A Permanent Plot Method for Monitoring Changes in Indigenous Forests: A Field Manual

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CONTENTS

SUMMARY

New Zealand's remaining indigenous forests are an important feature of the landscape and cover about 6 million hectares, or 23% of the land surface. The management and protection of this resource require techniques for monitoring its status (forest structure, species composition, and distribution). The use of permanent sample plots has long been recognised as a robust approach for determining detailed changes in forest. The 20 × 20 m permanent plot is widely used for this purpose, and this manual updates and standardises its use. Random, systematic, stratified, and subjective sampling systems are outlined for the location of plots, the choice of which depends on specific objectives. Each plot is a permanently marked quadrat, within which all trees are tagged, diameters are recorded by species, and all samplings are counted. Each plot also contains permanently marked understorey subplots within which all vascular species are recorded in several height classes. Most of the 20 × 20 m plot data collected so far are stored in the National Indigenous Vegetation Survey Database, held by Landcare Research New Zealand, Christchurch.

KEYWORDS: forest, permanent sample plots, forest inventory, forest dynamics, environmental monitoring, forest conservation.

1. INTRODUCTION

Environmental change has economic, ecological, social, and cultural implications. However, such change is often poorly documented, and there is a general need for long-term monitoring of the environment. Not only does this provide a quantitative record of the environment, but it also provides the key information required for understanding the processes involved (Likens 1989).

Two recent workshops, sponsored by The Royal Society and the Department of Conservation, considered that there had been an erosion of long-term environmental monitoring in New Zealand (Craig 1989; The Royal Society of New Zealand 1990). Factors contributing to this erosion include difficulties in obtaining sustained financial support in a climate of rapidly changing priorities and funding sources. Yet it is essential that we provide future generations with a broad enough base of quantitative information on environmental change for informed decisions to be made abut land use. Requirements under the recently passed Resource Management Act (1991) are likely to renew interest in environmental monitoring.

The remaining indigenous forests are a dominant feature of the New Zealand landscape and cover about 6 million hectares, or 23% of the land surface (Newsom 1987). The management and protection of this resource require techniques for monitoring its status (forest structure, species composition, and distribution).

A number of individuals and agencies have developed methods of monitoring indigenous forest for conservation purposes and to increase our understanding of ecological processes (see Craig 1989).

Approaches used have varied, partly because of different objectives, and include:

- Satellite and aerial imagery for forest distribution (e.g., McKelvey 1973; Timmins *et al.* 1984).
- Repeat photography for understorey changes (e.g., Mark 1978); aerial photography for canopy dieback (e.g., Pekelharing 1979).
- Measurement of individual trees for assessing changes in canopy condition (Meads 1976; Payton 1983).
- Repeated, large-scale surveys of forest structure (e.g., Batcheler & Craib 1985).
- Permanently marked plots for determining changes in structure and composition (e.g., Wardle & Allen 1983; Williams 1991).

Permanent sample plots have long been recognised as a robust approach for determining detailed changes in forests (e.g., Graves 1906; Solomon 1979; Canham 1987). One of the earliest examples of the use of permanent plots in New Zealand is the belt transects

established by Cockayne (1898) in beech (*Nothofagus*) forest, subalpine scrub, and red tussock (*Chionochloa rubra*) grassland at Arthur's Pass.
From 1950 till 1985, permanent sample plots were widely established in New Zealand indigenous forests (e.g., McKelvey *et al.* 1958; Allen & McLennan 1983; Meurk & Buxton, unpubl. DSIR Botany Division report 1988). The most frequently used permanent plot types were established by the former New Zealand Forest Service and included cruciform (Holloway & Wendelken 1957) and 20 × 20 m plots (Allen & McLennan 1983). The prime reason for initiating this work was to monitor the impacts of introduced browsing animals (Batcheler & Wardle 1976).

The function of the cruciform plot system (used in the 1950s and 1960s) was two-fold: to provide a description of the stand and stand parameters, and to provide permanently marked areas that could be remeasured over time to determine changes in structure and composition of the vegetation. Experience showed that this plot system had limitations: the two major functions could not be fulfilled by a single sampling strategy, the cruciform plots had a large perimeter-to-area ratio (each arm measured 20 × 5 m) so that many trees were located on plot margins, and many estimates were visual (e.g., for diameter). As a more objective approach was required, the plot system was redesigned into a two-system approach that included impermanent Reconnaissance Descriptions (see Allen 1992) and permanent 20 × 20 m plots. Over the last 25 years, more than 10 000 permanent 20 × 20 m plots have been established in indigenous forests (Forest Research Institute 1989).

