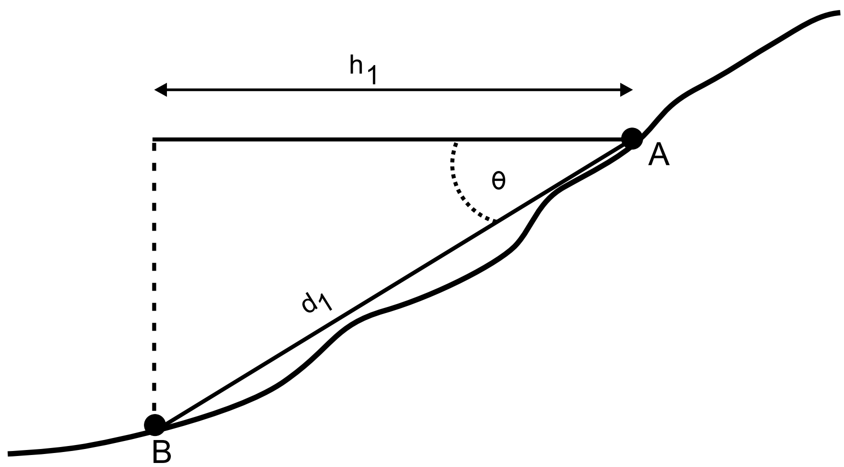


Figure IV.5: Slope correction. The distance between two points measured along a slope is always greater than the corresponding horizontal distance. On sloping ground, the 5 m interval between stakes must therefore be extended by a factor corresponding to the degree of slope. (h_1 horizontal distance, d_1 corrected distance, angle θ from the horizontal between A and B)

As the map is derived from horizontal distances between stakes, the 5-m interval between corner stakes on sloping ground must be increased by a distance related to the degree of slope.

The corrected distance (d_2) between stakes on sloping ground is determined as follows:

Step 1. Measure approximately 5 m from the set stake (A) along the bearing to the new stake (B)

Step 2. Measure the angle theta (θ) from stake A to stake B using the theodolite or Clinometer

---

[3] This method is after Dallmeier, Cominsky and Mistry, in preparation

[4] While the following discussion focuses on slope corrections in relation to establishing corner stakes, the same procedure is used to obtain slope-corrected measurements when mapping trees.

Step 3. Calculate d_1 using Table 1 and the formula:

$$d_1 = \frac{h_1}{\text{cosine}\ (\theta)}$$

Step 4. Measure the corrected distance (d_1) along the bearing and reposition stake B.

Step 5. Remeasure the angle (θ) from stake A to stake B

Step 6. If the angle has changed from the initial measurement (Step 2), repeat Steps 3, 4 and 5 until there is no change in the angle.

Example: If h_1 = 5 m and $\theta = 22.5^o$,
then *cos* (cosine) of θ (22.5^o) = 0.924 and d_1 = 5.412 m)

Measure to the closest centimetre. For accuracy, the final placement of all corner stakes should be made with the aid of a plumb-bob.

In determining the angle of slope, it is important that the measurement be taken along a line of sight parallel to the average slope of the ground, that is, the height of the instrument should be equal to the height of the target. Since the measurement begins at the eye level of the surveyor, it should end at an equal height on either the surveying rod or the body of the technician.

TABLE 1: Cosine table (correction factor for slope). Divide the horizontal distance by the factor for the specific angle

	Degree (units)																			
Degree (tens)	**0**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**	**5.5**	**6**	**6.5**	**7**	**7.5**	**8**	**8.5**	**9**	**9.5**
0	1	1	1	1	0.999	0.999	0.999	0.998	0.998	0.997	0.996	0.995	0.995	0.994	0.993	0.991	0.99	0.989	0.988	0.986
10	0.985	0.983	0.982	0.98	0.978	0.976	0.974	0.972	0.97	0.968	0.966	0.964	0.961	0.959	0.956	0.954	0.951	0.948	0.946	0.943
20	0.94	0.937	0.934	0.93	0.927	0.924	0.921	0.917	0.914	0.91	0.906	0.903	0.899	0.895	0.891	0.887	0.883	0.879	0.875	0.87
30	0.866	0.862	0.857	0.853	0.848	0.843	0.839	0.834	0.829	0.824	0.819	0.814	0.809	0.804	0.799	0.793	0.788	0.783	0.777	0.772
40	0.766	0.76	0.755	0.749	0.743	0.737	0.731	0.725	0.719	0.713	0.707	0.701	0.695	0.688	0.682	0.676	0.669	0.663	0.656	0.649
50	0.643	0.636	0.629	0.623	0.616	0.609	0.602	0.595	0.588	0.581	0.574	0.566	0.559	0.552	0.545	0.537	0.53	0.522	0.515	0.508
60	0.5	0.492	0.485	0.477	0.469	0.462	0.454	0.446	0.438	0.431	0.423	0.415	0.407	0.399	0.391	0.383	0.375	0.367	0.358	0.35
70	0.342	0.334	0.326	0.317	0.309	0.301	0.292	0.284	0.276	0.267	0.259	0.25	0.242	0.233	0.225	0.216	0.208	0.199	0.191	0.182

5. How to nest 1 m x 1 m quadrats in 5-m-wide transects

Equipment:

- list of quadrat locations
- steel survey tape
- survey stakes
- heavy mallet
- waterproof record book and pencils

Team: two people

The determination of the number of 1 m x 1 m quadrats for a single transect will depend on the type and distribution of ground vegetation and the length of the transect. General guidance only can be given.

Method: Nest ground vegetation quadrats on the outside lines of the transect (i.e. at right angles to the BRL) and two metres from a corner (Figure IV.6). This will reduce trampling effects on the transect. To locate the quadrats, measure with metal tapes, and permanently stake the 1 m x 1 m quadrat corners. Depending on the situation, one or two 1 m x 1 m quadrats could be set in each quadrat. If two 1 m x 1 m quadrats are set in the same 5 m x 5 m quadrat, they must be on the opposite sides of the transect.

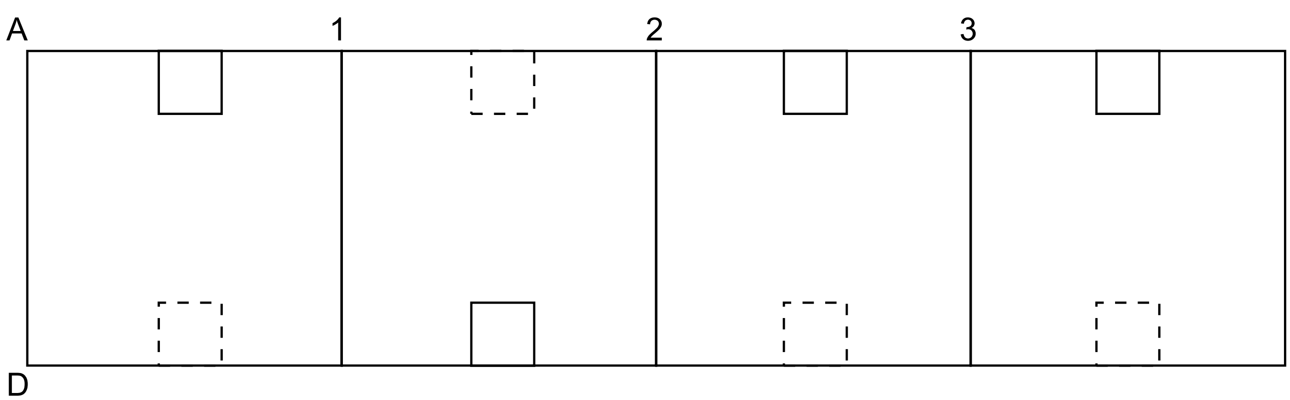


Figure IV.6: 1 m x 1 m quadrats nested in a 5-m-wide transect

Record Keeping

Listed below are the essential transect information and baseline data that should be recorded, the measurement schedules that should be followed, and the report contents. The methods are described in *Data/information collecting methods.*

Meticulous record keeping is essential. This applies not only to the variables that are measured in the monitoring program, but also to the descriptions of the location of the transects, the decisions made and the actions taken. The value of the monitoring program will be only as good as the level of informative detail kept about the transects, the accuracy of the data collected, and the systematic application of quality control and quality assurance measures. Ensure that all transect information and raw data are properly archived. EMAN recommends the use of Metamaker software for all electronically stored data (see <www.nbii.gov/tools/metamaker/metamaker.html>).

