Two Permanent Plot Methods For Monitoring Changes In Grasslands: A Field Manual

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Landcare Research Contract Report: LC

PREPARED FOR:
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P.O. Box 10-420 Wellington
DATE: April 1997

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SUMMARY

Close to sixty percent of New Zealand's vegetation is grassland or a mosaic of grassland and shrubland. Much of the less modified grasslands has high conservation values (e.g., alpine tussock grasslands, red tussock wetlands). To protect these values requires knowledge of grassland structure and composition as well as how these are changing. The use of permanent sample plots is recognised as an effective way to monitor such change. This manual describes two methods widely used to monitor grassland vegetation on New Zealand's Conservation estate. The Wraight 20 x 20 m quadrat involves collecting plant species frequency data from a series of subquadrats, assessing species cover at eight randomly selected locations, and measuring stature and density of the dominant tussock species on the plot. The Scott height-frequency transect involves collecting plant species frequency data over a range of height tiers from a series of subquadrats along a 50 m transect. Applications of the two methods are discussed and standard data collecting protocols are outlined. Methods for summarising and analysing data are outlined.

Keywords: conservation, environmental monitoring, grassland, inventory, permanent sample plots

1. INTRODUCTION

1.1. Monitoring grasslands

Why have a manual on grassland monitoring? Between fifty and sixty percent of New Zealand's vegetation is grassland or a grass/shrub mosaic (Blaschke *et al.* 1981, Daly 1990). This ranges from alpine tussock grasslands dominated by snow tussocks *(Chionochloa* spp.) to pastoral lands at lower altitudes dominated by introduced grasses such as browntop *(Agrostis capillaris)* and sweet vernal *(Anthoxanthum odoratum)* (Daly 1990, Wardle 1991). Some grasslands occupy sites where environmental conditions naturally preclude tree or shrub growth (e.g., alpine and wetland areas); others were induced after podocarp or beech forests were burnt by Polynesians from 1000 to 500 years b.p. (Molloy *et al.* 1963) and by European settlers in the last 150 years. Some induced grasslands are maintained because grazing or burning prevents their reversion to shrubland or forest. Conservation management issues differ between grassland types. Feral animal impacts and climate change are major concerns for alpine grasslands; retaining an open condition (for aesthetic or cultural reasons) while preventing invasive weed spread commands more attention for induced grasslands at lower elevations.

In grasslands, as for virtually all ecosystems, change is the rule rather than the exception. Long-term research and monitoring is important for understanding the direction, causes, and consequences of such change (Likens 1989, Craig 1989, Royal Society of New Zealand 1990). For conservation, monitoring is essential to provide concrete evidence that specific management actions are needed, to efficiently allocate management resources, to evaluate the results of different management regimes, and to modify management as required (White & Bratton 1980, 1981).

New Zealand has an invaluable network of permanent vegetation plots in grasslands and forests, many of which were established before 1970 (Forest Research Institute 1987, Stewart *et al.* 1989, Meurk & Buxton 1991, Hall *et al.* 1991). In recent years, however, research priorities have shifted to short-term projects largely because of government restructuring, funding shifts, and the increasing orientation to contract-based research (Stewart *et al.* 1989, Steven 1990). Changes in organisational structure have disrupted the continuity essential to long-term monitoring. At the same time there has been a call for increased environmental monitoring by government agencies and scientists (e.g., Ministry for the Environment 1989, 1990, Craig 1989, Royal Society of New Zealand 1990, New Zealand Ecological Society and New Zealand Society of Soil Science 1994), and statutory obligations to protect vegetation under the Wild Animal Control Act 1977, Conservation Act 1987 and Resource Management Act 1991 depend on resource monitoring. Monitoring requires repeated data collection at permanent, well-defined locations (Jongman *et al.* 1987). Approaches used on conservation lands have varied with the scope and objectives of different studies. Approaches used have included:

- aerial photography or satellite imagery to detect shifts between grassland and other vegetation types over time and to update maps of generalised vegetation categories (e.g.,Timmins et al. 1984).

- repeat photography to show changes in grassland condition or vegetation boundaries (e.g., Mark 1978, Roxburgh *et al.* 1988)
- mapping individual plant positions to determine vegetation transitions at specific points (e.g., Lough *et al.* 1987) and quantify survival and recruitment of individuals (e.g., Primack 1978).
- measuring individually tagged plants to study growth rates and reproduction (e.g., Sewell 1952, Payton & Mark 1979).
- permanently marked plots to quantitatively assess compositional change (e.g., Meurk 1982, Rose & Platt 1987, Scott *et al.* 1988).

This manual is a guide to grassland vegetation monitoring on conservation lands, and updates an earlier manual (Allen *et al.* 1983). The two methods outlined have also been used in other short-statured vegetation (e.g., alpine herbfields) and occasionally in shrublands (e.g., Dickinson *et al.* 1992). The Wraight 20 x 20 m quadrat method involves collecting plant species frequency data from a series of subquadrats, determining species cover at eight randomly selected locations, and measuring stature and density of the dominant tussock species. The Scott height-frequency transect method involves collecting plant species frequency data from a series of subquadrats along a 50 m transect. Data are collected from a range of height tiers to provide information on both structure and composition. Instructions for computer data entry, summary, and analysis will be provided in a companion manual (Hall, 1996).

1.2 Permanent plots in grasslands

Calder's belt transects, established at Arthur's Pass from 1931 to 1934, were the first permanently marked plots in conservation grass/shrublands (Cockayne & Calder 1932). From the 1940s to the mid 1980s catchment boards established permanent plots and exclosures in North Canterbury, Otago, and South Canterbury. The purpose of these plots was to determine consequences of burning, restriction of or retirement from grazing, oversowing, and topdressing on vegetation cover and erosion of pastoral leasehold land (Dick 1952, Scott *et al.* 1988, Meurk & Buxton 1991). Former catchment boards are now incorporated into the corresponding regional councils. Some of these plots continue to be monitored either by the regional councils themselves or through contracts with research agencies.

By far the greatest number of permanent grassland plots was established by the New Zealand Forest Service from 1955-56 to 1977-78. Some 3000 plots are distributed from Stewart Island to Hawkes Bay. Early efforts were motivated by a need to monitor the condition of forests and alpine grasslands and shrublands for watershed protection (Wraight 1962) and to comply with obligations to control feral animals under the Noxious Animals Act 1956. Impacts of introduced browsing mammals, then thought to accelerate erosion, were emphasised (Holloway 1969).

Early grassland plots crossed ecotones between eroded areas or screes and closed communities, and were established to help understand the erosion process. Later emphasis shifted to understanding vegetation composition and animal impacts across the range of alpine and montane grasslands where introduced animals occurred (Holloway 1969, Allen *et al.* 1983, Forest Research Institute 1987). Exclosures were used in conjunction with permanent plots in some areas (Stewart *et al.* 1989). Originally, plots were established and remeasured by the Forest and Range Experiment Station, Rangiora, which later became the Forest and Wildlands Ecosystems Division of the Forest Research Institute and is now incorporated into Landcare Research New Zealand Ltd. Forest Service Conservancies took responsibility for some monitoring from the mid 1970s (Hall *et al.* 1991). Some plots have never been remeasured, others have been remeasured as recently as 1990, but most have not been remeasured for at least 15 years. Initial findings were reported in numerous in-house reports. In 1985 the National Indigenous Vegetation Survey Database began to computerise, centralise and standardise the indigenous vegetation survey and permanent plot data collected by the Forest Service (Hall *et al.* 1991). The grassland permanent plot data are currently being incorporated.

In the early 1970s, the former Department of Lands and Survey began a vegetation monitoring programme for Crown Land Management Areas including South Island high-country pastoral lease land (see Webster 1994). Knight-Frank New Zealand Ltd. now maintains the programme as part of a contract to administer Crown pastoral leases. Over 1100 permanent plots have been established in 145 survey areas over a range of vegetation types. Many plots are on conservation lands that were grazed in the past. The primary goal is to determine vegetation response to retirement from grazing and various management regimes and activities. Methods used include quantitative vegetation sampling along permanently marked transects, stereophoto pairs, releves, and photopoints. Exclosures were established at some sites. Controlled agronomic field trials have been carried out as well.

Specific monitoring studies have been carried out by individuals associated with universities or government departments other than those described above, e.g., the former Botany and Grasslands Divisions of DSIR (now part of the new Crown Research Institutes), the Ministry of Agriculture and Fisheries, and the National Water and Soil Conservation Organisation. Most such studies were initiated after 1970 (Meurk & Buxton 1991).

1.3 Monitoring issues

1.3.1 Existing permanent plots

The 3000+ permanent plots established in grasslands (Stewart *et al.* 1989, Meurk & Buxton 1991) are an invaluable resource for understanding change in grassland vegetation. In the current funding environment, initiation of new large-scale grassland monitoring programmes is unlikely; new monitoring will be limited to addressing specific problems (Steven 1990) or providing baseline data in unusual habitats where no permanent plots exist. As a consequence, existing permanent plots will form the bulk of the grassland monitoring network; opportunities to apply improved methods to new plots may be limited. A pressing issue is whether existing plots will be remeasured and maintained at all. If they are to be abandoned, this must be a conscious decision rather than an outcome arising by default.

1.3.2 New monitoring programmes

In new monitoring programmes, objectives need to be clearly stated from the outset (Stewart *et al.* 1989, Heal 1991, Allen 1993). Objectives may be narrow (e.g., relating to a specific question or management objective) or broad (e.g., to provide baseline data with the ability to detect changes from a wide range of sources such as climate change, pollution, land use and species introductions). Data gathered from a single locality will be of limited use in providing generalisations or in application to other areas (Austin 1981). Likewise, data gathered to satisfy very specific objectives may be inadequate for addressing new problems that arise. One solution is to complement intensive site-specific monitoring with more extensive, general-purpose monitoring undertaken less often (Heal 1991). For broad monitoring it must be kept in mind that uses to which one might want to apply these data may be impossible to anticipate at the time plots are established.

A second issue is whether there is long-term commitment to the project. Are financial resources sufficient for the project to attain its objectives? Lack of resources may result in plots never being remeasured, or in attempts being made to use inconclusive short-term data to represent long-term trends (Heal 1991, Scott *et al.* 1988).

Finally, comparability of the intended sampling method with methods applied previously in the region must be determined. If the data collected will satisfy the study objectives, we strongly urge the adoption of one of the methods described in this manual. As a practical consideration, there is extensive technical knowledge of these two methods, and computer programs are available for consistent data storage and analysis. Further, as aptly stated by Gauch (1982), "A small sacrifice in appropriateness may be amply repaid by gaining comparability with other studies and compatibility with other data bases."

1.3.3 Measuring the success of a monitoring programme

For conservation, a monitoring programme's success is best gauged by whether the findings are incorporated into actions that achieve management goals. This will depend on the ability of the information collected to detect ecosystem change, unforeseen management problems, and the consequences of management actions, and how effectively results are communicated and incorporated into management plans. It is important that results be effectively communicated via management reports, scientific and popular articles, conferences, etc.