It is difficult to design a system appropriate for all New Zealand forest types, as they vary a great deal in their structure and composition. For example, low-elevation forest in the north may have widely spaced podocarps up to 50 m tall that emerge agove a main canopy of hardwood species, with a dense understorey of subcanopy trees, shrubs and ferns, as well as epiphytes perched at all levels in the forest. The simplest subalpine forest may have an 8-m-high canopy dominated by one species, with little understorey. In addition, different objectives for individual surveys may need quite different information. It is not the purpose of this manual to review alternatives, which has been done elsewhere (e.g., Mueller-Dombois & Ellenberg 1974; Barbour *et al.* 1980; Økland 1990).

The 20 × 20 m plot method has been used in many areas for monitoring structural and compositional changes in different forests and for different purposes, and generally performs reliably in comparisons with other techniques (Wilkinson & Daly 1976; Batcheler & Craib 1985; Iball 1989). The method is probably most limited for monitoring changes in comparatively low-density canopy tree species.

The 20 × 20 m plot has been variously known as the "square chain", the "twenty metres square plot", or the "quadrat". It is a permanently marked quadrat, within which all trees are tagged, diameters are recorded by species, and all saplings are counted. Each plot also contains permanently marked seedling subplots within which all vascular species are recorded in several height classes. These are the types of measurements commonly made on permanent sample plots in forest (e.g., Synnott 1979). Also, it has been standard practice to establish a Reconnaissance Description (see Allen 1992) on each 20 × 20 m plot, as this provides site and other information for the stand. Although the method was designed for large-scale monitoring of mountain forests, numerous surveys of more limited extent and in lowland forest have also successfully used the method outlined.

Most of the 20 × 20 m permanent plot data collected so far are stored in the National Indigenous Vegetation Survey (NIVS) Database (Forest Research Institute 1989) held by Landcare Research, Christchurch. Permanent plots are expensive to establish and require continuing maintenance. Present resources are insufficient to maintain the large number of permanent plots, and we need to identify and focus on key datasets. For example, some countries have responded by setting up a network of long-term monitoring sites (e.g., the Environmental Change Network in the United Kingdom). However, we also need to extend monitoring activities as new problems arise. It is essential that any previous information provided by NIVS is ascertained.

This manual standardises the 20 × 20 m permanent plot methodology and updates earlier versions (Allen & McLennan, FRI unpubl. report 1978; Allen & McLennan 1983; Forest Research Institute 1983; Stewart & Orwin 1986). An updated analysis manual for such data is also being written (Hall in prep.). There will sometimes be sufficient reason to change aspects of the methodology for specific objectives, but collecting the standard data outlined in this manual will maximise future comparability of data. It is therefore recommended that any changes should be additions, rather than alterations, to the standard methodology. Additions need to be carefully detailed, as it may be many years before the plots are revisited. Brief descriptions are given in the relevant sections of some additions previously found useful.

1.1 Examples of uses of permanent plots

Determining vegetation responses to animal impacts

Fiordland National Park has a long history of the monitoring of vegetation changes in responses to the impact of red deer (*Cervus elaphus*). Stewart *et al.* (1987) used 24 plots established in 1975 and remeasured in 1984 to determine forest understorey changes after a reduction of deer numbers in northern Fiordland. When compositional variation is being specifically related to the distribution and abundance of introduced browsing animals, it is useful to record additional data on animal distribution and abundance (see Baddeley 1985).

Monitoring canopy dieback in tree species

Dieback can be a prominent feature of indigenous forests and is of concern to forest managers (e.g., Rose *et al.* 1992).

In the mountain beech (*Nothofagus solandri* var. *cliffortioides*) forests of the Harper–Avoca Valley, 250 permanent plots have been used to determine canopy mortality patterns over the last 17 years and to describe the understorey response (Wardle & Allen 1983; Allen & Platt 1992).

Describing compositional and structural variation

The indigenous forest resource has been described at a range of scales (e.g., Manson & Guest 1975; Guest & Wilkinson 1977; Wardle 1984). Wardle & Guest (1977) used 208 plots located at 180-m intervals along 56 randomly chosen transects to describe the forests of the Waitaki and Lake Hawea catchments. The tree-diameter data were used to show that the mountain beech forests contained a higher proportion of large-diameter trees than was common in other localities.

Quantifying changes in forest exclosures

Changes in structure and composition inside fenced exclosures have been contrasted with changes in adjacent forest subjected to understorey browsing by introduced animals. For example, the impact of white-tailed deer (*Odocoileus virginianus*) on regeneration in the coastal forests of Stewart Island was studied using 18 exclosure plots and 51 non-exclosure plots (Stewart & Burrows 1989).

Developing models of forest dynamics

Models contribute to our wider understanding of forest dynamics (e.g. Wardle 1984). Osawa & Allen (1993) used 540 plots located within pure mountain beech forests of the South Island as part of a study examining self-thinning relationships in mountain beech stands.