After the base data have been processed (see *Data Compilation and Processing*), a report on the state of the stand should be prepared, followed every five years thereafter by a new report. The first report should contain the goals, objectives, rationale, all the essential information, and the baseline data. The five-year reports should update the original report and give the details of new decisions; and report on the results of remeasurements and discuss their significance. It should pay special attention to the original goals, objectives and rationale of the plant biodiversity monitoring program. Any recommendations for modifying the approach or the variables to be measured during the next period should be clearly articulated, recorded and included in this report. All reports should be archived in electronic and hard-copy forms

Essential information

! name of stand and number of transects
! map of stand with all transects located and numbered, and their relation to any prominent feature indicated
! latitude, longitude and elevation of the base reference stake (stake A) and the compass bearing of the direction of each transect
! where applicable, plan of discontinuous transects, showing monitored sections
! compass bearing of base reference line (Line A-D) of each transect
! length of each transect
! elevation of the last stake of the transect
! plan of each transect with all quadrats numbered and, if applicable, with locations of all nested quadrats
! written description of access route to transect(s)

Baseline canopy-tree, shrub and small-tree data (5-m wide transects)

It is essential that the following data be collected and recorded:

! tag number and species of all woody individuals >1 m high (individuals under 4 cm dbh with tags marked "S" in addition to the number)
! location of all tagged woody individuals plotted on a map (by quadrat)

- dbh of all tagged woody species 4 cm dbh and over
- condition of all tagged individuals 4 cm dbh and over
- average canopy height of the community

It is desirable that the following data be collected and recorded:
- height of all tagged/numbered woody individuals
- height to lowest living branch of all tagged/numbered species 4 cm dbh and over
- canopy width[5] of all tagged/numbered woody individuals under 4 cm dbh
- in communities with scattered trees - canopy width of all tagged/numbered trees
- age of stand (determined from off-transect trees)
- photographs from standard positions at standard times
- degree of canopy closure (if appropriate)

Note that the photography and canopy closure protocols have not yet been developed.

Baseline ground vegetation data (1-m wide transect and 1 m x 1 m quadrats)

It is essential that the following data be collected and recorded:
- name and number of individuals of each woody species under 1 m in height
- name and number of individuals of each herbaceous species on each quadrat, no matter what their height

On a minimum of five 1 m x 1 m quadrats in each community type traversed:
- map of area occupied by each individual plant
- tag number of each individual perennial
- height of each tagged woody individual under one metre

It is desirable that photographs be taken of the mapped 1 m x 1 m quadrats. Other photographs from standard positions would also be advisable.

Minimum checking/measurement schedule

Every five years or as necessary the stands should be remeasured. If they are subject to severe weather, fire, or other extreme event, the quadrats should be remeasured and supporting information recorded as soon after the event as it is safe. The following activities should be undertaken and the results recorded:

[5] For small trees over 1.3 m in height, dbh measurements taken with carpenter's calipers, may be substituted for canopy width measurements.

Every year for the first two years:

- remap and remeasure all species in the mapped 1 m x 1 m quadrats
- replace any missing stakes, and replace any missing or outgrown tags

Every five years or as necessary:

- check that stakes are in place and replace if necessary
- measure dbh of all numbered trees (replace missing or outgrown numbers/tags)
- number, identify, measure dbh and determine location of all small trees or shrubs that have reached 4 cm dbh
- note the changes in status of all numbered individuals (note tag number or individuals that have died)
- prepare and check a new map for each 5-m transect
- core any numbered tree that has died
- identify and recount all individuals in unmapped 1 m x 1 m quadrats
- rephotograph (if part of baseline data)
- remeasure canopy closure (if part of baseline data)
- prepare a report on the state of the stand

Every ten years, if part of the baseline data**,** remeasure the height of tagged trees and remeasure the height to lowest living branch.

State of the stand report

This outline applies specifically to a program monitoring vegetation gradients.

Suggested outline for a baseline report:

- overall goals and objectives of the site monitoring program
- specific goals and objectives of the plant biodiversity monitoring program across a vegetation gradient
- general description of the stand(s) selected for transect monitoring (e.g. size, location, age, and history)
- decisions and rationale for selecting the methods, scheduling, etc.
- essential transect information
- detailed description of the vegetation gradient, based on the results of the data collection

Data/Information Collecting Methods

Directions are given for making the measurements or gathering the information listed under *Record Keeping*. Model field data sheets that monitoring groups may find useful are appended to this Section.

If the gradient is gradual, the transect may be of considerable length. Depending on the objectives of the program, consideration could be given to collecting data from only selected quadrats typical of the communities through which the transect passes (in which case follow the directions from Sections I, II, or III for the appropriate stratum), and to collecting data in consecutive quadrats across the obvious transitions.

1. How to number/tag a tree or shrub

Before starting any measurements, tie string to the stakes of the surveyed transect to facilitate orientation during tagging and mapping and to make transect quadrat boundaries clear. Remove the string when all measurements have been taken.

Equipment:
! tree paint (e.g. Nelson tube marker) or
! tree tags to be secured by grafting tape, commercial electrical cable ties, spiral UV-resistant plastic cord, or (least recommended) steel or galvanized nails
! metric dbh tape
! field data sheets and pencils

Team: two people

Method: For 5-m wide transects, starting at the base reference line, proceed along the transect and number consecutively (Figure IV.7) each living (and dead standing or leaning) tree that is over 1 m in height. (For wider transects, it is probably better to number by stratum and quadrat). Use either paint or tags for the trees, and tags for the shrubs and small trees, making sure that all numbers/tags in the transect face in the same direction. When a tree is multiple-stemmed with the attachments below 1.3 m, number/tag and measure each stem that is at least 4 cm dbh.

Figure IV.7: Tag numbering system for a) trees, and b) shrubs and small trees on a transect

When a tree is partly in one or more quadrats, tag (and record) it only in that quadrat where at least half of the stem is located. If the tree is on an outside line, only tag and measure it if at least half the stem is inside the quadrat, otherwise ignore it. When shrubs are in dense clumps and the individuals are impossible to distinguish, note this on the data sheet and treat the clump as an individual. Tag the clump and, if necessary, flag one or more branches to identify it. If the same clump extends into more than one quadrat, treat it as a single individual in each quadrat.

2. How to identify plants

Equipment:
- ! manuals, local species list
- ! plastic bags or plant press
- ! labelled fresh or dried specimens for reference

Team: two people

All plants must be correctly identified to species. To facilitate identification in the field, it is that advisable that the Responsible Group organize a workshop to familiarize the observers with the species they are likely to encounter[6]. As errors in species identification are found even among trained observers, any observer who has any doubt whatsoever should collect a specimen for expert identification[7]. The specimen if woody, should be at least 40 cm long with the leaves attached, and if possible, with attached flowers or fruit. If the unknown is small or herbaceous, the whole plant is usually collected. Each specimen should be labelled with a notation or number relating it to the unknown species in the quadrat. Never take a plant from the quadrat; choose a specimen of the same species from outside the quadrat. Place the specimen in a plant press (bend it into a "v" or "z" shape if it is too large for the press sheets) or, if the storage is temporary, in a plastic bag which is kept in the shade. Make sure that any group of individual plants given the same temporary identification are really the same species.

Always have a manual in the field for making identifications. A list of recommended manuals (including nomenclatural standards) covering national and regional flora is found in the bibliography. Field guides to the local flora and species lists should always be used in conjunction with these manuals. Always record the latin binomial (i.e. scientific name), authority for the scientific name (e.g. balsam poplar should be listed as *Populus balsamifera* L.), and the manual used for the identification.

For information on making herbarium/voucher specimens, see *Making Plant Collections* (Haber, E. *Guide to Monitoring Exotic and Invasive Plants*, Appendix 3). Internet address <http://www.cciw.ca/eman-temp/research/protocols/exotic/append3.htm>.

---

[6] Participants in a workshop should be made aware of any rare or species listed as endangered, threatened or vulnerable by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC - web address <http://www.cosewic.gc.ca/COSEWIC/Default.cfm>) that they may encounter and be warned against harming them.

[7] If an observer has reason to believe that an unknown plant is rare or COSEWIC-listed, it should not be collected. Three options are possible for identifying the plant: a) bring an expert to the field; (b) take a photograph; or (c) make a sketch of its salient features. Accompany the last two with a good description of the habitat.

3. How to recognize tree condition

Equipment:
- illustrations of tree status
- field data sheets and pencils

Team: two people - usually the tagging or dbh team

Method: Note the condition of all tagged trees using the illustrations in Figure IV.8 for guidance. Record observations on the data sheet using the following symbols:

- standing alive (AS)
- leaning alive (AL)
- broken alive (AB)
- fallen/prone alive (AF)
- standing dead top (AD)
- standing dead (DS)
- leaning dead (DL)
- broken dead (DB)
- fallen dead (DF)

Do not record any fallen/prone dead trees when the initial measurements are taken. At each subsequent measurement period, record the condition of all tagged trees (alive and dead). Record the length, diameter and orientation of all numbered dead trees that have fallen since the baseline data were collected. These measurements are important over the long term because of the role that dead and decaying trees play in the life of other species and in ecosystem function.