1.4 Examples of studies using permanent plots

1.4.1 Assessing animal impacts on vegetation

In the early 1900s, red deer *(Cervus elaphus)* were introduced into northern Fiordland for recreational hunting, and by the 1950s and 1960s were recognised to be strongly modifying the alpine grasslands. Rose & Platt (1987) used 57 permanent plots established in 1969 (when deer numbers were high), remeasured in 1975 (soon after commercial hunting began) and again in 1984 (after 11 years of intensive hunting), to examine alpine grassland recovery. Grasslands on fertile soils were most heavily affected by deer but also showed the most dramatic recovery. Collection of deer pellet data enhanced the ability to assess animal use of the plots.

1.4.2 Determining long-term trends in exotic weeds

Invasion by exotic weeds is a serious threat to many New Zealand ecosystems; invasion of tussock grasslands by *Hieracium* spp. is widely recognised as a threat both to conservation values and to sustained pastoral use. Composition and ground cover data collected on seven permanent transects in the central Waimakariri Basin, on five occasions, from 1956 to 1993 allowed Scott (1993) to document the early establishment and expansion phases of *Hieracium,* and to determine relationships among the rate of change of*Hieracium,* ground, and principal species cover.

1.4.3 Quantifying changes in soil erosion

To determine trends in erosion rates, Whitehouse *et al.* (1988) examined changes in bare ground on permanent plots established in unimproved montane grasslands of the Waimakariri Basin. No consistent trends in percentage bare ground were observed, although significant changes had occurred on individual sites or between specific remeasurement periods.

1.4.4 Evaluating vegetation after disturbance

In 1974 road building destroyed adjacent plant cover in an alpine area of the Old Man Range. After road construction was completed, nine transects were established across the disturbed area and continuing through intact vegetation. Transects were remeasured in 1976, 1977, 1978 and 1986 (Roxburgh *et al.* 1988). Over the 11-year period species composition in the undisturbed area showed little change, while in the disturbed area it changed markedly. By 1986 most of the dominant species in the undisturbed vegetation had re-appeared in the disturbed vegetation, although in the disturbed area total vegetation cover was less (34% *vs* 59%) and overall species composition was different.

1.4.5 Determining impact of excluding browsers

Animal exclosures have been erected to quantify animal impacts in a range of habitats. In the montane-subalpine grassland of the central North Island's Kaimanawa Mountains, the desire to protect a herd of feral horses as well as conservation values created a management conflict. Permanent plots in a grassland exclosure and control area, and a network of permanent plots over the area, allowed Rogers (1991) to assess horse impacts on vegetation. In particular, the exclosures allowed grazing preferences, grazing impact on seedling recruitment and short-term effects on vegetation of release from grazing to be determined (Rogers 1991).

Describing compositional variation

Using data collected from 43 subjectively located permanent sample plots, Wraight (1960) described ten alpine grassland communities from the Hokitika River catchment. Distinctiveness of three communities appeared to result from heavy grazing by deer, chamois, or hares. Wraight considered vegetation on greywacke to be more prone to erosion than vegetation on schist.

1.4.6 Understanding causes of change in insect abundance

Permanent vegetation plots existed on some of the sites chosen for comparisons of endemic moth fauna abundance in 1961-63 and in 1987-89 (White 1991). A general collapse in populations of common moth species was observed over time, browntop *(Agrostis capillaris)* had become increasingly dominant, and many indigenous plant species had declined in abundance. The common moths feed on a range of plant species and it was suggested that their decline could have resulted from the increased foraging time required to locate their respective food plants.

1.5 Other uses of permanent plots

- Rare plant monitoring in a vegetation context. Rare plant monitoring usually follows individual species (e.g., Palmer 1987, Lee 1990), but trends in associated species and communities may relate to or influence trends in the species of concern (Bradshaw & Doody 1978, Given 1989).
- Determination of optimal disturbance levels for retention of desired species and communities (Wardle 1989).
- Quantification of visitor impacts, particularly trampling (e.g., Hall & Kuss 1989).
- Providing context for study of long-term trends in biophysical processes or other groups of organisms and the interactions between them (i.e., 'multi-media' monitoring *sensu* Heal 1991).
- Quantification of progress in areas being restored, to determine the need for further intervention (Atkinson 1988).

2. VEGETATION SAMPLING DESIGN

Before establishing a new grassland monitoring programme, the appropriate agencies and individuals (see Introduction) should be contacted to ensure that no permanent plots exist in the area that could serve the intended purpose. When setting up a new study using either of the two plot methods one must also decide 1) how to locate sample plots and 2) how many sample plots are required. To make these decisions usually requires site reconnaissance or a pilot study. While specifics will depend on your objectives, some basic principles apply to most situations.

2.1 Plot location

When deciding how plots are to be located you must consider (1) how to adequately represent both dominant and rare species, communities and combinations of environmental conditions; (2) minimising observer bias, e.g., choosing sites with high species diversity, 3) assumptions of statistical analyses that you plan to use; and (4) practical considerations, such as time available (Gauch 1982, Jongman *et al.* 1987, Økland 1990). The four approaches used to determine plot locations are random, regular, stratified random, and subjective. Each approach has different strengths and weaknesses relative to the considerations above and different approaches may be combined in a given study.

For random sampling, plot locations must be determined before field sampling begins, typically by using random numbers to select locations on a coordinate system laid over a map or aerial photo of the study area. Random sampling allows the use of inferential statistics and prevents systematic bias in sampling. However, rare species and communities will tend to be missed, and locating preselected plot positions in the field can be difficult, if not impossible. In most contexts the disadvantages of strict random sampling outweigh the advantages (Gauch 1982, Økland 1990).

Regular or systematic sampling involves positioning plots systematically on a grid or along a transect. This is a good approach for understanding spatial pattern, variation within communities, and responses to obvious environmental gradients (Gauch 1982). Plot location in the field is straightforward. However, rare communities will tend to be missed, as with random sampling.

Stratified or restricted random sampling may entail either random sampling within randomly located blocks or transects, or random sampling within blocks predefined on criteria such as the desire to sample the range of combinations of the major environmental gradients (e.g., altitude, slope, bedrock type) within the study area. To best define such blocks, some knowledge of vegetation-environment relationships in the region is necessary, and this may be based on either previous studies or reconnaissance (Mueller-Dombois & Ellenberg 1974, Økland 1990). Sample numbers may be chosen in proportion to block area or more variable blocks may be sampled more intensively (Gauch 1982). In areas that are not homogenous, stratified sampling will produce more precise statistical estimates than either random or regular sampling, as rarer communities and environmental extremes will be sampled (Gauch 1982).

Using subjective (also called selective or preferential) sampling, plots are located according to whether they are perceived as typical, representative, undisturbed etc. This approach may require fewer samples to describe the compositional variation and plot location is convenient. Disadvantages are that sampling may reflect the observer's biases, statistical estimates are not valid, and findings cannot be extrapolated to the study area as a whole. However, these data are adequate for descriptive purposes (Gauch 1982). Other problems to be aware of when designing a sampling scheme, particularly to compare management treatments, are pseudoreplication and spatial autocorrelation (Hurlburt 1984, Legendre & Fortin 1989, Webster 1992).

Regardless of approach, in the field each plot should be located in relatively homogeneous vegetation (unless objectives dictate otherwise). If plots are not subjectively located, you must define consistent criteria for rejection of a nominal plot location before fieldwork begins. For example, in a study on unimproved grazing land, plot localities might be excluded where more than half the potential plot site is on a debris slide, or where sites have been recently oversown or topdressed.

Designs combining elements of random, subjective, and regular sampling that could be employed with either of the two plot methods are described below.

2.2 Sampling design examples:

The inventory design traditionally used with the Wraight 20 x 20 m quadrat method provides good coverage in mountainous areas. Random transect origins are selected by using NZMS 260 maps (1:50,000) and dividing the survey area into 1000 x 1000 m blocks, as indicated by the map grid. Using a random number chart, X and Y coordinates are determined to select a number of these squares, depending on sampling intensity. The transect origin is the nearest point on a forest/shrubland margin (or, in their absence, watercourse) from the centre of the square selected. The transect runs directly uphill to the nearest ridge top or upper vegetation limit, and is drawn on the map. If the origin falls on a watercourse, a coin toss decides whether the line should be on the valley's true right or left. If systematic sampling along this line is desired, the distance between plots is set by the desired plot density (see below). Typically plots have been sampled at 200 m altitudinal intervals, although subjective location along the lines was used in some surveys.

In difficult alpine terrain, randomly selected transect origins often were impractical. Lines were then distributed so as to cover the range of slope, aspect, altitude, physiography, geological types, etc., within the limits imposed by the terrain or by accessibility.

Some inventories employ both random and subjectively located plots. To determine the success of a boardwalk at minimising trampling damage to vegetation, Sutter *et al.* (1993) established 21 belt transects with randomly selected origins within a low heath community. They subjectively located six additional transects in areas suspected of receiving the most trampling. The randomly located transects allowed the authors to quantify trampling impacts on the community as a whole; the subjectively located transects allowed quantification of the most severe trampling impacts.

In small reserves few plots (often less than 10 per reserve) may be used for monitoring. Typically such plots have been located subjectively, often at sites suited to a particular objective, such as the desire to monitor the range of vegetation types present (e.g., Dickinson *et al.* 1992).

2.3 Sample plot numbers

The following issues should be considered when deciding on the number of sample plots (Gauch 1982, Økland 1990): (1) expected variation in vegetation and site conditions - the more variable the vegetation the more plots will be required; (2) plot placement method - subjective placement will require the fewest plots to monitor all vegetation types, and random placement will require the most; (3) required replication level of each vegetation type; (4) desired precision of results; and (5) budgeted resources and field time. Some reconnaissance before sampling will be required to address these issues. Sampling densities employed in selected grassland surveys are indicated in Table 1. Most published studies do not report the sampling density used and there are no commonly accepted guidelines. Geographic information systems have been used to evaluate sampling adequacy of past surveys and can aid in planning a sampling strategy (Neldner *et al.* 1995).

Table 1 Sampling intensities for selected grassland surveys.

Locality	Area (ha)	Density (no. plots/10^3 ha)	Reference
Hokitika	30 000	2	Wraight (1962)
Waimakariri	80 000	3	Wraight (1966)
Northern Fiordland	78 000	3	Evans(1972)

2.4 Marking permanent plots

Plots should be well marked so as to be easily and accurately relocated. Conspicuous markers aid relocation, but can attract disturbance by people and animals. In areas grazed by sheep, 10 mm steel reinforcing rod 50 cm long is a good option as it can penetrate hard, compacted ground and is not chewed by animals. 5 cm x 5 cm wooden stakes, angled aluminium standards, or waratah steel standards located 5 m from the plot origin or corner and protruding 0.8-1 m above the ground are more visible and aid relocation.

Animals liketo rub on them, however, so they should not be too close to the plot. In remote areas, 45 cm x 0.7 cm aluminium pegs are suitable, and lighter to carry. A rock cairn can serve the same function as wooden stakes. Coloured aluminium strips (i.e., "permolat") are not recommended for South Island alpine zones as they attract kea. Where plots are densely placed, the line and plot number should be written with a wide, UV-resistant, spirit-based felt-tipped pen on wooden stakes and carved or etched into both wooden and metal stakes. In areas at risk from vandals use inconspicuous markers.