2. OBJECTIVES

Forest inventory must be based on an explicit statement of the problem and the resulting objectives (Jongman *et al.* 1987). The objectives form the basis for decisions about the sampling design, and the comparisons to be mad,e as well as any explanatory or response variables to be measured (see Cochran 1983). This allows an efficient use of resources. The task is often complex because:

- Resource inventories are often multi-faceted, and it is difficult to optimise sampling for all the objectives. If objectives are not determined beforehand by all those involved, they may change and diverge during the survey.
- Field sampling can lead to new issues that may result in modification of the original objectives. This may well reflect a problem statement that has not been carefully researched.
- In the long term, permanent sample plots will often be used to answer questions for which they were not specifically designed. In anticipation of this, a broad range of information is often collected.

Existing information should be researched carefully, as this will partly determine whether an inventory is justified and what the particular objectives should be. The ability to access existing data has been greatly enhanced by the formation of the NIVS database.

3. INVENTORY DESIGN

A well thought out inventory design or strategy is the foundation for meaningful analysis of vegetation patterns, and the application of statistical tests to realise the objectives (see Jongman *et al.* 1987). The purpose of an inventory will influence the sampling design and hence the number and location of 20 × 20 m plots, and this in turn influences the forest characteristics that can be determined. The strategy will also need to take account of any constraints, such as the nature of the terrain to be surveyed.

In many areas, 20 × 20 m plots have already been established. Before carrying out a survey it is advisable to check with Landcare Research, Christchurch, to see whether plots are already present. These plots are expensive to establish and require maintenance, so it is important not to be over-committed because of limited resources. Allowance must also be made for remeasurement.

3.1 LOCATION OF PLOTS

The most frequent use of 20 × 20 m plots is to sample vegetation over a survey area or under different treatments. Plots may be located as a representative, stratified, or subjective sample of the study area. These different approaches will affect the statistical properties of the data, the representativeness, and the variation included, and will have practical implications (Økland 1990). In subsequent analyses the sample is often used in the belief that it reflects properties of the vegetation as a whole (Økland 1990). Whatever sampling approach is used, the location of all 20 × 20 m plots should be transcribed on to aerial photographs and topographic maps. Some of the more widely used approaches to sampling with 20 × 20 m plots are given below, with examples (also see Allen 1992).

3.1.1 Representative sample of study area

Representative samples of the study area can be obtained by random, restricted random, or systematic location of 20 × 20 m plots. Such approaches are often used when the focus is resource inventory of an area. Randomised sampling eliminates systematic errors, allows the use of powerful inferential statistics, and gives the relative frequency of various ecological conditions (Jongman *et al.* 1987). However, such an approach means that rare but ecologically important sites may not be sampled, and setting up the plots is time consuming.

Systematic sampling can be done on a grid or along transects (a one-dimensional grid). Such sampling can give better coverage of the study area and faster location of plots than random sampling (Økland 1990).

Because it is difficult to establish randomly selected plots in mountainous country, early surveys often compromised and located 20 × 20 m plots at fixed intervals on predetermined transect lines (see Allen & McLennan 1983). Starting points for such transects were selected on a restricted random basis so that the plots would still be representative of the area as a whole. Two methods for the placing of transect lines are as follows:

(a) Use a grid pattern based on the X and Y coordinates found on a NZMS Series 260 metric map (or the NZMS Series 1 equivalent) If the NZMS Series 260 is used, divide the survey area in 10 000 × 10 000-m blocks. Each block is subdivided into one hundred 1000-m squares. Using random X and Y coordinates, choose 5–10 of these squares, depending on the required sampling intensity. Identify the point on a watercourse that is nearest to the centre of the selected 1000-m square. This point becomes the line origin. Randomly assign the transect to one side of the watercourse. Draw a line from the origin to the nearest main ridge or timberline.

(b) Divide the survey area into block or catchments on a map, then allocate the required number of lines to each block. Start at the head or the mouth of a river and run a planimeter along the main stream and all tributaries. Select a random number (usually two-figured) and stop when the planimeter reaches that number. This point is the line origin. Randomly assign the transect to one side of the watercourse. Draw a line from the origin to the nearest main ridge or timberline.

The compass bearing to be used in the field for each transect is determined from the line drawn on the map, with correction for magnetic declination.

Example: Seventy-five 20 × 20 m plots were located at 200-m elevation intervals along 26 transects in the 8300-ha forests of the Hope catchment (Guest & Wilkinson 1977). The data were used to determine forest structure and regeneration in relation to the impact of browsing animals.

3.1.2 Subjective sample of study area

The least formal sampling approach is to locate 20 × 20 m plots subjectively. When this is done by attempting to sample the range of vegetation from in a study area, rather than by selecting sites considered in some way 'typical', the approach is termed "subjective sampling without preconceived bias" (Mueller-Dombois & Ellenberg 1974). When vegetation plots are located subjectively it is difficult to extrapolate the results to the study area as a whole, and the types of analyses that can be validly applied to the data are limited. However, subjective sampling is widely applied in ecological studies, partly because careful subjective selection of sampling sites often includes greater variation on fewer plots than more formal schemes.