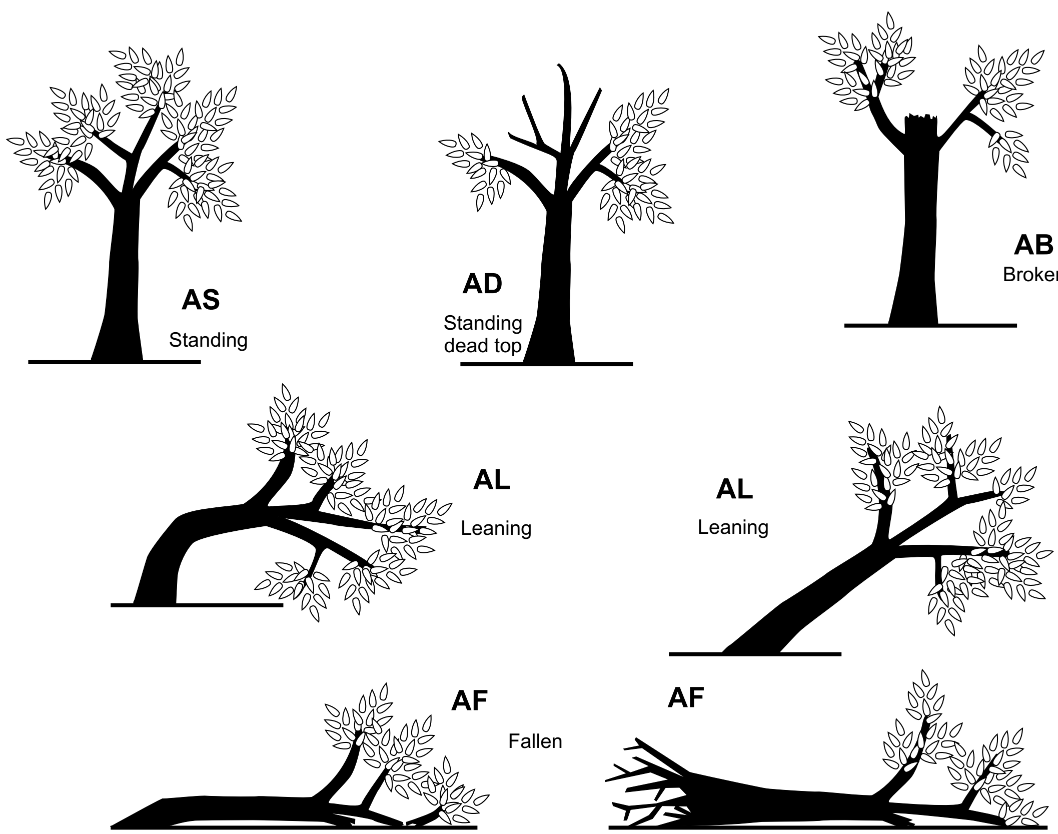


Figure IV.8: Illustrations of tree condition (after Dallmeier, 1992)

4. How to take diameter at breast height (dbh)

This measurement is taken to measure growth of small trees over time and to determine the area occupied by each species. Normally, only small trees or shrubs that are at least 4 cm dbh are measured, but if time and resources permit, diameters of small trees <4 cm dbh and $\geq$ 1.3 m in height could be measured using small calipers instead of diameter tapes (in which case, cover may not be measured).

Equipment:
- dbh tape (metric)
- lead-free blue or red paint (e.g. Nelson Tube Marker)
- data sheets and pencils

Team: two people

Method: Mark each tagged tree with a small daub of environmentally friendly paint at 1.3 m above the ground. This is a permanent mark to ensure that all dbh measurements will be taken at the same place. Make sure the tape is correctly placed around the tree at right angles to the direction of growth (Figure IV.9) and not over an atypical part of the stem. Many trees are irregular in form (e.g. leaning, branch at 1.3 m, buttressed etc.) and therefore require special handling when measuring the dbh. When the dbh is not taken at 1.3 m, record the height at which it is taken. Measure and record separately the dbh of branches that originate below 1.3 m.

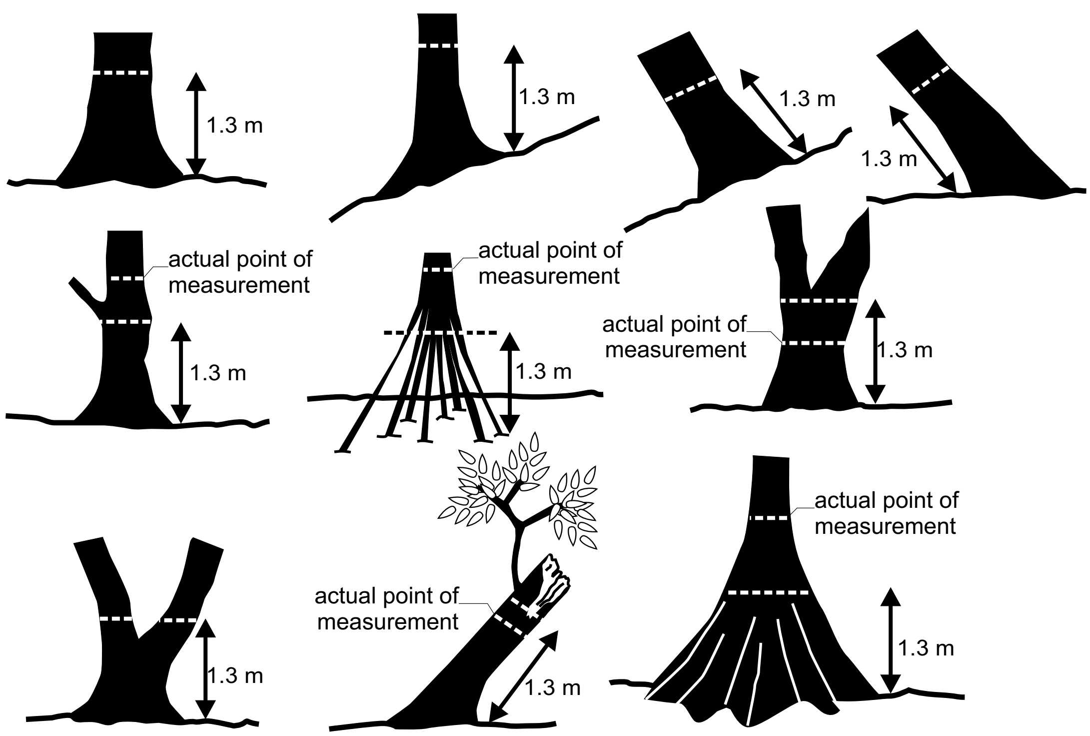


Figure IV.9: Measuring positions for dbh (after Dallmeier, 1992). The single dotted line shows the measurement position - if because of a fault two dotted lines are shown, the correct measurement position is labelled.

5. How to determine the age of a tree

Equipment:
- ! increment borer
- ! milk shake drinking straws and masking tape
- ! felt marker to label straws
- ! metric dbh tape
- ! field notebook and pencils

Team: two people

Method: Identify the species of trees that together represent the largest and most common canopy trees on the transects. From the surrounding stand, select five specimens of each species for age determination making sure they mirror the range of sizes on the transects and record their dbh. **Do not take cores of the trees on the plot.** The Responsible Group should decide whether the cored trees are tagged or marked in some way for future reference - a valuable action which allows for resampling.
To give accurate ring widths, take the core on the north-facing side of the tree (if deformed core the stem outside the deformed area) and at right angles to the stem axis. If the tree has a definite lean, core from the upper side. Take the core at 30 cm above the ground - just above the swelling (butt swell) where the roots originate. Record the stem position of each core. Cores from the stem base will give a minimum age closer to the real age than from breast height (provided the stem is solid) and are best for dendrochronological studies.

Insert the bit of the increment borer in the handle and remove the extractor. Punch the bit through the bark and turn it gently until the end is beyond the centre of the tree. Insert the extractor, lifting it slightly to make sure it goes under the core, and then back off the borer about one turn to break contact between the core and the tree tissue. The notch on the extractor should be up so that if the core breaks, it will still rest in the extractor. Pull out the extractor with the core. (Adapted from Phillips,1959.) **Immediately remove the borer to prevent it becoming "frozen" in the tree.**

Place the core in a milk shake drinking straw, close securely with masking tape, label (species, date, location and dbh) and store in a safe place, preferably in a refrigerator especially if the cores are wet or full of sap (in a freezer if ring widths are also to be measured), until the counting can be done. If a refrigerator is not available for wet cores, mount (see below) as soon as possible to avoid fungal attack. After counting, store the cores for future reference, they are part of the voucher specimens and may be used for further study.

Coniferous trees are generally easier than deciduous trees to bore and their rings easier to count - often with a 10 x hand lens. Cores from diffuse-porous deciduous species must be mounted (glued) into wooden grooves (core trays), and sanded successively with finer and finer grades of wet-or-dry sandpaper (grades recommended are # 80, 150, 250, 320, 400, 600) backed with a pencil eraser (Dr Gerard Courtin, personal communication). Count the rings using a dissecting microscope. For accurate counting, all species should be mounted, sanded and counted under a microscope.

6. How to map trees and shrubs

Equipment:
- one steel survey tape (minimum length 10 m)
- 2-m telescoping surveying rod (with levelling bubble)
- Compass
- data sheets and pencils

Team: three people

Method: Each tagged woody species is mapped in relation to two adjacent, precisely located corner stakes of a quadrat in the transect in which it is found (Figure IV.10).