3. THE TWO PERMANENT PLOT METHODS

This manual describes the two permanent plot methods generally used for monitoring grasslands on the Conservation estate. The first is the 20 x 20 m quadrat method initially developed by Wraight (1962) and later modified by G.R. Evans. Widely used by the former New Zealand Forest Service, it involves collecting frequency data with small sampling rings evenly spaced along a transect, cover data using stereophoto pairs or cover quadrats located at eight random points in the 20 x 20 m quadrat, and tussock stature measurements at these same points (Allen *et al.* 1983). The second is the Scott height-frequency method (Scott 1965, Dickinson *et al.* 1992) as used by the former DSIR and by university researchers. It entails collecting frequency data from different height tiers in small quadrats evenly spaced along a 50 m transect.

Both methods are repeatable, allow a quantitative assessment of species composition, can be applied to a range of low-statured vegetation types and overcome many limitations of point analysis, a method widely used in agronomic trials in grasslands (Wraight 1962, Scott 1965, Dickinson *et al.* 1992). Both methods rely heavily on frequency data (i.e., the number of occasions that a given species occurs in a series of quadrats) which is likely the most objective and repeatable measure of abundance. Frequency, however, confounds assessment of cover (i.e., the part of a sample plot covered by a particular plant species) with dispersion: a high-cover, clumped tussock species may have the same frequency as a low-cover, widely dispersed understorey herb (Økland 1990). Frequency data are also dependent on sampling frame size and shape. Depending on time constraints and study objectives, for both methods it may be desirable to collect supplementary data, e.g., on soil fertility, feral or domestic animal numbers and use, phenology, and insect populations.

3.1 Wraight 20 x 20 m quadrat method

Species frequency measurements provide the method's 'core' data. They overcome the problem encountered in monitoring grasslands that vegetation changes are difficult to quantify and often 'noisy' owing to (1) structural complexity, (2) phenological timing of remeasurement and (3) windiness. These frequency data provide a coarse measure of composition that is sensitive only to large changes; trends are less obscured by random variation than when more sensitive measures are used.

In situations where a rapid assessment of the vegetation is all that is needed, the frequency data alone can be collected. When more comprehensive information is required, the tussock stature or species cover measurements, or both, are good complements in detecting change. The tussock stature measurements allow a coarse assessment of structural change in the physiognomically dominant species. The method used to assess species cover is dictated by the vegetation height. Stereophoto pairs (Wimbush *et al.* 1967, Wells 1971) are suitable in vegetation less than half a metre tall. In taller grasslands they are inadequate, so cover is estimated in quadrats instead. The photographs are useful for presentations and visual displays of change, and provide accurate cover measures in low vegetation. Further, they allow vegetation change to be examined at a variety of scales within the quadrat photographed (e.g., individual plant, vegetation patch, area of ground). Cover estimates in quadrats provide more detailed information on floristic composition as species can be difficult to identify and ground species may be obscured in stereophotos. Further, in tall vegetation they overcome the problem of stereophotos that species height and cover are confounded.

Three or four experienced people can establish and measure one 20 X 20 m permanent plot in roughly 1-2 hours. Data are recorded on RECCE Description Sheets (Appendix 1), Species Frequency (A and B) Sheets (Appendix 2), Species Cover Estimate Sheets (Appendix 3), and Distance/Stature Measurement Sheets (Appendix 4), which are available from Landcare Research, Lincoln. Equipment required for establishing these plots is detailed in Appendix 5.

3.1.1 Plot layout

Plots are oriented so that two opposite sides are perpendicular to the contour (Fig. 1) and the plot origin is on the uphill side of the plot. Layout the plot as follows:

- Mark the plot origin with the appropriate metal peg (half protruding above ground). From the origin, run the 20 m centre tape (for measuring species frequency) downhill at 90 □ to the general contour. Pull the tape taut and permanently mark the 20 m point with a second peg. Temporarily secure the tape and mark the 10 m point with a permanent peg as well (Fig. 1a). To avoid trampling the sampling area, walk a few metres to the side of its intended position while running the tape out, and then pull the tape into the correct position from the bottom end.

  Lay out the remaining four tapes as shown in Fig. 1b, c. Tapes should run horizontally from corner A to B and D to C and downhill from corner A to D and B to C. Use a compass to help run tapes at right angles to one another, and pull the tapes taut. Double-check that the centre tape intersects the horizontal tapes at their 10 m points, the corners are located exactly 20 m apart, and the plot is square. You may need to make several adjustments to obtain the correct positions, but persevere - an exact layout will aid relocation of pegs. Permanently mark each corner with a large metal peg and temporarily secure the tape ends to the pegs.

- Remove one of the side tapes and use it to locate the centre pegs for the eight photocentres or cover quadrats. This is best done with two people holding the tape ends and one person locating the photocentres. The pegs have the same co-ordinates for all plots, and are most efficiently located in the order 71, 52, 22, 16, 28, 46, 67, 79 (Fig. 2). Insert a small aluminium peg (half protruding) at each coordinate. To help locate these pegs while measuring the plot, they can be made more conspicuous by spiking pieces of paper onto them (remove the paper before taking the stereophotos). Replace the side tape.
- Place a larger identifying stake (wooden or metal) or cairn 5 m directly above the plot origin (Fig. 1).

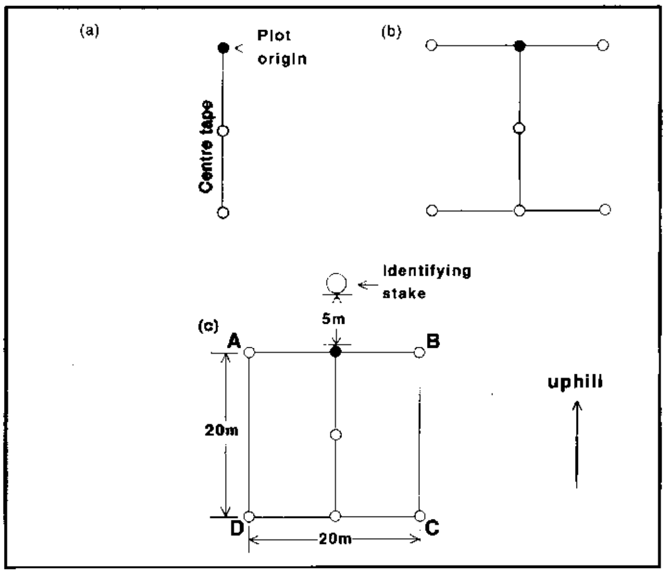

Figure 1 Steps for establishing a 20 x 20m plot. Note the orientation of the plot, side A-B is across the slope on the uphill side; side D-C is across the slope on the downhill side. Solid lines represent 20m tapes; aluminium pegs are indicated by circles.

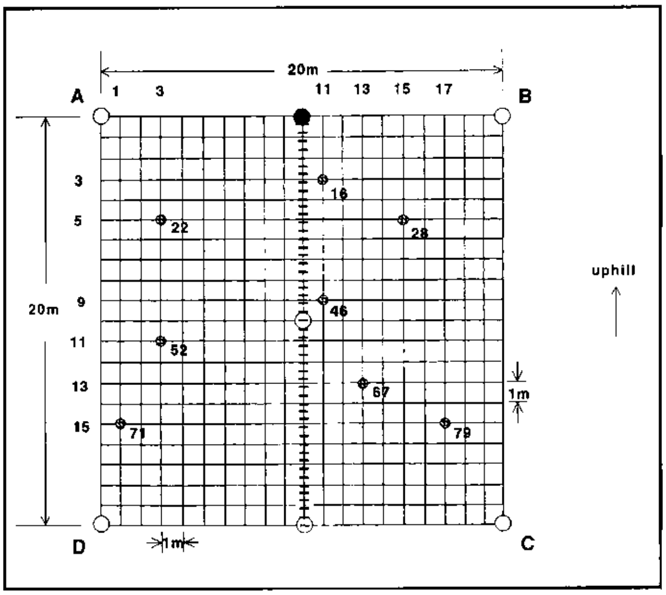

Figure 2 Location of pegs (small circles) on 20 x 20m plots for either photocentres or cover quadrats. Large circles represent large aluminium pegs marking the plot. Short dark lines along the centre line represent locations of 50 circular subquadrats comprising the specific frequency transect.

3.1.2 Plot measurement

Location information: Releves or reconnaissance descriptions (RECCEs -- Allen 1992) are made for both plot types. Plot location details are recorded on the RECCE Description Sheet (see Appendix 1 for an example of a completed sheet). Some of this information (indicated below with an asterisk) is also recorded on all other plot data sheets and on the white plaque used in stereophotos. If a feature is absent it should be recorded as 'Nil' since a blank implies that you omitted the measurement. Record the following information.

- Line*: line number as marked on the topographic map (does not apply to subjectively located plots).
- Plot*: plot number, as it occurs sequentially if along a transect line.
- Survey*: inventory name, e.g., Hokitika Survey.
- Catchment: the name of the catchment where the plot is located, e.g., Toaroha.
- Area: describe the approximate location of the plot, e.g., Squall Peak.
- Aerial photo no: aerial photograph series and number for the photograph on which the plot occurs, e.g., 3972/6.
- Date*: the date, in the format day, month, year (e.g., 30 Feb 95).
- Measured by*: name of the person taking the measurements.
- Recorded by*: name of the person recording the measurements.

- Location: note features that may aid future plot relocation. Include distinctive features of the plot and immediately adjacent areas, recording their approximate distances from the plot. If along a survey line, note features between this and the previous plot.
- Map coordinates: record these after the fieldwork is completed. For each plot, determine a grid reference using the NZMS 260 (metric) topographical map. Use the method described on the map to obtain a six-integer grid reference. Record the map sheet code (e.g., K34 for the Harper-Avoca) in front of the grid reference. Where there are fewer than four map sheet code characters, use zero as a place holder (thus S79 will become S079). The map co-ordinate for each plot will thus be 10 figures in alphanumeric format.
- Orientation: take a magnetic compass bearing to the nearest 5^0 facing up-slope along the centre tape or transect line. This bearing will be used to relocate the tape when plots are remeasured.
- Location Diagram: Sketch the plot position. The conventional orientation for this sketch is looking down-slope. Mark in any prominent landscape features, e.g., distinct community boundaries, erosion pavements, snow hollows, small slips, bluffs, guts, shrubs, and the location of any cairns built. Include an approximate scale and distance to landscape features shown. If relevant, show the plot's position relative to the survey line and its direction. Detail is essential here -- this and the location photos (described below) will be the chief guides for relocating the plot.

To aid plot relocation take two photographs, one from either end of the centre tape. Hold the camera at standing eye height and sight along the tape. Use colour slide film in a 35 mm single lens reflex camera fitted with a standard (50-55 mm) lens. For scale, insert a one metre stake graduated in 10 cm sections close to the tape centre point. Record site name, line and plot number, date and altitude on a small blackboard. One person should stand holding it so that it will be readable in the photograph. If practical, take a third photograph of the plot from a distance, showing plot position relative to recognisable local terrain features, cairns, etc.