Example: In Westland National Park, 45 permanent 20 × 20 m plots were established in 1978–79 to determine forest mortality, regeneration, and changes in canopy condition in three localities of different possum population history (Stewart 1992). The plots were subjectively located in nearby stands at each locality. Remeasurement of these plots showed high mortality in Hall's totara (*Podocarpus hallii*).

3.1.3 Stratified sample of study area

With sufficient prior knowledge, the area can be stratified for efficient sampling. The strata can then be sampled randomly, systematically, or subjectively. This approach has often been used in multi-faceted studies. Such sampling can focus the estimation of vegetation parameters more closely to specific objectives (Jongman *et al.* 1987). However, stratified sampling requires justification of the assumptions about the type of variation to be sampled before statistically sound conclusions can be made.

Examples: A recent trend towards using stratified sampling to locate permanent plots is illustrated by a Stewart Island study where the forest was stratified into eight forest types with a number of plots subjectively located in each type (Stewart & Burrows 1989). In addition, of the total 69 plots used in the study, 18 were fenced to exclude the impacts of deer browsing.

Another type of stratification is to specify a predetermined sampling framework and intensity. Such a strategy is appropriate when monitoring vegetation change along selected environmental gradients. Although not using 20 × 20 m plots, Allen & Peet (1990) formed a framework of 35 "potential sampling" sites in a study of Rocky Mountain forests (USA), using all possible combinations of seven elevation classes and five topographic position classes. Plots were then subjectively located within each potential sampling site.

3.2 PLOT SAMPLING INTENSITY

A number of factors must be considered when determining the density of 20 × 20 m plots to meet objectives for an inventory of a particular area. These factors include:

- The diversity of vegetation in the study area. For example, the Wairau forest survey covered a large area containing relatively low-diversity beech forest, and a comparatively low sampling intensity was used (Table 1).
- The resources available: The higher costs associated with inventories of increasingly large areas usually result in a decreased sampling intensity (Table 1). The average cost of establishing 20 × 20 m plots will vary considerably for individual inventories, reflecting in particular the nature of the terrain and access.
- The level of precision required. This must be considered when statistical tests and estimation of characteristics for subgroups are required.

TABLE 1. Sampling intensities for selected 20 × 20 m plot inventories

Locality	Area (ha)	Density (No/10^3 ha)	Reference
Fiordland	12 000	2	Stewart *et al.* (1987)
Harper–Avoca	9 000	28	Allen & Platt (1992)
Stewart Island	1 000	69	Stewart & Burrows (1989)
Taramakau	14 285	1	Wardle & Hayward (1970)
Wairau	77 060	5	Manson & Guest (1975)
Waitaki	32 000	7	Wardle & Guest (1977)

4. PLOT PROCEDURE

Typically, four experienced people can establish a permanent 20 × 20 m plot in 2–4 hours, although this is variable. Data from 20 × 20 m plots are recorded on Stem Diameter Sheets (Appendix 1) and Understorey Subplot Sheets (Appendix 2), which are available from Landcare Research, Christchurch. For a list of equipment to complete one 20 × 20 m plot see Appendix 3.

The access to each permanent plot must be carefully described and marked, and its location recorded on detailed maps such as the NZMS 260 sheets and aerial photographs. Access, such as a transect, has commonly been marked using “permolat” flagging. The development of Global Positioning Systems may eventually replace route markers. Where representative samples of the study area or strata are required, plots should be located as near to the selected sampling points as possible. Where plots are located subjectively they should be within an area of comparatively homogeneous site and vegetation.

4.1 Plot layout

The layout of a 20 × 20 m plot is shown diagrammatically in Fig. 1. The plot layout procedure can be divided into a number of stages:

- Lay a 20-m tape to form one side of the plot, using the compass bearing if located on a transect. Lay two 20-m tapes at right angles to the first, one at each end. Join the open end with a fourth 20-m tape to form a 20 × 20 m square.
- Mark the plot corners permanently with large strips of permolat attached to aluminium pegs (see Fig. 2). Permolat strips are marked with the appropriate corner letters (see Fig. 1). Nail a permolat strip on a tree near each corner peg but outside the plot. Nails should remain protruding to allow for tree growth. On the permolat, mark the distance from the tree base to the peg and an arrow indicating the direction of the peg.
- Subdivide the plot into 16 equal-sized squares. The 20-m boundary tapes are subdivided into 5-m intervals, and six other tape (or nylon cords) are laid out to

join each 5-m mark with the corresponding mark on the opposite boundary. The 16 subplots are labelled A to P on the plot sheets from the top left-hand corner (Fig. 1). The tapes are pulled tight when laying out a plot on even ground. When the plot is in a gully or over a ridge, the tapes follow the ground surface.