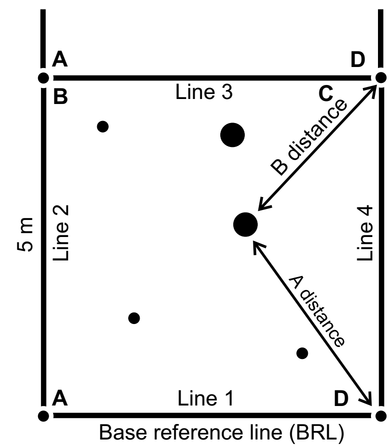


Figure IV.10: Set-up for mapping trees and shrubs

One team member, holding one end of the survey tape, stands at the tagged tree that is to be mapped. With the second team member holding the other end of the tape, measurements are taken from the tree to two adjacent corners of the quadrat, for example, to corner C and to corner D, which are at either end of Line 4. The tape must be kept taut, with each end at the same height above the ground. The naming of these distances is from the point of view of the person standing at the tree: to his/her right is the "A distance" (i.e. the distance from the tree to corner D); and to his/her left is the "B distance" (i.e. the distance from the tree to corner C). The third team member records the quadrat number, tag number, the A and B distances and the line number. (Note that the sum of the A distance and the B distance must be equal to or greater than 5 m.) The correctly identified lines are essential for mapping the trees and shrubs. Alternatively, the lines could be recorded as A-B, B-C etc., and the measurements expressed as distances from the tagged tree to the specific corners.

How to fail: The two most common errors in mapping are switching A and B distances and incorrectly recording the line number.

Map generation: Use a mapping software package or squared paper to map the results. If preferred, the shrubs and trees could be mapped directly in the field using plane table or a similar technique.

7. How to measure tree and shrub height

Heights are measured of all tagged trees (alive and those dead but still standing or leaning). The length and orientation of fallen trees is only measured on tagged trees (alive and dead) that fall after the initial measurements have been taken. These measurements are important over the long term because of the role dead and decaying trees play in the life of other species and in ecosystem function.

Equipment:
- 2-m telescoping survey rod (with a levelling bubble) for trees less than 2 m
- clinometer (Haga Level is recommended) for trees over 2 m
- steel survey tape (minimum length 10-m)
- Compass
- field data sheets and pencils

Team: two people

Note: If individual height measurements are not taken, it would be useful to determine the average height of the stand and the depth of the canopy of the shrub dominated communities, and of groups of small trees in non-forest communities. These canopy heights and depths can be determined using one of the methods below.

Methods:

Telescoping survey rod: One person holds the telescoping rod against the tree or in the centre of a shrub (Figure IV.11) and the other person records the height. At the same time, record the height of the lowest live branch if over 1 m above the ground level. These two figures will determine the canopy depth.

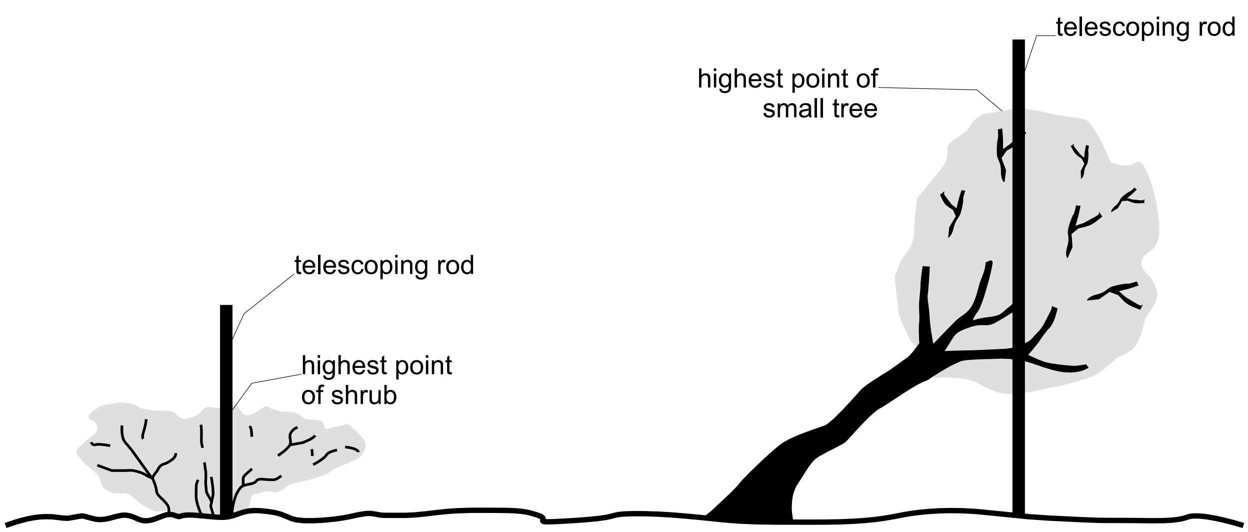


Figure IV.11: Measurement of small-tree or shrub heights using a telescoping survey rod

Clinometer: From a measured distance (usually 20 m) from the base of the tree, record the readings (Figure IV.12) for the top and base of the tree, and the horizontal line from the eye-level of the observer to the tree stem, or equivalent below the base of the tree. Record the eye-level height of the observer and whether the base of the tree is above, the same, or below the eye-level of the observer. In addition, take the reading for the lowest live branch. Calculate the height and canopy depth of each tree.

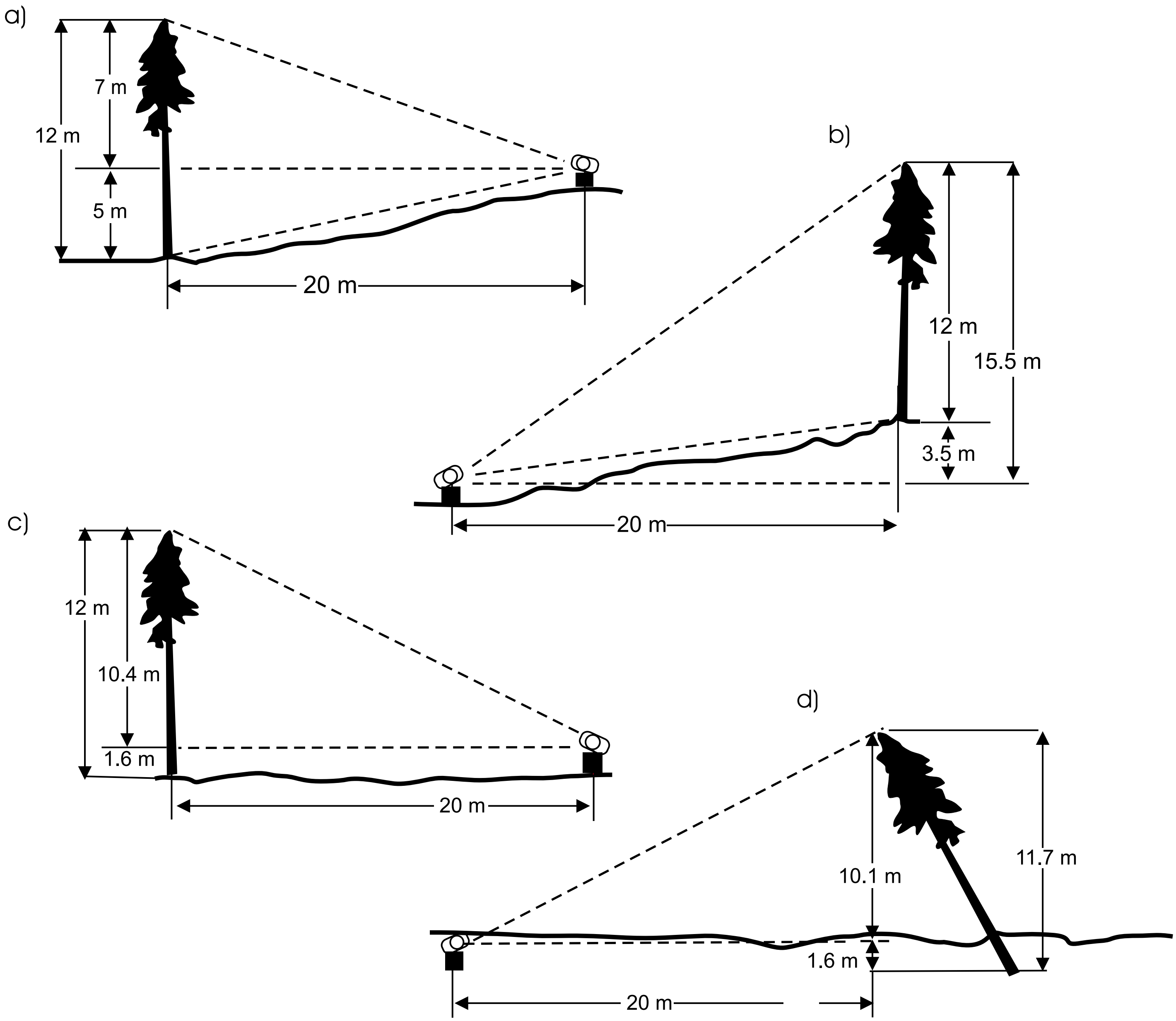


Figure IV.12: Measurement of the height of a tree. The height of the tree (12.0 m for a, b, and c, 11.7 m for d) is determined by:
a) adding the two measurements above and below the horizontal reading.
b) subtracting the distance from the base of the tree to the horizontal, from the total.
c) adding the height of the instrument from the ground to the distance above the horizontal line.
d) adding the height of the instrument above the ground to the distance between the top of the tree and the point on the horizontal line directly beneath (use a survey rod as a target).