Global Positioning Systems (GPS) work well in grasslands: with suitable equipment, position can be determined to within 1 m. This has good potential for aiding plot relocation and incorporating permanent plot data into Geographic Information Systems.

<u>Site characteristics and vegetation description</u>: RECCE descriptions also record site characteristics, species lists in height tiers and associated cover estimates and additional vegetation parameters (Appendix 1; Allen 1992). RECCEs are made for the area of the whole 20 x 20 m quadrat. Note that these RECCE plots have definite boundaries, and that height tiers are different from forests (Allen 1992). In the past, selected site characteristics for Wraight 20 x 20 m quadrats were entered on a plot description sheet; these are now incorporated into the RECCE description. Site characteristics considered necessary and included on RECCE descriptions are:

Altitude	Drainage	Soil Depth
Aspect	Standing canopy height	Surface characteristics
Slope	Cultural influences Browse	
Physiography	Birds	
Parent material	Ground Cover	

RECCE descriptions moreover provide information on total vegetation composition for the area, broken down into height tiers, and will be especially useful in areas where succession may lead to major changes in dominant species, e.g., conversion of a grassland into a woodland or shrubland. For further instruction consult Allen (1992).

Species frequency transect: The central transect is made up of 50 circular subquadrats (Fig. 2), each delineated by a 15 cm internal diameter steel ring (Fig. 3). These subquadrats are centred at 40 cm intervals (i.e., 40 cm, 80 cm, 120 cm ... 2000 cm) along the tape, starting at the top end (the 10 m, 0.4 m co-ordinate - see Fig. 2) and are positioned perpendicular to the tape. Sequentially record the first 25 subquadrats on the Species Frequency A plot sheet (Appendix 2), beginning in the first column headed "40". Record the following 25 subquadrats on the Species Frequency B plot sheet beginning in Column "1040". For each subquadrat record the following information.

Figure 3 Delineating a specific subplot using the 15-cm diameter steel wire ring.

- Cover. Lower a pencil or pen vertically at the centre of the ring and record the first thing hit by its point as follows (reproductive parts - e.g., seed heads, flower stalks - are excluded):

S	-	scree
V	-	live vegetative tissue (includes browned tissue still attached to the plant)
L	-	litter, i.e., dead detached plant material
BG	-	bare ground (topsoil or subsoil: particles < 2 mm in diameter)
EP	-	erosion pavement, where vegetation and soil have been removed to expose the subsoil and rock fragments.
BR	-	broken rock (deposited rock, e.g., talus, moraine).
R	-	rock that is part of the intact parent material, i.e., bedrock

Note: With litter (L) there are nearly always problems defining live versus dead vegetation; this distinction between attached and detached litter is an arbitrary convention. Litter and vegetation intercepts are often summed in the analysis. Note that dead leaf-tips of tussocks under this definition are recorded as 'live' vegetation. When large, partially buried boulders cannot be distinguished from bedrock, record as rock rather than broken rock.

- Rooted Inside Ring. Record all live plant species rooted, at least in part, within the 15 cm metal ring defining the subquadrat. Record species by abbreviation of their generic and specific names which must be unique for each species. Usually this is the first three letters of the genus (upper case) and the first three letters of the species (lower case), e.g., *Chionochloapattens* becomes "CHIpal" (see Hall 1992). Each species takes one row, with the species code written in the column corresponding to the first subquadrat in which it is encountered. Record occurrence in all subquadrats following the first with a tick in the appropriate column. Add new species down the rows.

  Where a species is unknown, collect a single specimen including as much of the vegetative and floral parts as practical. Clearly label with the provisional code used on the plot sheet, date, survey area, and line, plot and subquadrat numbers. For the short-term store in a plastic bag; if storing for longer, press the specimen in dry paper. When possible, collect the specimen from outside the ring subquadrat.

- Overhanging Ring. Record all species for which live vegetative tissue overhangs the 15 cm subquadrat in its vertical projection. Do not record in this category species that are rooted within the same subquadrat. For an example of a completed data sheet see Appendix 2.

Note: In windy conditions, stones can be used to hold the centre tape in position. Make sure ring remains centred while searching for species. When there are not enough rows on the plot sheet to record all the species, continue on another, similarly identified. Although often combined with rooted species in analysis, overhanging species should be recorded separately to avoid overlooking them.

Stereophotos: At each of the eight randomly located points within the plot, marked by short aluminium pegs, take a pair of colour slides. The equipment required to establish stereophoto points consists of a strong rigid aluminium-framed tripod (Fig. 4 & 5), a single lens reflex camera fitted with a 20 mm wide-angle lens well corrected for distortion and loaded with Kodachrome 25 ASA colour slide film, and an engraved plaque used to identify each photocentre. For transport the tripod can be broken down into its five parts, i.e., the square frame for mounting the camera, the three legs, and the perpendicular rod (stored inside one of the legs). Procedure:

- Assemble the tripod and adjust the legs to a length of about 1 m. Screw the loaded camera onto the sliding base plate. Attach the cable shutter release to the camera.
- At the first photocentre, position the tripod so the side with two legs is downhill. For stability, force the leg tips into the ground. Adjust as necessary so that the camera frame (and hence the film plane) is parallel to the slope and contour at the photocentre. The angle reading of the Abney level mounted on the frame should be the same as the slope (Fig. 4). Use the recessed level to ensure that the frame is not tilted from side to side. The aluminium rod projects in a perpendicular line from the frame. Adjust its length below the frame so that it touches the point where the photocentre peg enters the ground. Refine the adjustments to the tripod legs and the aluminium rod until both are correctly positioned.
- After the tripod has been fully adjusted (Fig. 5), fill in the white plaque used to identify the photopoint with a spirit-based felt tip pen. Record survey, area, line, plot, and date as before. Additional information required is as follows.

Figure 4 Camera frame with detachable tripod legs bolted on and camera in position for the first photograph. Before taking photographs, the perpendicular rod is removed from the field of view. The slope at the photocentre is read from the Abney level mounted on the side of the frame. The small level recessed in the frame is used to align the frame parallel to the contour.

Figure 5 Taking photograph with sterophoto tripod with the stereophoto tripod set-up.

Photocentre: the photocentre number (as in Fig. 2)
Ht. Perp. Rod: the length (to the nearest 0.5 cm) of the aluminium rod from where it touches the ground at the photocentre peg to the point where it emerges from the top of the camera frame.
Abney Angle/Slope: the slope (to the nearest degree) from the Abney level mounted on the camera frame.
Time: To the nearest 10 minutes, e.g., 13.10 hours.
Weather: Note weather conditions in relation to brightness e.g., overcast and dull.

- Secure the sliding camera mount in the RIGHT-hand position. Release the perpendicular rod and secure it up out of the field of view. Place the inscribed plaque within the field of view in a position where no detail is obscured. Adjust the camera to give the greatest depth of field possible. Avoid casting a shadow on the plot. Take the first slide, then move the sliding camera mount to the LEFT-hand mark and secure. Remove the plaque and take the second slide.
- Complete the cover quadrat estimates (if applicable) and distance/stature measurements (both described below) for this photocentre.
- Clean the plaque using isopropyl alcohol and a rag.
- Repeat the procedure for the remaining seven photocentres.

Note: Each slide covers about 1 m^2; the exact area depends on the final height of the tripod. Because the camera is moved in the sliding frame between photographs, there is a small area of non-overlap of images at the edges.

Record identifications (or make collections) for any species that will be difficult to identify in the photographs (e.g., where distinguishing key characters require a hand lens) on a Species Cover sheet (Appendix 3).

Wells (1971) describes a double camera apparatus enabling stereophoto pairs to be shot simultaneously. This overcomes problems associated with changing light conditions and wind gusts.

Fill-in flash may help to reduce shadow in sunlight.

Cover quadrats: When vegetation exceeds 0.5 m, make cover estimates in quadrats centred at the stereophoto points.

Within a 1 m x 1 m quadrat centred around each of the eight aluminium pegs, visually estimate cover of each species and record the appropriate cover class. Cover is defined as the proportion of ground area occupied by the vertical projection of the vegetative parts of all individuals of a species (Greig-Smith 1983). This is usually less than the total leaf area of the species, as leaves often overlap (Mueller-Dombois & Ellenberg 1974). Total cover of all species may exceed 100%. Cover classes are '1' (< 1%), '2' (1 - 5%), '3' (6 - 25%), '4' (26 - 50%), '5' (51 - 75%), and '6' (76 - 100%). A completed cover data sheet is shown in Appendix 3.

Distance and Stature Measurements: For the tussock species that is dominant in terms of ground cover on the plot, height, diameter, and nearest-neighbour distance are measured at each of the eight pegs. These measurements show relative abundance and stature, and they are sensitive only to gross changes. If there are no tussocks, do not measure other graminoids. Measure and record the following (to the nearest cm) on the Distance/Stature Measurements sheets (Appendix 4).

- **Survey, line, plot, date, cover peg, ht. perp. rod,** and **Abney angle/slope** (the last two are recorded as 'N/A' if a cover quadrat was examined).
- **Species:** the physiognomically dominant tussock species on the 20 x 20 m quadrat. The dominant species is assessed for all eight measurement points, even if it is not the local dominant at any one point.
- **DIST 1**: the horizontal distance from the photocentre peg to the centre of the base of the nearest tussock (Tussock 1, Fig. 6). To determine the tussock centre, imagine two axes going across and perpendicular to the slope: the first connects opposite sides of the tussock and bisects the tussock base; the second bisects the first at 90^0. The tussock

centre is the intersection of these two lines.

- **HT 1:** the distance from the tussock centre at ground level to the leaf-tip (including tip die-back). This must be measured immediately adjacent to the tussock crown at ground level. Measure at 90^0 to the slope; pull the tiller taut along this axis and record maximum extended tiller length, not standing height (Fig. 7).
- **DIAM 1:** the tussock base diameter. Record the average length of the two axes (diameters) used to determine the tussock centre.
- **DIST 2:** the horizontal distance from the centre of Tussock 1 to the centre of the nearest conspecific neighbour (Tussock 2).
- **HT 2:** as for Tussock 1.
- **DIAM 2:** as for Tussock 1.

Note: As a convention, tussock fragments separated by less than 1 cm at the base can be considered part of the same individual.

Distinguishing individual tussocks is usually possible only in stands having less than 50% tussock canopy cover (Rose & Platt 1990). Measure distance and diameter only if individuals are distinguishable; otherwise enter 'n.d.' in those columns, and enter the maximum extended leaf length of the nearest patch to the photocentre point. Where the dominant tussock forms a mat, (e.g., *Chionochloa oreophila,* write "mat" in the distance column and record cover peg number, species, height, and slope only.

Do not measure the same tussock from more than one of the eight points. If a tussock fits the selection criteria but has been measured already, note this in the row beside the appropriate cover peg number.

Before leaving the plot, thoroughly check all data sheets to ensure that there are no errors or omissions in the data and that the writing is legible.