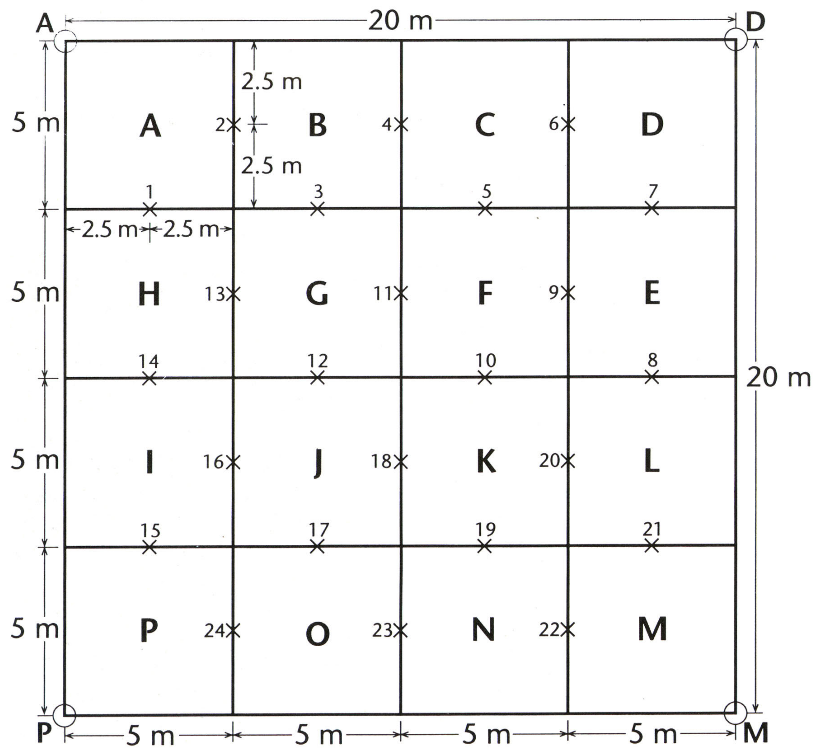

Figure 1 Diagrammatic representation of 20 × 20 m plot layout showing location of tapes, pegs and understorey subplots. O = corner pegs, × = understorey subplots.

4.2 Plot measurement

Plot identification information is recorded on the top right-hand corner of the Stem Diameter and Understorey Subplots sheets (eventually these may be replaced by hand-held field computers). The following information is required:

4.2.1 Identification information

- **Survey:** Record the name of the survey, e.g., Fiordland.
- **Area:** Record the immediate locality of the plot, e.g., Worsley River.
- **Plot Number:** Record the plot number as an identifier, including the transect line number when appropriate, in the space provided.
- **Measured by:** Record the name of the person doing the measurements.
- **Recorded by:** Record the name of the person recording the measurements.

- **Date:** Record the date.

It is normal practice to include a location diagram, map coordinates, and site information as part of a Reconnaissance Description for each 20 × 20 m plot (see Allen 1992).

Figure 2 Layout and method for measuring an understorey subplot.

4.2.2 Tree diameter measurements

The diameters of all stems greater than 3.0 cm dbhob (diameter breast height–1.35m–over bark) are measured at a fixed position using a diameter tape and recorded by species on the Stem Diameter Sheet.

- Attach a numbered "cruising" tag to each stem to be measured with a nail at breast height. Leave at least 1 cm protruding for growth.
- Move away moss or any vegetation such as lianes from around the stem just above the tags without removing or damaging the bark.
- Measure the diameter 1 cm above the tag. Keep the tape at right angles to the axis of the stem, as any deviation from this position will cause a positive bias in measurement. When the plot is on a slope, measure breast height from the side of trees rather than from the uphill or downhill positions.
- Record subplot code, species code, tag number, and diameter for each tree on the plot (Appendix 1). Record species by abbreviations of the generic and specific names. Usually this is the first three letters of the genus and the first three letters of the species, e.g., *Metrosideros umbellata* (southern rata) becomes MET umb (see Hall 1992).

Occasionally, the diameter cannot be taken at breast height. Where malformation occurs the diameter is taken at the nearest point, either above or below breast height, where the stem diameter becomes more regular [Fig.3(a)]. When crowning occurs below breast height, the diameter should be taken below the level of branching on nodal swelling and in a region where the stem diameter is again relatively regular [Fig.3(b)]. The cruising tag should be attached 1 cm below the point where the measurement was taken in order to ensure that later measurements are taken at the same position.

Multi-leader stems (two or three main leaders) are dealt with as groups of individual trees and measured and tagged accordingly [Fig.3(c)]. The group of stems is bracketed on the Stem Diameter Record Sheet (Appendix 1). In forest where the vegetation has a horizontal growth form, e.g., avalanche forest or windthrow, the trees are tagged and measured 1.35 m along the stem from ground level, rather than a breast height. These modifications to the standard method of tree measurement are indicated by writing appropriate comments alongside the diameter measurements.