7. How to measure canopy width

Normally, the measurement of canopy width is taken only on woody species under 4 cm dbh. However, when trees are widely spaced, canopy width may be an important variable to record, especially in relation to other biota being monitored in the same ecosystem. The Responsible Group must decide whether the canopy width in this situation should be recorded.

Equipment:
- measuring tape (10 m)
- Compass
- data sheet and pencils

Team: two people per tape

Method: One person holds the tape at the stem of the sapling or small tree, or holds a rod in the centre of the shrub (Figure IV.13). The other draws out the tape to the drip-line of the canopy and measures the distance, which is recorded. For shrubs and saplings, take four measurements at the cardinal points of the compass; for trees, take eight measurements at 45° intervals, starting with the north.

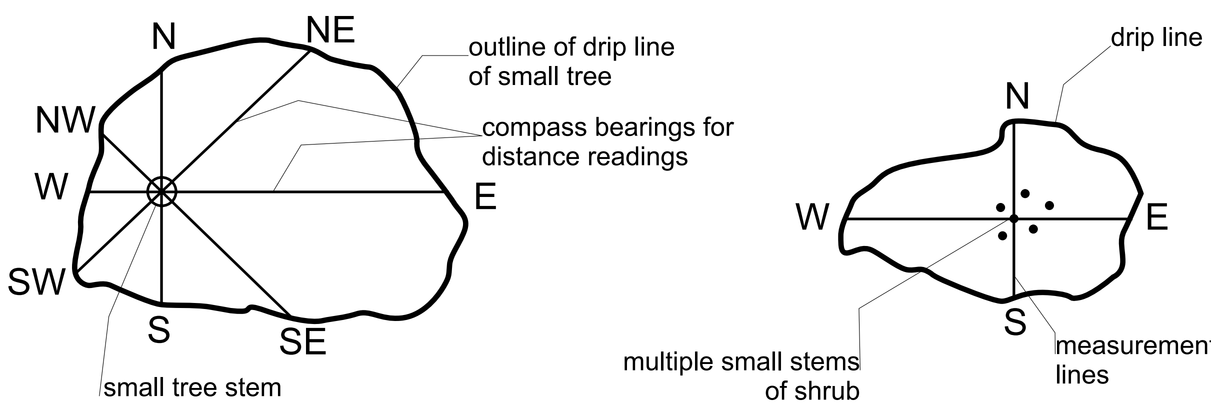


Figure IV.13: Measurement of shrub and small-tree canopy width

9. How to count and map ground vegetation species

Equipment:
! 2 square frames with the inside arms each exactly 1 m (constructed from wood or pvc pipe), one plain and one gridded in 10-cm squares with strong but fine cord, or capable of supporting a piece of rigid clear plastic scored with a 10-cm-square grid
! reference specimens of plants likely to be encountered
! tags, tongue depressors, bird bands, etc for labelling plants
! waterproof field note book
! pantograph and pencils or
! squared graph paper and pencils

Team: two people

Season: When counting and mapping ground vegetation, it is essential that the quadrats be visited several times a year to ensure that all species are identified. Record the dates when the measurements were taken or mapping done - they will determine the dates of all future counting or mapping.

To ensure that all species are counted and mapped, the following schedule is suggested:

a) in late spring or early summer, when spring ephemerals are still visible and most of the other plants have started to grow (but might not be easily identified). At this time, mapping is easiest because height growth is still slow and the positions of most plants are easily determined.
b) in mid-summer, when most of the plants can be identified (except for the fall bloomers, such as the aster family and many grasses and sedges).
c) in the fall, when the balance of the plants can be identified, and the final cover of each plant can be determined.

During the first two years of monitoring, all perennial species in the plots should have been identified so that their recognition will no longer depend on flowering material. The observers should develop a "feel" for the best time(s) to remeasure so that the greatest number of species are measured at their maximum cover. In most of Canada one visit per year may be sufficient, but where spring ephemerals are present, two visits will be needed (and therefore two sets of data collected which can be combined). It is very important to record the exact date of each visit. The appropriate times in different parts of the country will be dependent on the individuals species and the climate zone. A standard schedule is essential. The appropriate times will vary across the country depending on the species involved and the ecozones.

Methods

Species count: To count the ground vegetation species, surround the quadrat stakes with string or place a 1 m x 1 m wooden frame precisely over the quadrat stakes. A collapsible frame is particularly useful if the herbaceous vegetation is tall. Identify each species rooted within the space, and count the number of individuals of each species that are present.

When it is not possible to separate individual shrubs from one another (common in shrub-dominated communities), count the number of clumps and note that clumps, not individuals, have been recorded. Plants that form runners, or trail across the ground surface, create difficulties when counting. It is probably best to count such plants as one individual per quadrat and record how they were handled.

Observers should always be vigilant in recording the appearance of species new to the quadrats.

Mapping: Select from the transects already established, five 1 m x 1 m quadrats from each community type.

Set a gridded frame over the quadrat to be mapped. If the vegetation is tall, then legs or other supports will be necessary to bring the frame to a suitable height. In this situation, a string connecting the stakes is necessary to outline the area exactly.

If using a gridded frame, transcribe to scale the outline of the plants in the quadrat on to gridded paper; if using a scored plastic sheet, the outlines of the plants can be traced directly on to tracing paper supported on the plastic. A pantograph is useful, especially in the early summer or when plants are low-growing. Its advantage is that it can transcribe to scale, directly on to paper, the outlines of plants or other details of the transect. The maps will be used to calculate the cover (area occupied) by each of the species.

The decision as to what part of a plant to measure when trying to determine the area a plant occupies can be very difficult. For clumped species such as grasses and sedges, measure the base of the clump at the ground level. For taller species, record the stem position, and the approximate area the leaves cover when looked at from above.

Tag or otherwise mark each plant that is mapped.

10. How to tag or mark ground vegetation species

Permanently marking ground vegetation species is necessary if individuals are to be followed over time. A map alone cannot be relied upon to ensure that individuals present in any one year are the same ones that were present the year before. Marking individual ground vegetation species is difficult and the task leaves considerable room for individual initiative.

Equipment:
- tags and plastic ties
- numbered bird bands
- tongue depressors
- permanent ink markers

Method

Use ties to attach tags to shrubs under 1 m in height. For trailing perennials and tree seedlings, bird bands make useful tags. For plants that have perennial below-ground parts and annual above-ground parts, the position of the individuals must be marked with numbered tongue depressors or similar small stakes.

Data Compilation and Processing

The instructions and formulae set out below are for the initial analyses of the data from the transects. Appended to this section are some model data summary sheets that monitoring groups may find useful.

Prepare a master species list (alphabetically by family and scientific name) for the different communities through which the transects pass. Make a note of which tree and shrub species are in the transect and which ground vegetation species are present in the 1 m x 1 m quadrats, or in a 1-m wide transect.

The calculations are based on the community types included in the transects, and the vegetation strata (canopy tree, shrub and small tree, ground vegetation) within each type. Therefore, before beginning the calculations:

- classify the transect (by quadrat) into its community types (e.g. forest, shrub, river shoreline, grassland, tundra, etc.)
- determine the number of quadrats of each size in each community type actually sampled
- calculate the total transect area (by quadrat) of each community type actually sampled.

Keeping the different community types separate and using the appropriate data sheets, work up the data according to the directions below:

a) for each stratum separately (e.g. tree, shrub and small tree, ground vegetation - mapped and unmapped quadrats), determine abundance, density,frequency, relative density, and relative frequency of each species. Make separate calculations for species >10 cm dbh, and <10 cm dbh.
b) using dbh measurements for the canopy tree stratum and the shrub and small tree stratum of each community type, calculate for each species: basal area, dominance, relative dominance and importance value
c) for the canopy width figures for the shrub and small stratum of each community type, calculate for each species: cover, dominance, relative dominance and importance value
d) using only the mapped 1 m x 1 m quadrats of the ground vegetation stratum,for each community type, calculate for each species: cover, dominance, relative dominance and importance value

Abundance: total number of individuals of each species in the total area sampled. When preparing summary tables, list species in order of abundance starting with the most abundant. Always use the scientific names in the tables.

Basal area: cross-section area of woody plant stems. Using conversion tables, calculate the basal area for each individual from the dbh measurements, then determine the total basal area of each species.

Cover: area occupied by individuals of a species. It is determined by calculating the area the canopy covers when projected on the ground (determined from the canopy width measurements or the ground vegetation maps).