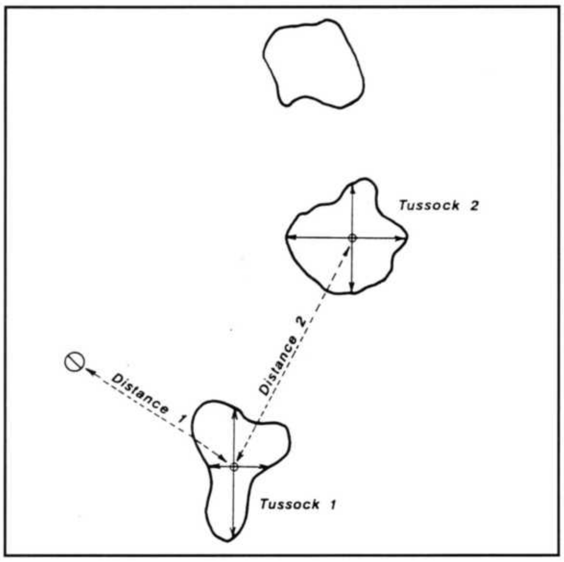

Figure 6 Tussock distance/stature measurements, showing nearest tussock (Tl), nearest neighbour (T2) and the bases of adjacent tussocks.

Figure 7 Measuring the extended tiller length (height) of a tussock.

3.1.3 Summarising data

Species frequency transects: The package PC-TRANSECT allows entry, checking and analysis of species frequency data. This package allows plots to be classified into communities, and provides summaries of species frequency and environmental data by community or other plot groups of interest (e.g., Rose & Platt 1987). Moreover, it writes data in formats compatible with other community analysis packages such as CANOCO (ter Braak l987).

Cover quadrat data: Cover quadrat data can either be analysed at the quadrat scale, or summarised to provide mean cover values across the entire 20 x 20 m plot. Cover class scores are converted to the mean cover value of that class i.e., '1'D0.5%, '2'D3.0%, '3'D15.0%, '4'D37.5%, '5'D62.5%, '6'D87.5%. These values are averaged by species.

Stereophoto pairs: In the past, stereophoto data were summarised after fieldwork was completed. The high degree of variation between observers in these summaries, however, suggests that to quantify change one observer (or team of observers) should summarise all the stereophotos taken at different times from a given plot at once.

A full point-analysis by species (Allen *et al.* 1983) is very time-consuming, and may not be required to meet some study objectives. Analysis of bare ground and vegetation categories may be enough. A rapid, subjective approach is described here, following Rose & Platt (1987). If your objectives require a full point-analysis by species, see Allen *et al.* (1983) or contact Landcare Research for advice.

- Using a slide projector, project a single transparency and adjust the image size so that the diagonal length is 66 cm.
- Visually estimate percentage cover for each vegetation category (see below) and record the appropriate cover class (see p.). Use reference cards showing the area parameters of each class to improve the accuracy of cover estimates.
- Where categories are difficult to determine from projected slides, examine slides using a stereoscope or a stereo image projected on a light table (Wimbush *et al.* 1967, Wells 1971, Allen *et al.* 1983) for clarification.
- Compare slides from initial surveys and resurveys directly, using two slide projectors. This allows you to see if the areas photographed match or if cropping is needed. To add a conservative bias, use two or more observers and require consensus among them to change the cover score of a vegetation category between surveys.

Examples of Vegetation Categories: In their study of grassland recovery in northern Fiordland, Rose & Platt (1987) used the following categories:

Tussocks: mostly *Chionochloa* species, but including tall sedges or rushes;
Celmisia: visually conspicuous and other readily identifiable species of this genus;
Dicots: the large-leaved dicotyledonous herbs (except *Celmisia* spp.);
Shrubs: woody shrub species;
Mat: low-growing inter-tussock species, including bryophytes; (many cannot be distinguished or identified).

Litter: dead plant material unattached to living plants;
Bare: bare soil or rock.

In his study of feral horse impacts in the Kaimanawa Mountains, Rogers (1991) used shrubs, mat, bare, and litter categories as above and added as individual categories red tussock, *Chionochloa pallens,* hard tussock, *Poa colensoi, Rytidosperma setifolium, Celmisia spectabilis,* and moss.

In a Canterbury tussock grassland study, Whitehouse *et al.* (1988) examined changes in the proportion of bare ground.

Distance and stature data: Tussock distance and stature data can provide information on tussock stature and density. Data are best summarised by community type or plot groups, as this provides sufficient sample size for robust parameter estimation. The most straightforward approach to examining stature is to average the height measurements and diameter measurements (both are measured 16 times in a plot) so as to allow comparison of different community types at a given time, or groups of plots over time.

Distance measurements can be used to calculate tussock density. Again, density should be calculated by community type or for plot groups using distance measurements from a total of at least 30 points. The simplest calculations are based on either the point-to-nearest-tussock distances (Distance 1) or the tussock-to-nearest-neighbour distances (Distance 2); see Mueller-Dombois & Ellenberg (1974) or Greig-Smith (1983) for examples of calculations. Individual tussocks may be highly clumped, however, and these approaches will then underestimate total density (Mueller-Dombois & Ellenberg 1974, Greig-Smith 1983). Batcheler & Bell (1970) suggest a modification which uses the point-to-nearest-tussock distances to obtain an estimate of density assuming random distribution of individuals. A correction is then applied to this figure using the tussock-to-nearest-neighbour distances, which suggest the degree of clumping. Batcheler & Bell (1970) and Baddeley (1985) explain the required computations in detail.

3.2 Scott height-frequency method

The height-frequency method was designed to sample vertical structure and composition of tussock grasslands (Scott 1965). In unimproved grassland it has usually been employed as a non-permanent sampling method, e.g., to examine soil development and vegetation trends along a rainfall gradient (McIntosh *et al.* 1983), or to contrast vegetation and soils associated with two snow tussock species (Williams 1975). Most permanent plots were established in the central Otago region after the mid 1980s by university scientists or former DSIR (now Landcare Research) scientists (Meurk & Buxton 1991, Dickinson *et al.* 1992). The method has also been incorporated into existing monitoring schemes elsewhere (Rogers 1991, Webster 1994).

The strength of this approach is its ability to detect changes in vertical structure of vegetation and provide indirect biomass estimates (Scott 1965, Williams 1975). This is of particular use when assessing impacts of management expected to affect vegetation height (e.g., change in grazing regime, burning). It is more appropriate for higher-statured vegetation (>1 m) than the Wraight 20 x 20 m quadrat, and is more sensitive to subtle vegetation changes. A weakness is that the observer must make subjective decisions on the plant boundary locations in different height tiers (Scott 1965) which can be especially difficult in windy conditions. Height-frequency data take longer to collect than the frequency data from the Wraight 20 x 20 m quadrats, and may be most appropriate for more intensive monitoring at fewer sites rather than broad-scale monitoring. As the method provides only frequency data, quantitative assessment of vegetation change would be enhanced by collecting complementary data, e.g., stereophotos or cover estimates in quadrats centred on a subset of the sampling points as described for the Wraight 20 x 20 m quadrat method.

Two experienced people can establish and measure one permanent 50 m line in roughly 2 hours. Height-frequency data are recorded on Height-frequency Sheets (Appendix 6), available from Landcare Research (see footnote). Equipment required for establishing these plots is detailed in Appendix 5.

3.2.1 Plot layout

The sampling plot layout consists of a series of sample points on either a line transect or coordinates along two axes (Scott 1965). Typically points are sampled along 50 m lines; the number and orientation of lines is dictated by study objectives and survey design. Lay out the plot as follows:

- Mark the plot origin with the appropriate metal peg, half protruding above ground (see p. 00). The peg should exceed the vegetation in height. From the origin, run a tape to 50.2 m and place a second peg and stake at that point. Mark the 25.2 m position with a shorter metal stake to aid line relocation. To avoid trampling the sampling area, walk a few steps to the side of the intended line transect while running out the tape and pull it into the correct position from the end. Pull the tape taut and attach it securely to the stakes at canopy height.
- Place a long identifying stake (wooden or metal) 5 m directly above or below the plot origin.

3.2.2 Plot measurement

Location information, site characteristics and vegetation description: Record location information, site characteristics and vegetation description on the RECCE Description Sheet (Appendix 1) as described on p. 00. A RECCE is made for the area within 2.5 m of either side of the Scott height-frequency transect (a 5 m x 50 m plot). To aid plot relocation take two photographs, one from either end of the transect tape as described on p.

00.

Height frequency transect: The transect is made up of 100 sampling locations centred at 0.5 m intervals (i.e., 0.5 m, 1.0 m, 1.5 m ... 50 m) on the left edge of the tape as viewed from the origin stake.

Vegetation is sampled using a rod 2 m long marked at 5 cm intervals. A volume of 100 cm^3 is defined by two or three metal rings 5 cm in diameter attached to the rod to define a column or two pairs of horizontal pins to define an open box (Figs. 8 & 9; Bulloch 1973). Species are recorded according to which 5 cm height interval(s) of this volume they occur in. The number of height intervals examined at each sampling position is dictated by vegetation height; if the vegetation is 1 metre high then twenty 100 cm^3 volumes will be examined.

- At each sampling point, lower the rod through the vegetation until it touches the ground. Position the rod vertically (not perpendicular) to the slope (Fig. 8).
- For each species at each sampling point, record the 5 cm height intervals at which vegetative plant parts are included in the volume. If the plant intercepts only part of the interval, it is recorded as intercepting the whole interval (Fig. 9). Record the data for each species as shown in Appendix 6. Record species using unique 6 letter abbreviations of generic and specific names as described on p. 00. Where a species is unknown record and collect as described on p. 00. Record the dominant ground cover in the 5 cm volume at ground level using the categories defined on p. 00. If litter is more than 5 cm deep, record the height intervals that it occupies.
- If the dominant tussock on the transect is rooted in the ground-level volume, measure and record its maximum extended leaf length as described on p. 00.

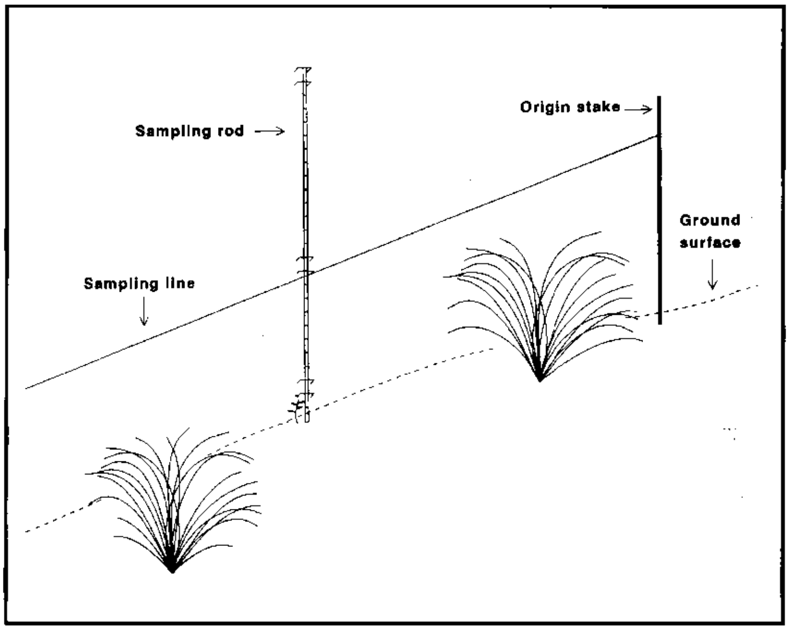

Figure 8 Sampling rod positioned vertically to record species occurrence in 5cm height intervals.