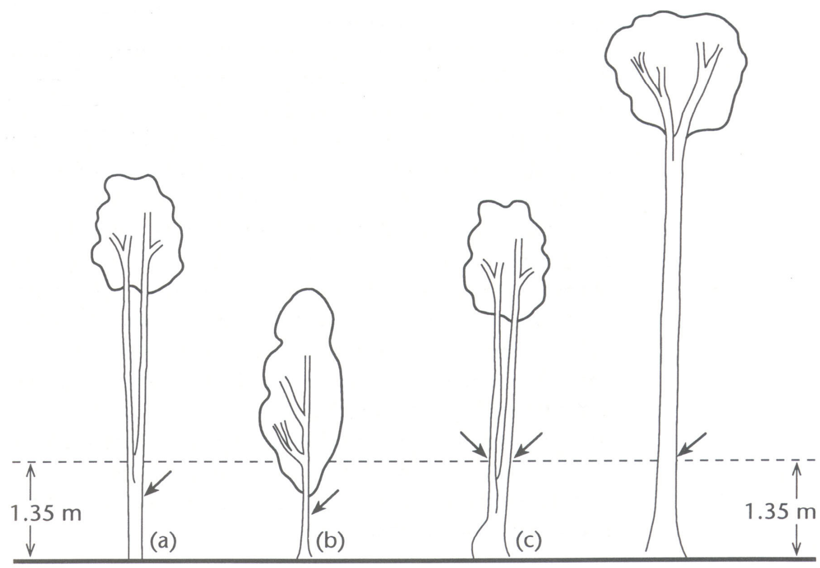

Figure 3 Diameter measurements: the arrow indicates where the measurement is taken for each example.

Note:

- Nail the cruising tags and take the measurements in a position where they are not likely to be overgrown, e.g., do not nail a tag between two leaders that are likely to fuse together in the future.
- Do not tag or measure tree ferns and lianes with stems over 1.35 tall. They are recorded under Sapling Counts (see 4.2.3).
- Record the diameters of dead trees but do not tag them. When rot is obviously influencing the diameter, do not measure the tree.

- Record only trees rooted within the plot.
- In the few instances where stems are fused, estimate the tree diameter using the standard scale on the reverse side of the diameter tape.
- Tag, measure, and record any epiphytes rooted below breast height that are over the minimum diameter. Identify these by an "e" beside each on the recording sheet.

Extra information has been collected for some, or all, of the tagged trees on a plot for specific objectives. For example, in a study of changes in canopy condition in Westland rata-kamahi forest, defoliation of southern rata (*Metrosideros umbellata*) and Hall's totara (*Podocarpus hallii*) was scored for individual trees at 2-yearly intervals (Stewart 1992). Tree height is a useful additional parameter when studying changes in forest biomass (Goulding & Lawrence 1992).

4.2.3 Sapling counts

The sapling counts are the total count by species of all saplings (stems taller than 1.35 m but less than 3.0 cm dbhob, i.e., not tagged), tree ferns, and lianes for each of the 16 subplots comprising the 20 × 20 m plot. They are recorded after the tagged stems for each subplot on the Stem Diameter Sheet (Appendix 1).

4.2.4 Understorey subplots

Twenty-four understorey (seedling) subplots are measured on each 20 × 20 m plot. These subplots, which are circular with a radius of 49 cm and an area of 0.75 m^2, are located halfway between the intersection points of the tapes dividing the 20 × 20 m plot into 16 subplots (Fig. 1). The radius is measured from the base of the understorey subplot peg and follows the contour of the ground surface. The seedling data are recorded on the Understorey Subplot Sheet (Appendix 2).

- Mark each understorey subplot centre with a small aluminium peg stuck into the ground. Attach a strip of permolat to each peg. This strip should be numbered (1–24) to identify the understorey subplot (Fig. 2).
- Record separately all species occurring within each subplot. Records on the Understorey Subplot Sheet differ for a number of height classes. Record woody species less than 15 cm high by presence alone. For eqch woody species greater than 15 cm high, count and record the number of stems within each of the following height classes: 16–45 cm, 46–75 cm, 76–105 cm, 106–135 cm, and >145 cm (including any trees). For an example, see Appendix 2. Count a woody stem that forks visibly above or on the surface of the ground as one stem, but for a woody plant that forks below the ground surface count the number of stems present.

- Record fern, herbaceous, liane, and grass species by frequency (presence) in the height classes used for woody seedlings.

Seedlings on raised surfaces such as logs and tree-fern trunks present an additional sampling problem. As an addition to the basic method, Stewart & Burrows (1989) selected the two tree ferns >2 m tall nearest each understorey subplot for seedling counts. Seedlings on these tree-fern trunks were measured in height classes as for understorey subplots.