Density: average number of individuals of a species on a unit area basis

$$D = \frac{\text{number of individuals in the sample}}{\text{total area of the sample (m}^2\text{)}}$$

Relative Density: density of one species relative to the density of all species

$$RD = \frac{\text{number of individuals of a species in the sample}}{\text{total number of individuals of all species in the sample}} \times 100$$

Dominance: area a species occupies in a stand on a unit area basis. It is determined using either basal area or cover

$$Dom = \frac{\text{area occupied by a species in the sample (m}^2\text{)}}{\text{total area of the sample (m}^2\text{)}}$$

Relative Dominance: area a species occupies relative to the total area occupied by all species. It is determined using either basal area or cover

$$RDom = \frac{\text{area occupied by a species in the sample (m}^2\text{)}}{\text{area occupied by all species in the sample (m}^2\text{)}} \times 100$$

Frequency[8]: distribution of a species through the stand, i.e. percentage of quadrats in the sample area in which a given species occurs

$$F = \frac{\text{number of quadrats in which a species occurs}}{\text{total number of quadrats in sample}} \times 100$$

Relative Frequency: distribution of one species relative to the distribution of all species

$$RF = \frac{\text{frequency of a species}}{\text{total frequency of all species in the sample}} \times 100$$

Importance Value[9]: an index made up of Relative Density, Relative Dominance and Relative Frequency that profiles the structural role of a species in a stand. It is also useful for making comparisons among stands in reference to species composition and stand structure.

IV = Relative Density + Relative Dominance + Relative Frequency

---

[8] Frequency and Relative Frequency can only be calculated, compared or pooled when data are from quadrats that are of the same size and shape.

[9] When comparing or pooling Importance Values from different stands, all values must be based on quadrats that are the same size and shape.

TRANSECT TREE OR SHRUB SAMPLE: FIELD DATA SHEET Stand name.. Date.......................................

Community Type.. Transect location (lat. & long.).. Transect nº .... Quadrat.nº.........................

Quadrat dimensions.................. Av. Canopy height ....Identification Manual .... Observer(s)...

Tag #	Species name	Number of stems	Line (1, 2, 3, 4)	A Distance (m)	B Distance (m)	Canopy Width **OR** dbh (m)	Height (m)	Condition	Notes

TRANSECT TREE OR SHRUB SAMPLE:SUMMARY DATA SHEET Stand name.. Date...

Stand location (lat. & long.) .... Community type... Av. canopy height..................................

Number of transects in sample .... Quadrat dimensions.............................. Number of Quadrats......................... Sample area (m^2)......................................

Data processor(s)..

Species name	Abundance	Density	Cover OR Basal Area	Dominance	Frequency	Relative Density	Relative Frequency	Relative Dominance	Importance Value	Notes

TRANSECT UNMAPPED GROUND VEGETATION SAMPLE: FIELD DATA SHEET Transect Nº .... Date.......................

Stand Name ....Stand location (lat & long)... Quadrat Nº ....

Nested in quadrat Nº .... Quadrat dimensions............................Community type...

Identification manual... Observer(s) ....

Species name	Number of stems or clumps	Comments

TRANSECT MAPPED GROUND VEGETATION SAMPLE: FIELD DATA SHEET Date...

Stand Name .... Location (lat & long)..Community type..

Quadrat N°................... Nested in quadrat N°................. Quadrat dimensions................... Identification manual................................

Observer(s).. ***COVER IS DERIVED FROM MAPS***

Tag #	Species name	cover (cm^2)	Comments

TRANSECT UNMAPPED GROUND VEGETATION SAMPLE: SUMMARY SHEET Stand name... Date.......................................

Stand location (lat. & long.)................................ Community type...................................... Number of transects in sample...................... Number of quadrats............................

Quadrat dimensions................. Sample area (m^2)............................. Data processors(s)..

Species	Abundance	Density	Frequency	Relative Density	Relative frequency	Notes

TRANSECT MAPPED GROUND VEGETATION QUADRATS: SUMMARY SHEET Stand name... Date..

Stand location (lat. & long.).................................... Community type... Number of transects in sample............ Quadrat dimensions ....

Number of quadrats...................... Sample area (m^2)........................... Data processors(s)..

Species	Abundance	Density	Frequency	Cover	Dominance	Relative Density	Relative Frequency	Relative Dominance	Importance Value	Notes

GLOSSARY

Abundance: total number of individuals of each species in the total area sampled.

Appraisal: as used in this document, initial work (e.g. preparation of a preliminary species list, rough chart of the area, etc,) on a stand of vegetation where permanent biodiversity monitoring plots are to be established. *Survey* is often used as a synonym, but in this document is used solely for the process of establishing plots using a theodolite, tapes etc.

ARNEWS: Acid Rain National Early Warning System

Basal area: the area of the stem of a tree calculated from the diameter measured at breast height. It is the measurement used to describe the area occupied by a tree.

Biodiversity: a term derived from "biological diversity" that includes three levels of biological variability - ecosystem complexity, species richness, and genetic variation**.** In this document, the prime concern is at the level of species.

Breast height: as used in this document, the point on the stem of a tree 1.3 m above the soil level with debris removed. It is at this point that the diameter of a tree is measured.

Canopy: part of a forest or shrub community that is formed by the branches and leaves (or crowns) of its major woody species; also, any terrestrial plant community where a distinctive habitat is formed in the upper, denser regions of the taller plants.

> **Closed canopy:** the continuous layer formed when the branches (crowns) of the species making up the canopy interlace or overlap. Little sunlight penetrates to the ground vegetation, except when the leaves are absent.
>
> **Open canopy:** the discontinuous layer in forests or other plant communities when the branches (crowns) of the individual species do not overlap. Sunlight penetrates to the ground vegetation year round.

Clinometer: instrument for measuring slopes; in ecology, used as an aid for measuring tree heights.

Community: a general term applied to a grouping of plants or animals that form part of an ecosystem and give it a certain degree of individuality, e.g. plant community, or animal community of a prairie ecosystem. In this document, *community* refers to plant community unless otherwise qualified.

Cover: the area occupied by individuals of a species. It is usually determined by measuring the area of the ground covered by a plant, either by vertical projection of the area covered by the leaves of an individual or by measuring its canopy width. It is used to determine dominance.

Density: describes the number of individuals of a species on a unit area basis.

$$\mathbf{D} = \frac{\text{number of individuals of a species in the sample}}{\text{total area sampled } (m^2)}$$

Dominance: area occupied by a species on a unit area. Use basal area or cover as the measurement for area occupied.

$$\textbf{Dom} = \frac{\text{basal area or cover of a species in the sample } (m^2)}{\text{total area of the sample } (m^2)}$$

dbh: diameter at breast height; measurement taken on the stem of a tree 1.3 m above the ground.

Dwarf forest: in Canada, coniferous or alder/birch-dominated communities in the taiga or at high altitudes. The trees are mature although small in stature and are often old.

EMAN: Ecological Monitoring and Assessment Network. EMAN comprises a network of approximately 100 research and monitoring sites in Canada which are organized in 14 terrestrial Ecological Science Cooperatives. EMAN provides a national perspective on the impacts of environmental changes on ecosystems, an early warning system that identifies new ecosystem changes as they emerge and reports on their distribution.

Ecotone: a typically narrow, usually sharply defined zone of vegetation (transition zone) that separates two different plant communities, e.g. in riparian or lacustrine zones but sometimes quite broad as between two different biomes e.g. the prairie parklands between the prairies and the boreal forest.

Ecosystem: A dynamic complex of organisms (biota) including humans, and their physical environment interacting as a unit. They may vary in size and composition, the term being applied to the whole world and its atmosphere, to units dominated by particular plant types (prairies, boreal forest) to a local pond, or quarry. In its broadest sense it includes environmental, biological, social and economic elements.

Ecozone: the largest ecological unit in the ecological land classification for Canada. Ecozones are subdivided into progressively smaller units based on similarities or dissimilarities in ecological characteristics, such as climate, soil or water properties, and the biota. Each ecozone is subdivided into ecoprovinces, each ecoprovince into ecoregions, and each ecoregion into ecodistricts.

Emergents: individual trees, or clumps of trees that stand prominently higher than the continuous canopy of the forest e.g. in eastern Canada, white pine may be an emergent in hardwood forests; also refers to those plants rooted in water that have leaves above the water surface e.g. cattails are often emergents.

Epiphyte: any non-parasitic plant that grows on another a plant without direct connection to the soil e g. a moss or lichen that grows on the trunk of a tree.

Flora: All the plant species that grow spontaneously in a particular area/region or period, listed by species and considered as a whole; presence, not numbers of individuals, is what counts.

Field Layer: see stratum.

Forest ecosystem: ecosystem dominated by trees; the canopy may be closed or open. See also non-forest ecosystem.

Frequency: describes the distribution of a species through the stand. It is determined by calculating the percentage of plots in a sample on which a species occurs.

$$\mathbf{F} = \frac{\text{number of plots in which a species occurs}}{\text{total number of plots in the sample}} \times 100$$

Ground layer: see stratum.

Ground vegetation: as used in this document, a combination of the field and ground layers (see stratum); includes all herbaceous species in a community and all woody species up to 1 m in height, and non-vascular species such as mosses, lichens and mushrooms; includes small shrub and tree seedlings.

GPS: Global Positioning System. GPS is a satellite navigation system which provides specially coded satellite signals that can be processed in a GPS receiver to compute the location of the instrument. Four GPS satellite signals are used to compute positions in three dimensions.

Herbaceous: not woody. The entire plant or the above-ground parts die back at the end of each growing season. If perennial, the overwintering buds are at or below the soil surface.