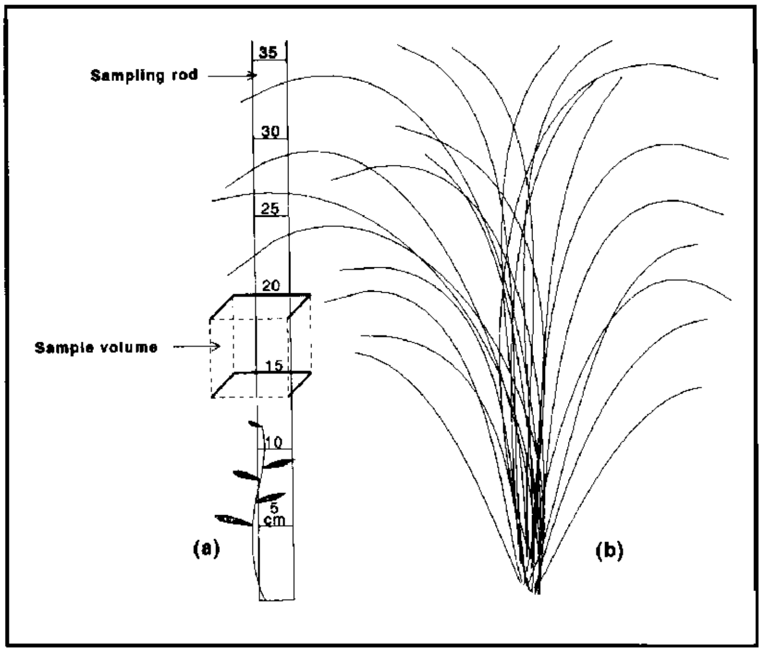

Figure 9 Recording height intervals. The small herb (a) occurs in 3 height intervals, and is

recorded as "0-15". The larger grass (b) intercepts the sampling volume over 3 intervals (recorded as 20-35), but not at ground level.

Note: Record the 5 cm height intervals of the taller-statured species first, determining them from a side view. Then these plants can be pushed aside to examine species closer to ground level. In windy conditions record species as occupying the height intervals that they would in the absence of wind. Make sure that the tape does not weigh the vegetation down.

Before leaving the plot, thoroughly check all data sheets to ensure that there are no errors or omissions in the data and that the writing is legible.

3.2.3 Summarising data

Data are summarised as follows.

- Tally the total number of sampling points in each layer in which the species occurs (Appendix 7). Calculate the frequency in a height interval as a percentage of the total number of sampling points. Calculate the total frequency in all height intervals to provide a single importance value for each species on the site at that time ('above ground biomass index of McIntosh *et al.* 1983 or 'summed height-frequency value' of Dickinson *et al.* 1992.)
- When more than one species occurs at a sample point in a given height interval, this frequency tally will overestimate the mass of individual species and the total mass of vegetation. Williams (1975) has modified the data summary approach to cope with this problem.

  Data collected from height-frequency transects are often displayed graphically, with histograms representing a vertical community profile (Scott 1965, McIntosh *et al.* 1983, Dickinson *et al.* 1992). Height classes are shown on the vertical axis. For each height class, the width of the bar along the horizontal axis is proportional to the frequency of the given species in that height class. The diagram represents the vegetation composition and structure, not the shape of plants (Scott 1965). See Fig. 10 for an example.

  The package PC-Transect (see p. 00) can be used on summarised data to classify plots into communities, summarise species frequency and environmental data by community or other plot groups of interest, and write data in formats compatible with other community analysis packages.

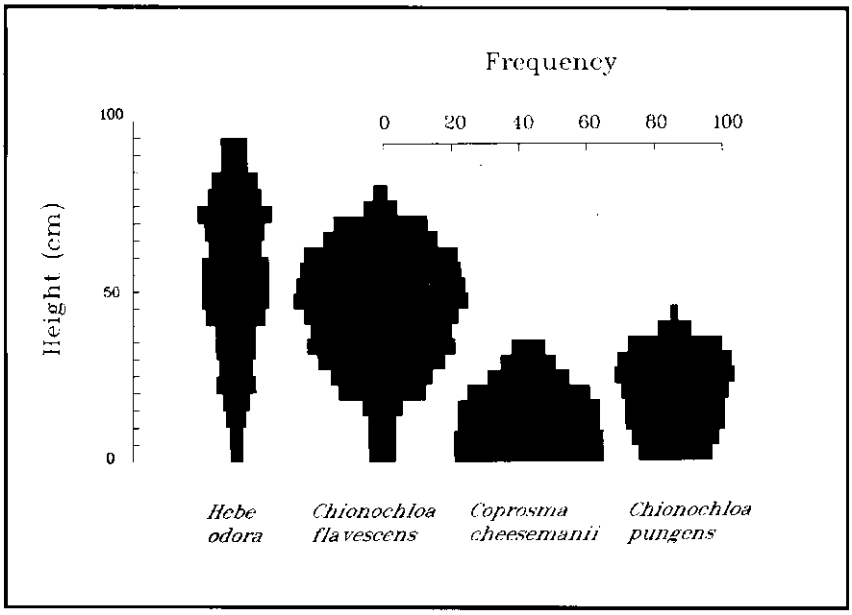

Figure 10 Height-frequency structure diagram. Frequency of an individual species 9horizontal axis) in a given height interval (vertical axis) is calculated as a percentage of the total number of samples taken at that height interval. (Data are from Appendix 8).

4. REMEASURING PLOTS

Resurveys are often prompted by management needs, and goals may differ from those of the original survey (Rose 1986). Finances may dictate that only a subset of plots are remeasured. Alternatively, extra plots may have to be established and/or supplementary data collected on existing plots to address the desired questions. Rose (1986) describes some considerations to address before resurvey. Rose & Platt (1987) describe one objective way of selecting subsets of plots to remeasure. Before their 1984 resurvey of northern Fiordland alpine grassland, they classified the original 174 plots into major grassland types using cluster analysis. Of these, 86 occurred within the subset of the area to be resurveyed, and 57 readily accessible plots encompassing the range of grassland types were chosen to remeasure.

Remeasurement intervals will depend on study objectives and grassland habitat type. For general-purpose monitoring, 5-10- year intervals should be enough, depending on the rate of vegetation change. Annual measurements may be desired in the initial years to establish the degree of year-to-year variation and the rate of change at a site (Scott *et al.* 1988). Typically, vegetation change will be slower in the alpine zone than in lowland grasslands. When studying management impacts, plots should be remeasured immediately before and after the management action. After that, annual remeasurement may be desirable for the first few years; later the remeasurement interval can be lengthened as appropriate. Green (1979) and Stewart-Oaten & Murdoch (1986) discuss considerations to address when monitoring impacts, management or otherwise. Vegetation damage by the persons doing the monitoring, however, may limit remeasurement frequency; annual monitoring may be too destructive (Dickinson 1992). Another consideration is that many statistical techniques for repeated measurements require the data to be collected at evenly spaced intervals. Permanent plots require maintenance (e.g., replacing marker pegs displaced by frost heave or animals, rebuilding marker cairns) as inadequately maintained plots may be impossible to relocate.

When a previously surveyed area is to be remeasured, determine the type, number, and distribution of plots previously established. Where possible, plots should be remeasured in the same order and month as when previously measured. Laminated print copies of the original plot location slides, aerial photographs, and topographical maps, all with the plot locations marked, and plot description sheets are needed to relocate plots. In some instances you will need to transcribe location data from Imperial to Metric maps.

Before fieldwork begins, observers should familiarise themselves with all species previously recorded on the plot. This is especially important if remeasurement intervals are long, and the observers have not measured the plot before. Changes in species names should be determined to ensure that data is collected using current nomenclature. It may be desirable to take photocopies of original plot data into the field.

When a line or plot has not been found after a very thorough search, do not establish a new line or plot as this can be confusing in the future; record the plot as 'lost'. 'Lost' plots have often been relocated during later surveys.

4.1 Wraight 20 x 20 m quadrat method

Most New Zealand Forest Service plots established since 1966 are standardised as in this manual and in Allen *et al.* (1983). However, before resurvey the layout and method previously used must be determined because a small change in method can cause a large change in results. Details of possible departures from standard methods can be obtained by contacting Landcare Research and by reference to original plot sheets and survey reports. Differences may occur in:

- species frequency transect length (pre 1970 transects may be 40 m long);
- species frequency data recorded in an uphill rather than a downhill direction;
- plot data may consist of species frequency measurements or stereophotos only;
- some plots do not have distance/stature measurements;
- on early surveys a 1 yd^2 area was mapped using a grid system (Wraight 1962);
- stereophotos may have been taken along the species frequency transect, and there may not be eight of them;
- lens focal length or film type for stereophotos may have been different than that recommended here;
- the height of the perpendicular rod in stereophotos was sometimes measured as the distance to the top of the photocentre peg, not to the point where the peg enters the ground.

The procedure for the plot's layout, measurement, and recording is essentially the same as that described for establishing permanent plots. For a list of required equipment, see Appendix 5. Copies of the Distance/Stature sheet and a summary of the aluminium rod lengths and Abney angles from all the photocentres are required in order to completely remeasure the permanent grassland plots. To provide data continuity on non-standard plots, the plot should be remeasured as established and then the standard methods outlined in this manual should be superimposed, where feasible. On the 1 yd^2 mapping plots, stereophoto points or cover quadrats should be established.

- Replace any missing aluminium pegs when the plot is laid out. Do this only after thoroughly searching for the missing pegs. A small portable metal detector is useful for locating pegs that have become buried.
- Complete a RECCE description. Certain plot characteristics will be unchanged from previous measurements (e.g., aspect, altitude), but others may have changed (e.g., soil characteristics, vegetation composition and cover).
- Collect species frequency data.
- Position the tripod and camera frame in the same position as was used for the original stereophoto pair. Double-check this by ensuring that (a) the length of aluminium rod projecting from the camera frame to the point where the photocentre peg enters the ground is the same as when originally measured, and (b) the frame is positioned so that the film plane in the camera back is again parallel to the slope, using the original Abney angle reading. Remember to fill out the white plaque and position it in the camera's field of view for the first slide. Use the same lens, film type, and processing as was used for previous surveys. Take print copies of earlier slides into the field to guide precise orientation of the field of view relative to fixed features e.g., bedrock, marker pegs, and enable accurate positioning of replacement pegs.
- For the distance/stature measurements, use the same species as were measured previously. Only when a species is no longer present on the plot should the new physiognomically dominant tussock be measured. Where there is a species change, note this on the top of the data sheet. Collect data as previously described.
- If the vegetation at the stereophoto points is over 0.5 m tall, establish a cover quadrat. If time permits, you also should take the stereophotos as this provides continuity if they have been taken on the plot in the past. When remeasuring cover quadrats take the previous measurement data into the field. The cover score for each species should be changed only if the change is readily apparent; this provides a conservative bias. Requiring agreement between two or more observers also helps to eliminate individualbias from change assessment.