4.3 REMEASURING PLOTS

Based on experience in a range of forest types, a 5–10 year period is generally suitable for revealing change within forest vegetation. When gaps in the canopy occur, e.g., as the result of snow-break, a response by the understorey is often seen within 2–3 years, but in some stable stands there will be little change in structure and composition over longer periods. However, permanent plots in these stands require maintenance, e.g., to ensure that tree tags do not become overgrown. Where possible, the plots should be remeasured in the same order and in the same months as the previous measurements. The aerial photographs and topographical maps marked with the plot locations are needed for remeasurement (Appendix 3).

Access lines to plots should e remarked where they are difficult to follow or relocate. New plots or new lines should not be established when old ones cannot be relocated. Note as "not found" for that remeasurement.

Because plot layout has not been standardised in the past, it is necessary to check the layout of plots being remeasured before field work starts. Much of this information is being accumulated in the NIVS database held by Landcare Research. Differences may occur in:

- the number of understorey subplots and their size;
- the placement of understorey subplots;
- the labelling of subplots;
- the orientation of the plot.

To provide continuity of data, plots should be remeasured as first established, then the standard plot layout should be superimposed. Four is the optimum number of people for remeasurement of a 20 × 20 m plot. For a list of equipment, see Appendix 3.

As for the establishment of a 20 × 20 m plot, 10 tapes should be used to mark out the plot perimeter and to divide it into 16 subplots (Fig. 1). Aluminium corner pegs and permolat used to mark the plot corners should be replaced where required. A lightweight metal detector can be used to find plot and understorey subplot pegs in a dense herbaceous layer.

4.3.1 Identification information

The plot identification information is recorded as before, on the top right-hand corner of the sheets.

4.3.2 Tree diameter measurements

The diameters are measured as before, and recorded on Stem Diameter Sheets. It is useful to have a photocopy of the previous measurements to check that species are identified correctly and that all tagged trees are remeasured. Hall (in prep.) describes computer-generated printouts for recording data and checking previous measurements. Where plots have already been measured more than once, a list of individual trees to be checked can be drawn up, based on error checks of the data.

- Tag and measure all trees with a dbhob greater than 3.0 cm not previously recorded. Where the diameter is just over 3.0 cm, write “Ingrowth” in the diameter column, with the diameter. Where it is obvious that the tree was missed during the previous measurement, write “Missed” in the diameter column, with the diameter.
- Note dead trees by putting an asterisk in the diameter column. The diameters of the dead trees are measured and recorded if no obvious shrinkage or rot has taken place. When a tree has been recorded as dead, the tag is removed and no further record of that tree is kept.
- If a tag has become overgrown, relocate it at the same height on the stem. If a tag is replaced, it is preferable that the new tag has the same number.

4.3.3 Sapling counts

All saplings are counted and recorded as described before.

4.3.4 Understorey subplots

The understorey subplots are remeasured as before and recorded on an Understorey Subplot Sheet. Replace missing understorey pegs according to the standard plot layout, and note beside the understorey subplot number as “Replaced”.

5. DATA STORAGE

Systematic storage of the various types of data collected is important. It may be many years before the data are looked at again, very likely by a different group of people. Information on datasets should be recorded, including sample design, plot locations, and any departures from the standard method. This information should be stored as a computer text file along with any data files developed for subsequent analyses. It is recommended that a copy of any data is lodged with the NIVS database held by Landcare Research, Christchurch.

5.1 PLOT SHEETS

Plot sheets are boxed or stored in ring-binder folders and are stored in ascending order by plot number. The area and year of survey are written on the folder back. The sheets are also microfilmed and stored in a fireproof room for extra security.

5.2 MAPS AND AERIAL PHOTOGRAPHS

Maps containing plot locations can be stored in a map cabinet. Each map is fitted with a file mount and hung in the cabinet. Maps for one survey area are grouped and the survey area is recorded on the map mount. Some of the NIVS database plot-location information is now being stored as part of a Geographic Information System.

Aerial photographs are stored in a filing cabinet, with all the photographs for one survey grouped together.

6. ACKNOWLDEGEMENTS

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8. APPENDICES

APPENDIX 1 : Understorey subplot sheet

UNDERSTOREY SUBPLOT SHEET

SURVEY Fiordland.
AREA Worsley River
PLOT No. Line 14 Plot 5

MEASURED BY L.E.B.
RECORDED BY D.E.C.
DATE 13/1/76

Subplot No.	SPECIES	< 15	16 - 45	46 - 75	76 - 105	106 - 135	> 135
1	POL ves	✓					
	BLE cap	✓					
2	POL ves	✓					
3	BLE dis	✓					
	PSE col			2			
	POL ves	✓					
	BLE cap	✓					
	COP ast					1	
	NOT men						1
	PSE sim	✓					
4	BLE dis	✓					
	BLE cap	✓					
5	PSE sim	✓	1				
	BLE cap	✓					
	CYA col	✓		✓			
	COP ast			1			
	MYR div		1				
6	BLE cap	✓					
	GRI lit	✓					
	PSE sim	✓	1				
	NOT men	✓	1				
	COP foe	✓					
7	BLE dis	✓					
	PSE col				1		
	CYA col	✓					
	COP ast			1			
8	CYA col	✓					
	BLE cap	✓					
9	MYR div	✓	1				
	BLE dis	✓	✓				
	PSE cra	✓					
10	BLE cap	✓					
	MYR div	✓	1		3		
11	NOT men	✓					1
	BLE cap	✓					
	COP foe	✓					
	RUB cis	✓					
	GRI lit	✓					
12	NOT men						1
	BLE dis	✓					
	BLE cap	✓					
13	BLE dis	✓					
	PSE col			1		1	
	BLE cap	✓					
	MYR div	✓					