Importance value: an index made up of Relative Density, Relative Dominance and Relative Frequency that profiles the structural role of a species in a stand. It is also useful for making comparisons among stands in reference to species composition and stand structure.

IV = Relative Density + Relative Dominance + Relative Frequency

Lacustrine: pertaining to lakes; also refers to the characteristic zones of vegetation fringing a lake.

Leaning tree: any tree standing at an angle of greater than 30^{o} from the vertical.

MAB: the United Nations Educational Scientific and Cultural Organization (UNESCO) Program on Man and the Biosphere. In Canada, the Canada/MAB Committee is the main contact.

Meta data: information about what is in a data set; often defined as "data about data".

Nested plots: a sampling system in which plots of different sizes are so arranged that larger plots contain the smaller ones.

Non-forest ecosystem: grasslands, shrublands, some bogs, semi-deserts, tundra, etc., where trees are not the dominant life form, although they may be present as scattered individuals or in patches. See forest ecosystem.

Plot: a general term referring to any area of land of any shape (e.g. circle, square, rectangle etc.) or size, which may be used for any purpose (e.g. sampling).

Phenology: the science dealing with the influence of climate (e.g. seasonal changes) on the recurrence of such annual phenomena as leafing out, flowering, ice cover or break-up, etc.

Photosynthetic surface: that area of the plant containing chlorophyll; usually leaves and herbaceous stems, but also includes young woody plant stems and branches.

Quadrat: a specific ecological sampling term that refers usually to a square (original definition) or rectangular sampling plot of a predetermined area/size. As used in this document, the sample shape is square, and basic recommended sizes are: 100 m x 100 m (1 ha), 20 m x 20 m, 5 m x 5 m, and 1 m x 1 m. Other sizes are recommended for specific purposes.

Relative Density: describes the number of individuals of one species in relation to the total number of individuals of all species.

$$\textbf{RD} = \frac{\text{number of individuals of a species in the sample}}{\text{total number of individuals of all species in the sample}} \times 100$$

Relative dominance: describes the area occupied by one species relative to the area occupied by all species. Basal area or cover are the variables commonly used for determining this value.

$$\textbf{RDom} = \frac{\text{basal area or cover of a species in the sample } (m^2)}{\text{basal area or cover of all species in the sample } (m^2)} \times 100$$

Relative Frequency: describes the distribution of one species relative to all species in the sample area.

$$\textbf{RF} = \frac{\text{frequency of a species in the sample}}{\text{frequency of all species in the sample}} \times 100$$

Responsible Group: as used in this document, refers to the decision-making team with overall responsibility for determining and managing all the research and monitoring at the site under consideration.

Riparian: pertaining to rivers; as used in this document for convenience, it refers to the characteristic zones of vegetation fringing water bodies whether bordering a river or a lake; forests fringing rivers in grassland areas are sometimes known as gallery forests.

Sample: Example or portion showing qualities and characteristics of a whole. The number of quadrats used for sampling a particular stand; the area enclosed by a quadrat.

Sapling: young tree, normally single-stemmed, over 1 m in height, and smaller in height than a mature tree. Included with shrubs and small trees in this document.

Savannah: grass-dominated ecosystem with scattered trees or tall shrubs or small clumps dotting the landscape; often transitional between forest and true grassland.

Seedling: product of a germinated seed; may often be recognized by the presence of cotyledons (seed leaves). For convenience, young trees up to 1 m in height are considered as "seedlings".

Shrub: multistemmed (i.e. without a clear trunk) woody plant; as used in this document a woody plant under 4 cm dbh and under 10 m in height that forms part of a plant community; may form the dominant woody vegetation in areas too wet or too dry to support trees (e.g. riparian areas subject to floods or ice damage; some tundra, and grassland communities).

Stand: standing growth of plants; a particular example of a plant community, e.g. forest or grassland in which monitoring plot(s) are established.

Stratification: the grouping into height classes of individual plants in a community or habitat.

Stratum (pl. strata): a horizontal layer of vegetation; most plant communities form well developed strata which are occupied by groups of species characteristic of that stratum. The strata are defined as follows:

Canopy: typically the uppermost, essentially continuous layer (stratum) of a plant community that is formed by the tallest individuals in a forest, shrub or herbaceous community; the area occupied by the leaves and branches of a single plant.

Shrub and small tree layer: beneath the canopy trees, consists of shade-tolerant woody species, consisting of small and immature canopy trees, small trees that do not reach into the canopy, and shrubs that are over 1 m in height.

Shrubs may form the canopy in communities where conditions are not suitable for trees.

Field layer: made up of herbaceous species of any height, and woody species up to 1 m in height. In this document combined with the ground layer and referred to as "ground vegetation".

Ground layer: vegetation on the surface of the ground; usually mosses, lichens, and fungi together with low-growing herbaceous species, especially those with trailing or rosette growth forms. In this document combined with the field layer and referred to as "ground vegetation".

Survey: as used in this document, the formal process for laying out a plot using survey methods.

Systematics: the study of taxonomy and phylogenetic relationships of organisms.

Taxon (pl: taxa): any unit of any rank within a taxonomic classification, e.g. genus, species, family, etc.

Taxonomy: the science of classifying and naming organisms.

Transect: A line or belt of vegetation selected for sampling; as used in this document, a continuous string of contiguous quadrats set in a line across vegetation gradients.

Theodolite: Surveying instrument for measuring horizontal and vertical angles by means of a telescope (transit and level).

Tundra: The vegetation type above the tree line at high latitudes and altitudes.

UNESCO: United Nations Educational, Scientific and Cultural Organization.

Vegetation: Plants collectively; the plant life of a region. Differs from "flora" because the populations of the different species are taken into consideration; common species are given more weight than occasional species.

Vegetation gradient: obvious changes in the type of vegetation across a landscape as a result of some physical change e.g. change in moisture regime: as the distance from a water body increases, the vegetation may change from herbaceous species, through shrubs and trees to a grassland; or change in elevation: as altitude increases, the vegetation may change from tall trees to small trees to alpine tundra (see also *ecotone*).

Voucher specimen: a properly mounted/preserved and archived specimen that serves to "document" the use of a specific name, or the presence of an organism in a particular place.

BIBLIOGRAPHY

I. General

Allaby, M. ed. 1992. *The Concise Oxford Dictionary of Botany*. Oxford University Press. Oxford.

Barbour, M. G., J. H. Burk and W. D. Pitts. 1999. *Terrestrial plant ecology*. 3rd ed. Toronto, Addison Wesley Canada.

Dallmeier, F. 1992. *Long-term monitoring of biological diversity in tropical forest areas: methods for establishment and inventory of permanent plots*. MAB Digest 11. UNESCO, Paris.

D'Eon, S.P. L.P. Magasi, D. Lachance, and P. DesRochers. 1994. *ARNEWS: Canada's national forest monitoring plot network manual on plot establishment and monitoring (revised)*. Petawawa National Forestry Institute. Information report PI-X-117. Chalk River.

Ecological Stratification Working Group. 1995. *A national ecological framework for Canada*. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Resources Research, and Environment Canada, State of the Environment Directorate, Ecozone Analysis Branch, Ottawa/Hull. Report and national map at 1:7 500 000 scale.

Hall, J. P. and P. A. Addison. 1991. *Response to Air Pollution: ARNEWS assesses the health of Canadian forests.* Forestry Canada. Science and Sustainable Development Directorate, Information Report DPC-X34. Ottawa.

Mueller-Dombois, D. & H. Ellenberg. 1974. *Aims and methods of vegetation ecology.* Wiley, New York.

Oosting, H.J. 1956. *The study of plant communities: an introduction to plant ecology.* 2nd ed. W.H. Freeman and Company, San Francisco.

Phillips, E.A. 1959. *Methods of vegetation study*. Holt, Rhinehart and Winston, New York.

Ringius, G. S. and R. A. Sims. 1997. *Indicator plant species in Canadian forests.* Natural Resources Canada, Canadian Forest Service, Ottawa.

Stohlen, T. J. 1995. Attributes of reliable long-term landscape studies: malpractice insurance for landscape ecologists. *Environmental Monitoring and Assessment* 36: 1-25.

Silvertown, J. W. 1987. *Introduction to plant population ecology*. 2nd ed. Longman, Singapore Publishers (Pty) Ltd. Singapore.

II. Plant Identification Bibliography

This bibliography is not an exhaustive list of floras and plant guides in Canada, but includes the most useful, up-to-date and complete references. The recommended nomenclatural standards for Canada are marked (*) below. *Flora North America* is the standard for vascular plants and mosses and *Lichens of North America* is the standard for lichens. The latter is in press, due for release in the spring of 2001, while the former is a work in progress. For this reason, we recommend other manuals, marked (**), as the interim standards for those families not yet published.

The list is divided into two main parts as follows:

1. Floras and specialized plant manuals that describe all plants within a given area. These are the best and most precise guides to use, but often lack pictures and may be difficult for the non-botanist to use. In addition, there are many useful technical taxonomic publications not listed here.

2. Picture book guides that cover only the most common or visible plants within a given area. These are the easiest guides to use, but do not describe all plants, so must be used in conjunction with the floras and plant manuals listed in the first part.