4.2 Height-frequency transects

Not all plots established using the height-frequency method have followed the layout described here. When remeasuring any of these plots, contact the individuals who established them, or who know about the layout. In some localities monitoring may have been initiated, but the exact layout of transect lines may not have been permanently marked; in these circumstances permanent transect locations will have to be established (cf. Dickinson *et al.* 1992). The size and shape of the vertical column from which species occurrence is recorded varies between studies. As frequency data are dependent on quadrat size and shape, these must remain consistent in later resurveys. Generally, RECCE descriptions have not been made for these plots in the past, but should be done as a part of future remeasurements.

5. DATA STORAGE

A systematic approach to data storage is essential as it may be several years before these data are looked at again, very likely by different people. In a computer text file accompanying any data files, describe pertinent survey details such as sample design, plot locations, extra data collected, and departures from standard methods. It is recommended that a copy of any data be lodged with the NIVS database held by Landcare Research, Lincoln.

Store plot sheets in file boxes or ring-binder folders. Group plot sheets by type (i.e., species frequency transects, distance/stature measurements) and sequence by ascending line and/or plot numbers within each type. Label the back of the box or folder with the survey area, survey year, and line and plot numbers it contains. Plot sheets should be microfilmed and stored in a fireproof room for extra security.

All slides should be labelled with the survey year, survey area, line and/or plot number and stereophoto point number, as applicable. Store slides in purpose-built cabinets with slotted sliding drawers. Label each drawer with a list of the survey area, line and plot numbers, and survey years of the slides contained. Store the stereophoto pairs and the location slides in different drawers. Slides are arranged sequentially by ascending line, plot, and stereophoto point number. Slide cabinets are best located in a fireproof room with little dust, low humidity, and constantly cool temperatures.

Store maps containing line and/or plot locations in a map cabinet. Group plots for one survey area together, and record the survey area on the map mount. Some NIVS database plot-location information is also stored as part of a Geographic Information System, which allows easy production of maps showing plot locations.

Store aerial photos in a filing cabinet, with all those for one survey grouped together.

6. STATISTICAL ANALYSIS OF VEGETATION CHANGE

This summary briefly describes some statistical approaches that have been applied to examine vegetation change. The intent is to illustrate a range of analytical options; one should not embark on statistical analysis without a firm understanding of the technique, its assumptions, and its limitations. Consultation of available literature and a statistician is essential. Keep in mind that many statistical tests require independent samples; repeated measures on permanent sample plots are not independent and require particular statistics
(Hurlburt 1984).

6.1 Paired t-tests and repeated measures ANOVA

To analyse change in individual features of permanent plots (e.g., species richness, frequency or cover of a given species, *Chionochloa* height) between two measurement intervals a paired t-test, two-way analysis of variance (ANOVA) without replication, or the non-parametric Wilcoxon's signed-ranks test for paired data can be applied (Sokal & Rohlf 1981). Rogers (1991) used a paired t-test to compare species frequencies between 1982 and 1989 surveys in the Kaimanawa Range. An arcsine square root transformation (Sokal & Rohlf 1981) was applied to the frequency data to ensure a more normal distribution. Keep in mind that as cover is estimated, apparent change must be at least 20% before it can be assumed to represent change other than that caused by seasonal fluctuations or measurement error (Kennedy & Addison 1987).

To analyse change in similar parameters over three or more evenly spaced measurements, or to compare plots with different treatments over two or more measurements, repeated measures ANOVA can be used (Green 1993). Rose *et al.* (1995) used multivariate repeated measures ANOVA to compare frequencies of individual species in sets of plots with two different grazing histories, measured at 5-year intervals from 1975 to 1990.

6.2 Ordination and classification

Ordination and classification (see Jongman *et al.* 1987, Økland 1990) allow one to examine changes in total species composition. Indirect ordination (e.g., detrended correspondence analysis) arranges plots according to their similarity to one another; classification sorts plots into different community types. By simultaneously analysing data from the same set of plots measured at different times one can determine (a) whether the vegetation is on a net trajectory or (b) whether communities are persisting or changing (Austin 1977). Direct ordination (e.g., canonical correspondence analysis) analyses compositional data in terms of known environmental gradients. This approach can be used to show 1) how communities in specific environments have changed, or 2) how relationships between vegetation and environment change over time. Treskonova (1991) used the latter technique to examine change in tall tussock grasslands in the Mackenzie Country. Glenn-Lewin & van der Maarel (1992, pp. 38-39) review the use of ordination and classification methods to study vegetation change. Clarke (1993) describes the use of multidimensional scaling ordination in environmental monitoring.

6.3 Transition matrices

Transition matrices (van Hulst 1979) are used to predict how vegetation cover types will change. This information can then be used to predict future cover types. Vegetation cover types are classed into nominal categories (e.g., based on cover of dominant species) and the probability that one vegetation cover type will change to another (or remain the same) over a given time period is calculated. This technique requires that plots be measured at regular intervals, and requires large sample numbers to produce reliable probability estimates. Examples of transition matrices applied to alpine cushionfields may be found in Lough *et al.* (1987), Scott *et al.* (1988) and Roxburgh *et al.* (1988).

6.4 Time segment analysis

This approach is used to examine changes in specific attributes on a permanent plot (e.g., percent frequency of a species, species richness) by calculating the mean of that attribute and its rate of change per year (Scott 1993). It can be used to determine long-term trends. Plot measurements do not need to be at regular intervals or even similar time intervals. Scott (1993) illustrates this approach in examining changes in *Hieracium* cover in the Waimakiriri Basin over 35 years.

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8. APPENDICES

Appendix 1: Example of a RECCE Description Sheet

Line: nil	Elevation: 640	% V 80
Plot: T16	Aspect: 135°	% M 5
Survey: Glendhu	Slope: 28°	% L 15
Catchment: Tussock	Physiography face	% B 0
Area: nil	Parent material: schist	% R 0
Aerial Photo No: Not available	Soil Depth:	A: >50cm
Date (d/m/y): 16 / 2 / 93	Drainage: Good	B: "
Plot size: 20 m x 20m	Standing Canopy Ht: 0.75 m	C: "
Measured By: RBA	Cultural: Charcoal in soil	D: "
Recorded By: KHP	Birds: Fernbird	MID:

Surface characteristics:

Rock on surface ~~YES~~/NO	Bedrock on surface ~~YES~~/NO	Broken Rock % 0
Size of loose rock > 30 < nil	Description Moraine Talus nil	Soil % 0

Notes:

Exposure = 3

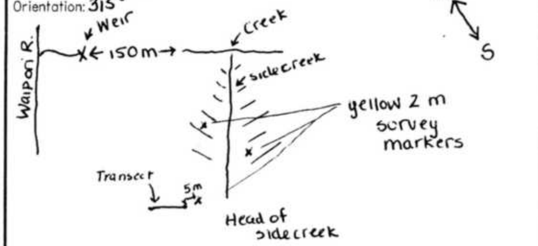
Topo = 3

2 – 5 m	1 – 2	0.3 – 1	0.1 – 0.3	< 0.1
	LEPsco 1	LEPsco 1	LEPsco 1	
	CHIrig 1	CHIrig 5	CHIrig 3	CHIrig 2
	CASlep 1	CASlep 2		
		COPcil 1	COPcil 1	
		ACIaur 2	ACIaur 1	ACIaur 1
			PERmac 4	PERmac 2
			LYCfas 2	LYCfas 1
			HELfil 2	HELfil 1
			HELbel 1	HELbel 1
			GENgri 1	GENgri 1
			UNCegm 1	UNCegm 1
			ACAans 2	ACAans 1
			AGRcap 3	AGRcap 2
			APObif 1	APObif 1
			BLEpen 3	BLEpen 2
			POAcol 1	POAcol 1
			ANTodo 2	ANTodo 1
			RYTgra 1	RYTgra 1
			LUZruf 1	LUZruf 1
			UNCruf 1	UNCruf 1
				HYPrad 1
				OREcol 1
				HYDnov 1
				LEUfra 1
				GERmic 1
				GUNpro 1
				HYMmul 1

Location: Plot at head of side creek indicated below. Plot is on true left side, just below head. yellow survey marker is 5 m to the east of transect origin.

Map coordinates: H044 556805

Orientation: 315°

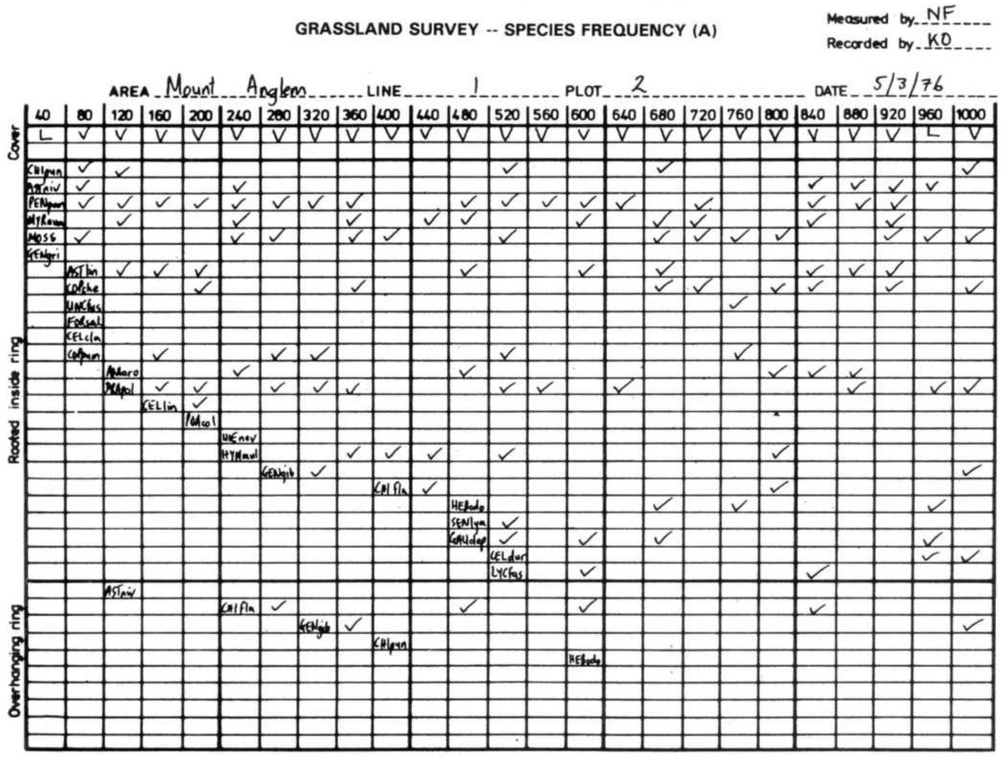


BROWSE

SPECIES	LOW	MOD	HEAVY	ANIMAL
CHIrig	✓			Hare

Appendix 2: Examples of Species Frequency Sheets (A and B)