Subplot No.	SPECIES	< 15	16 - 45	46 - 75	76 - 105	106 - 135	> 135
	GRI lit	✓					
14	BLE dis	✓					
	RUB cis	✓					
	BLE cap	✓					
15	BLE dis	✓					
	BLE cap	✓					
	NOT men	✓					
16	RUB cis	✓					
	MYR div		1				
17	RUB cis	✓					
	BLE cap	✓					
	BLE dis	✓					
	MYR div		1			1	
	COP foe					1	
18	PSE col					1	
	CYA col	✓					
	BLE dis	✓					
19	BLE cap	✓					
	BLE dis		✓				
	COP ast	✓					
	PSE sim	✓					
	CYA col	✓					
20	NOT men	✓					
	BLE dis	✓					
21	COP ast	✓					
	BLE dis	✓					
	BLE cap	✓					
	CYA col	✓					
	BLE flu	✓					
	NOT men	✓					
	MYR div	✓					
22	BLE flu	✓					
	MYR div	✓					
	COP ast	✓					
23	BLE flu	✓					
	BLE cap	✓					
	NOT men					1	
	COP ast		1				
	MYR div	✓					
24	BLE cap	✓					

APPENDIX 2 : Stem diameter sheet

STEM DIAMETER SHEET

SURVEY Fiordland
AREA Worsley River
PLOT No. Line 14 Plot 5

MEASURED BY D.E.C.
RECORDED BY L.E.B.
DATE 13/1/76

SUBPLOT	SPECIES	TAG No.	DIAMETER
A	NOT men	954	22·0
B	"	55	9·5
	MYR div	56	4·5
	NOT men	57	11·9
C	PSE col	58	4·9
	"	2>135<3·0 dbhob	
D	MYR div	59	5·4
	PSE col	60	5·6
	MYR div	61	5·7
	PSE col	62	3·7
	"	63	2·7
	"	64	4·2
	COP ast	65	2·8
E	MYR div	66	7·0
	NOT men	67	52·1
	MYR div	68	7·3
	NOT men	69	14·4
	"	70	16·2
F	"	71	11·6
	"	72	7·7
	"	73	6·8
	PSE col	74	9·2
	COP rha	1>135<3·0 dbh	
G	NOT men	75	43·6
	PSE col	2>135<3·0 dbh	
H	NOT men	76	29·2
	"	77	8·3
	GRI lit(e)	78	4·1
	NOT men	79	9·7
	"	80	22·0
	"	81	6·8
I	"	82	7·0
	MYR div	83	3·3
	NOT men	84	8·4
	PSE col	85	3·1
	ELE hoo	1>135<3·0 dbh	
J	NOT men	86	3·3
	PSE col	87	3·5
	PSE sim	88	6·3
	PSE col	89	3·4
	"	90	2·6
	"	91	6·2
	FUC exc	92	5·3
	NOT men	93	10·9
	"	94	10·8

SUBPLOT	SPECIES	TAG No.	DIAMETER
J cont.	PSE col	995	3·6
	COP ast	1>135<3·0 dbh	
K	NOT men	96	29·0
	"	97	26·2
	"	98	74·7
L	"	99	17·2
	"	1000	26·4
	"	01	19·4
M	"	02	14·3
	"	03	12·8
	"	04	13·5
	"	05	21·5
	"	06	10·0
N	PSE col(e)	07	2·8
	NOT men	08	13·7
	"	09	27·3
	"	10	12·6
O	"	11	14·8
	"	12	13·9
P	"	13	14·2
	"	14	14·9
	"	15	35·0
	"	16	9·7
	"	17	12·5
	"	18	13·2
	"	19	14·4

APPENDIX 3 : Equipment List

This list specifies the equipment needed for establishment of 20 × 20-m plot. Spares should be carried in case of loss or breakage.

- Topographical map
- Aerial photograph
- Pen and pencil
- Stem diameter sheet
- Understorey subplot sheet
- Aluminium pegs (large; 45 × 0.7 cm)
- Aluminium pegs (small; 30 × 0.5 cm)
- 20-m tapes
- 20-m nylon cord
- Diameter tape
- 49-cm nylon cord
- 2-m steel tape
- Hammer
- “Cruising” tags
- Nails
- Flagging (“permolat”)