1. Floras and specialized plant manuals

a) Canada

***** Brodo, I.M., S.D. Sharnoff and S. Sharnoff. In press. *Lichens of North America*. Yale University Press.

Cody, W. J. and D. M. Britton. 1989. *Ferns and fern allies of Canada*. Research Branch, Agriculture Canada, Ottawa.

Farrar, L. L. 1995. *Trees in Canada*. Canadian Forest Service, and Fitzhenry & Whiteside, Markham.

***** Flora of North America Editorial Committee. 1993. *Flora of North America North of Mexico. Volume 2. Pteridophytes and gymnosperms*. Oxford University Press, New York.

***** Flora of North America Editorial Committee. 1997. *Flora of North America. Volume 3. Magnoliophyta: Magnoliidae and Hamamelidae*. Oxford University Press, New York.

Goward, T., I. Brodo, S. Clayden, 1998. *Rare lichens of Canada: a review and provisional listing*. Committee on the Status of Endangered Wildlife in Canada. Canadian Wildlife Service, Environment Canada, Ottawa.

Lellinger, D. B. 1985. *A field manual of the ferns and fern allies of the United States and Canada.* Smithsonian Institution Press, Washington.

b) Eastern Canada

Crow, G. E. and C. B. Hellquist.   In press. *Aquatic and Wetland Plants of Northeastern North America*. University of Wisconsin Press. (An update of Fassett, 1969)

***** Crum, H. A. & L.E. Anderson. 1981. *Mosses of Eastern North America*. Columbia University Press, New York. 2 volumes.

Fassett, N. C. 1969. *A Manual of Aquatic Plants*. University of Wisconsin Press.

****** Gleason, H. A. and A. Cronquist. 1991. *Manual of Vascular Plants of Northeastern United States and Adjacent Canada*. 2nd ed. The New York Botanical Garden, Bronx.

Gowan, S. P. and I.M. Brodo. 1988. *The lichens of Fundy National Park, New Brunswick, Canada*. *The Bryologist*. 91: 255-325. (Key & list but the only lichen reference list for Atlantic Canada)

Hinds H. R. 1986. *Flora of New Brunswick*. Primrose Press, Fredericton.

Holmgren, N. H. 1998. *The Illustrated Companion to Gleason and Cronquist's Manual*. The New York Botanical Garden, Bronx.

****** Ireland, R.R. 1982. *Moss Flora of the Maritime Provinces. National Museums of Canada*. National Museum of Natural History, Publications in Botany No. 13, Ottawa.

Ley, L and J. Crowe, 1999. An enthusiasts guide to the liverworts and hornworts of Ontario. Lakehead University, Thunderbay.

****** Marie-Victorin, Frère. 1995. *Flore Laurentienne*. 2^{e} ed. Les Presses de l'Université de Montréal, Montréal.

Schuster, R.M. 1953. Boreal Hepaticae: a manual of the Liverworts of Minnesota and adjacent regions. *American Midland Naturalist*, 49:275-684. (Keys, descriptions, black & white illustrations)

***** Schuster, R. M. 1966-1980. *The Hepaticae and Anthocerotae of North America east of the hundredth meridian*. The Colombia University Press, New York. Vols 1-4. (Highly technical and comprehensive, with keys, detailed descriptions, ecological data, and black and white illustrations.)

***** Schuster, R. M. 1992. *The Hepaticae and Anthocerotae of North America east of the hundredth meridian.* Field Museum of Natural History, Chicago. Vols 5-6. (Highly technical and comprehensive, with keys, detailed descriptions, ecological data, and black and white illustrations.)

Soper, J. H. and M. L. Heimburger. 1982. *Shrubs of Ontario*. The Royal Ontario Museum, Toronto.

Zinck, M. 1998. *Roland's Flora of Nova Scotia*. 2 volumes. Nymbus Press, Halifax.

c) Western Canada (including the Prairies)

**** Douglas, G. W., G. B. Straley and D. Meidinger. 1989-1994. *The Vascular Plants of British Columbia.* 4 volumes. Research Branch, Ministry of Forests, Victoria.

Goward, T., B. McCune and D. Meidinger. 1994. *The Lichens of British Columbia, Illustrated Keys. Part 1 - Foliose and squamulose species*. BC Ministry of Forests. Special Report Series no. 8:1-181.

Hitchcock, C.L., A. Cronquist, M. Ownbey and J. W. Thompson. 1969. *Vascular Plants of the Pacific Northwest*. University of Washington Press, Seattle.

Hong Quian and K. Klinka. 1998. *Plants of British Columbia: Scientific and Common Names of Vascular Plants, Bryophytes, and Lichens*. UBC Press, Vancouver.

Lawton, E. 1971. Moss Flora of the Pacific Northwest. Hattori Botanical Laboratory, Nichinana.

**** Looman, J. and K. F. Best. 1987. *Budd's Flora of the Canadian Prairie Provinces*. Research Branch, Agriculture Canada.

McCune, B. and L. Geiser. 1997. *Macrolichens of the Pacific Northwest*. Oregon State University Press, Corvallis.

McCune, B. and T. Goward. 1995. *Macrolichens of the Northern Rocky Mountains*. Mad River Press, Eureka.

Moss, E. H. 1983. *Flora of Alberta*. 2nd ed. University of Toronto Press, Toronto.

Furthermore, the Royal British Columbia Museum has published numerous technical treatments of plant families for British Columbia, such as:

! Brayshaw, T. C. 1985. *Pondweeds and bur-reeds and their relatives of British Columbia*. The British Columbia Provincial Museum, Victoria.
! Douglas, G.W. 1995. *The Sunflower Family (Asteraceae) of British Columbia*. Royal British Columbia Museum, Victoria
! Taylor, T.M.C. 1974. *The Pea Family of British Columbia.* British Columbia Provincial Museum, Victoria.

There are also excellent floras to specific areas, for example:
Kuijt, J. 1982. *A Flora of Waterton Lakes National Park*. The University of Alberta Press, Edmonton.

d) Northern Canada

Aiken, S. G., M.J. Dallwitz, L.L. Consaul, C.L. McJannet, L.J. Gillespie, R.L. Boles, G.W. Argus, J.M. Gillett, P.J. Scott, K.T. Hansen and R. Elven (1999 onwards). *Flora of the Canadian Arctic Archipelago: Descriptions, Illustrations, Identification, and Information retrieval.* Version: 10 September 1999. URL : http://biodiversity.uno.edu/delta/.

****** Cody, W. J. 1996. *Flora of the Yukon Territory*. National Research Council Research Press, Ottawa. (nomenclature standard for northern Canada until *Flora North America* is complete - to be used in conjunction with Porsild & Cody)

Porsild, A. E. 1964. *Illustrated Flora of the Canadian Arctic Archipelago.* 2nd ed. National Museums of Canada, Ottawa.

Porsild, A. E. and W. J. Cody. 1980. *Vascular Plants of Continental Northwest Territories, Canada*. National Museums of Canada, Ottawa. (* for species not included in Cody, 1996.

2. Picturebook guides

a) Eastern Canada

Chambers, B., K. Legasy and C. Bentley. 1996. *Forest Plants of Central Ontario*. Lone Pine Publishing, Edmonton.

Groupe Fleurbec. 1987. *Plantes sauvages des lacs, rivières et tourbières.* Fleurbec, St-Henri-de-Levis.

Groupe Fleurbec. 1993. *Fougères, prêles et lycopodes: guide d'identification*. Fleurbec, St-Henri-de-Levis.

Ireland, R. and G. Bellolio-Trucco. 1987. *Illustrated Guide to some Hornworts, Liverworts and Mosses of Eastern Canada.* Syllogeus No. 62. National Museums of Canada. National Museum of Natural Sciences, Ottawa.

Legasy, K., S. Labelle-Beadman and B. Chambers. 1995. *Forest Plants of Northeastern Ontario*. Lone Pine Publishing, Edmonton.

Newcomb, L. 1977. *Newcomb's Wildflower Guide*. Little, Brown & Co., Boston.

Newmaster, S. G., A. G. Harris and L. J. Kershaw. 1997. *Wetland Plants of Ontario*. Lone Pine Publishing, Edmonton.

b) Western Canada

Johnson, D., L. Kershaw, A. MacKinnon and J. Pojar. 1995. *Plants of the Western Boreal Forest and Aspen Parklands*. Lone Pine Publishing, Edmonton.

Kershaw, L. , A. Mackinnon and J. Pojar. 1998. *Plants of the Rocky Mountains*. Lone Pine Publishing, Edmonton.

MacKinnon, A., J. Pojar and R. Coupé. 1992. *Plants of Northern British Columbia*. Lone Pine Publishing, Edmonton.

Parish, R., Coupé, R. and Lloyd, D. 1996. *Plants of Southern Interior British Columbia*. Lone Pine Publishing, Edmonton.

Pojar, J. and A. MacKinnon. 1994. *Plants of Coastal British Columbia*. Lone Pine Publishing, Edmonton.

Vitt, D. H., J. E. Marsh and K. B. Bovey. 1988. *Mosses, Lichens and Ferns of Northwest North America*. Lone Pine Publishing, Edmonton.