GRASSLAND SURVEY – SPECIES FREQUENCY (A)



GRASSLAND SURVEY -- SPECIES FREQUENCY (A)

Measured by NF

Recorded by KO

AREA Mount Anglem LINE 1 PLOT 2 DATE 5/3/76

40	80	120	160	200	240	280	320	360	400	440	480	520	560	600	640	680	720	760	800	840	880	920	960	1000

Cover

Rooted inside ring

Overhanging ring

GRASSLAND SURVEY- SPECIES FREQUENCY (B)

GRASSLAND SURVEY -- SPECIES FREQUENCY (B)

Measured by NF
Recorded by KO

AREA Mount Anglem LINE 1 PLOT 2 DATE 5/3/76

	1040	1080	1120	1160	1200	1240	1280	1320	1360	1400	1440	1480	1520	1560	1600	1640	1680	1720	1760	1800	1840	1880	1920	1960	2000
Cover	V	L	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
Rooted inside ring	AEBodo						✓			✓			✓		✓	✓	✓				✓		✓	✓	✓
	Colche	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
	MOSS	✓				✓													✓						
	HYMmol	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
	CAUdep			✓		✓	✓																		
		Lichen																							
		AMarp													✓							✓		✓	✓
		FENpum																							
			CHIfla		✓						✓	✓										✓			
			MYRnum	✓		✓		✓	✓	✓	✓			✓	✓	✓		✓	✓	✓		✓	✓	✓	✓
				SCHpau		✓	✓	✓																	
					ASTniv	✓	✓		✓	✓		✓			✓	✓					✓	✓			✓
							UNCfus	✓		✓					✓	✓							✓		
							CELdur																		
								CHIpum	✓				✓	✓			✓	✓	✓	✓	✓		✓	✓	
										GEUuni											✓				
												CELgra				✓									
														UNKN1	✓								✓		
																	LYCfas								
Overhanging ring	DRApol																								
		CHIfla		✓		✓							(✓)	✓									✓		
				ASTniv		✓					✓							✓		✓			✓		
									AEBodo		✓								✓	✓					
									SCHpau																
										CHIpum					✓	✓									✓

Appendix 3: Cover Estimate Sheet

GRASSLAND SURVEY – SPECIES COVER MEASUREMENTS

SURVEY: Fiordland			LINE: 62			PLOT: 2			DATE: 8/1/86
MEASURED BY: AR						RECORDED BY: KB			
COVER PEG #	SPECIES	COVER	COVER PEG #	SPECIES	COVER	COVER PEG #	SPECIES	COVER	
16	CHIcra	4	52	CELpet	2				
"	ANInaa	2	"	ASTlin	3				
"	SCHpau	3	"	Carex	2				
"	Carex	2	"	Moss	1				
"	SENsca	1	"						
"	COPser	2	67	CHIcra	4				
"	LUZruf	2	"	CELcor	2				
"	CELcor	3	"	OURmac	2				
"	BULgib	2	"	CELhol	2				
			"	FORten	1				
22	CHIcra	4	"	SCHpau	2				
"	ANInaa	2	"	CHIpol	2				
"	SCHpau	3	"	ANInaa	2				
"	OURmac	2	"	CELpet	2				
			"	ASTlin	4				
28	CHIcra	4							
"	ANInaa	2	71	CHIcra	5				
"	SCHpau	3	"	CELcor	2				
"	CELpet	3	"	SCHpau	3				
"	DRAlon	2	"	OURmac	2				
"	ASTlin	3	"	CELpet	2				
"	CELwal	2	"	ANInaa	2				
			"	ASTlin	2				
46	CHIcra	3							
"	CELcor	1	62	CHIcra	4				
"	OURmac	2	"	CELcor	3				
"	CELarm	2	"	OURmac	2				
"	FORten	2	"	CELpet	3				
"	SCHpau	4	"	ANInaa	2				
"	CHIpal	3	"	ASTlin	3				
"	BULgib	2	"	SENsca	2				
"	ANInaa	2	"	CHIpal	3				
			"	BULgib	2				
52	CHIcra	4	"	Carex	1				
"	FORten	2							
"	SCHpau	3							
"	CHIpal	2							
"	ANInaa	2							

Appendix 4: **Distance/Stature Measurement Sheet**

GRASSLAND SURVEY - DISTANCE / STATURE MEASUREMENTS

SURVEY	Mt. Anglem	MEASURED BY	NF
LINE	1	RECORDED BY	KO
PLOT	2	DATE	5/3/76

COVER PEG #	SPECIES	HT PERP ROD	SLOPE	DIST 1	HT 1	DIAM 1	DIST 2	HT 2	DIAM 2
71	CHIFla	88cm	40°	320cm	52.8cm	19cm	120cm	75cm	24cm
52	"	80	41°	83	58.2	22	40	54.6	22
22	"	85	41°	298	55.5	13.4	330	87	13
16	"	93	38°	20	74.4	29	30	54.3	23.5
46	"	81	40°	20	48.0	24	68	75.3	26.0
67	"	87	40°	13	73.8	7	40	69.3	10
28	"	90	33°	39	43.7	14	30	46.2	5
79	"	79	31°	29	54.4	10	24	75.4	15

Appendix 5: Equipment list for establishing or remeasuring permanent grassland plots. Spares should be carried in case of loss or breakage.

	Wraight 20 x 20 m quadrat	Scott height-frequency transect
Topographical map	x	x
Aerial photograph	x	x
Pens, pencils, rubbers	x	x
Spirit-based felt tip pen	x	x
Chalk	x	x
Red chinagraph pencil (for use on aerial photos)	x	x
Clipboard	x	x
Plot sheets (printed on waterproof paper)		
RECCE Description sheet	x	x
Species Frequency sheets (A and B)	x	
Species Cover Estimate sheet	x	
Distant/Stature Measurement sheet	x	
Height-Frequency Measurement sheet		x
Compass	x	x
Altimeter	x	x
Abney level or clinometer	x	x
Plat stakes (see text for suggestions on types to use)		
2 large (1-1.5 m) wooden stakes, steel waratah standards, or angled aluminium standards	x	x
1 graduated 1 m stake	x	x
6 aluminium or steel pegs (45 cm x 0.7 cm)	x	
8 aluminium or steep pegs (30 cm x 0.5 cm)	x	
3 aluminium or steel pegs (45 cm x 0.7 cm)		x
15 cm internal diameter steel ring	x	
2 m graduated rod with 2+ pairs of horizontal pins attached		x
5 tapes (20 m)	x	
2 m tape graduated to nearest 0.5 cm	x	
100 m tape		x
100 m nylon cord		x
Film (20 or 36 exposures) Kodachrome 25 ASA	x	x
SLR camera fitted with 50-55 mm lens	x	x
20 mm lens	x	

		x
Cable shutter release	x	
Tripod designed for taking stereophotos	x	
Engraved white formica plaque (21 cm x 7 cm)	x	
500 ml isopropyl alcohol	x	
Plastic bags (for plant specimens and for covering clipboard when recording in the rain)	x	
Labels (for plant specimens)	x	
Small blackboard	x	
Rigid 1 m x 1 m frame for cover quadrats	x	
Small portable metal detector	x	
Global Position System (if available)	x	
	x	
	x	
	x	
	x	

Appendix 6: Example of a Height-frequency Sheet

GRASSLAND SURVEY – HEIGHT–FREQUENCY MEASUREMENTS

page 1 of 3

SURVEY: Mt. Anglem | LINE: 1 | PLOT: 2 | DATE: 5/15/86

MEASURED BY: RBA | RECORDED BY: SKW

POSITION	COVER	SPECIES OCCURRENCE							
0.5	V	ASTniv 0-20	Moss 0-5						
1.0	LC 0-5	CHIpun 30-40	ASTniv 0-30						
1.5	V	ASTniv 25-30	ASTniv 0-20	CORcne 0-20					
2.0	V	CORcne 0-40							
2.5	V	CHIpun 0-30	moss 0-5			Chipun ext	lf length =	42 cm	
3.0	V	CHIpun 30-45	PENpum 0-25						
3.5	V	CHIpun 25-40	PENpum 0-20						
4.0	V	MYRnum 0-20							
4.5	V	CHIfla 40-70	PENpum 0-20						
5.0	V	ASTniv 0-30							
5.5	V	CHIfla 20-40 60-75	DRApol 0-15	ANIaro 0-5					
6.0	V	DRApol 0-20							
6.5	V	CELcla 0-5	FORsed 0-5	UNCfus 0-5					
7.0	LC 0-5	CHIfla 25-70							
7.5	V	MYRnum 0-25							
8.0	V	GENgib 15-25	GENgri 0-5	MOSS 0-5					
8.5	V	GENgib 15-25	COPpum 0-5						
9.0	V	CHIfla 35-75	PENpum 0-25						
9.5	V	PENpum 0-10	COPpum 0-5						
10.0	LC 0-5	CHIfla 50-80	PENpum 0-25						
10.5	LC 0-5	CHIpun 20-45							
11.0	V	CHIpun 0-30				Chipun extended leaf length = 38 cm			
11.5	V	CHIfla 30-70	MYRnum 0-20						
12.0	V	HYMmul 0-10	HIEnov 0-20	CHIfla 0-10		Chifla extended leaf length = 12 cm			
12.5	V	ANIaro 0-5	POAcol 0-5						
13.0	B	CHIfla 40-80							
13.5	B	CHIfla 20-60 75-85	ASTniv 0-30	MOSS 0-5					
14.0	LC 0-5	CHIfla 20-70							
48.0	LC 0-5	HEBodo 10-100	CHIpun 30-40						
48.5	B	CHIpun 10-45							
49.0	B	CHIpun 10-35	ASTniv 15-30						
50.0	V	HEBodo 50-100	CHIpun 0-25 35-40			Chipun extended leaf length = 52 cm			

Appendix 7: Summarised Height-frequency Data.

GRASSLAND SURVEY – HEIGHT–FREQUENCY SUMMARY

SURVEY: Mt. Angelm	LINE: 1	PLOT: 2

	HEIGHT INTERVAL																			
SPECIES	0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	85–90	90–95	95–100
CHIpun	11	13	15	15	16	18	17	14	5	1										
CHIFla	4	4	4	6	13	15	19	22	21	23	26	25	24	23	17	14	5	2		
HEBodo	2	2	3	4	6	5	6	6	9	10	10	10	8	9	11	11	8	7	4	4
COPcne	22	22	21	21	18	12	8	5	1											

9. ACKNOWLEDGEMENTS

We thank the numerous individuals who developed and refined these sampling methods over the years. Several people have contributed their expertise to this manual, particularly Rob Allen, Larry Burrows, Graeme Hall, Grant Hunter, Bill Lee, Caroline Mason, and Ian Payton. We thank Ralph Allen, Rob Allen, Peter Bellingham, Tymon Duvall, Grant Hunter, and Kevin Platt for critically reviewing the manuscript. Preparation of this manual was funded by the Department of Conservation.