Manaaki Whenua
Landcare Research

A permanent plot method for monitoring indigenous forests – expanded manual

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Manaaki Whenua – Landcare Research

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Summary

New Zealand's remaining indigenous forests cover about 26% of its land area and are an important feature of the landscape. Their management and protection require techniques for monitoring forest structure and composition, and permanent sample plots are recognised as a robust approach for this purpose. This manual incorporates updates and standardises the methodology for the use of permanent plots for forest monitoring throughout New Zealand.

Random, systematic, and subjective sampling systems are considered for the location of plots. The choice of system will depend on the specific objectives of the monitoring programme. Each plot is a permanently marked quadrat of 20 × 20 m, on which a reconnaissance (Recce) description is undertaken that records plot location, site data, and detailed data on vegetation composition. On each plot, trees are tagged, their diameters measured, and their species recorded. All saplings are counted. Each plot has 24 understorey subplots (circular, 49 cm radius), within which species are recorded in height classes.

This manual provides guidelines on planning a permanent plot survey, and on field techniques such as the use of GPS, the collection of unknown plant specimens, and quality control procedures. As well as the standard plot measurement protocols, collection of ancillary data (e.g. soil samples, non-vascular plant species, animal browse, plant traits) is discussed; this kind of data may be useful depending on the objectives of the survey. The manual also contains instructions for archiving data in the National Vegetation Survey (NVS) Databank, where data from the many existing permanent plot surveys are stored. Guidelines for data analysis are not included.

1 Introduction

1.1 Why monitor New Zealand's indigenous forests?

The remaining indigenous forests are a dominant feature of the New Zealand landscape and cover more than 6 million hectares, or 26% of the land surface. This figure increases to 30% if kānuka/mānuka is included (Cieraad et al. 2015). The need to manage forests and protect natural values is enshrined in New Zealand legislation (e.g. Forests Act 1949; Conservation Act 1987; Resource Management Act 1991). New Zealand also has legally binding international reporting obligations as a signatory to the Convention on Biological Diversity, and as a participant in the Forest Resource Assessment of the Food and Agriculture Organisation (FAO) and the Montreal Process (Bellingham et al. 2000). Since 2015, New Zealand also has national monitoring obligations for atmosphere, air quality, land, freshwater and marine systems through the Environmental Reporting Act 2015.

At the beginning of this century New Zealand government agencies were under increasing pressure to quantify New Zealand's environmental performance through monitoring and reporting (Kneebone et al. 2000; Parliamentary Commissioner for the Environment 2004; Green & Clarkson 2005; Ministry for the Environment 2006). A review of progress towards the goals of the New Zealand Biodiversity Strategy, 5 years after implementation, considered that inadequacies in the comprehensiveness and relevance of biodiversity data collected at the time were an impediment to effective biodiversity management (Green & Clarkson 2005). A key recommendation was to develop biodiversity indicators that were clearly linked to regional and national monitoring and reporting systems (Green & Clarkson 2005).

In 2002 the Ministry for the Environment established its Land Use and Carbon Monitoring System (LUCAS) to help New Zealand meet its international carbon reporting obligations (see section 1.3.5). Concurrently, the Department of Conservation (DOC) commissioned a report to review New Zealand's monitoring and national monitoring systems (Lee et al. 2005). The report identified ecological integrity as an overarching goal for a national monitoring system, while outlining possible indicators and metrics for a Biodiversity Monitoring and Reporting System (BMRS) (Lee et al. 2005). In 2010 DOC's Tier 1 BMRS programme was approved, and in 2012 the department's annual report included monitoring data from this for the first time (MacLeod et al. 2012).

As of 2021, monitoring programmes administered by DOC, the Ministry for the Environment and regional councils all contribute to national information in New Zealand on carbon stock status and biodiversity trends (DOC 2019b). This information is also crucial internationally, where pressure for the collection of widespread, objective biodiversity data continues (Jackson et al. 2016; Pereira et al. 2017). However, implementation and measurement of national plot networks has overshadowed the utilisation of local plot networks over the last decade (2010–2019). Data from local plot networks have frequently been analysed to examine applied community ecology and conservation ecology questions (see examples in section 1.3).

Considerable conservation expenditure is justified on the grounds of minimising threats and the negative consequences of human-related impacts on indigenous biodiversity (e.g.

Parkes & Murphy 2003). To evaluate the outcomes of management activities on indigenous biodiversity at a local level, it is important for conservation managers to have monitoring information. Such monitoring is often directed at very explicit local problems or concerns, such as the benefits to forest vegetation of culling introduced animals (e.g. Payton et al. 1997; Duncan et al. 2006). To ensure monitoring will meet the immediate data requirements, the design (e.g. the sampling design, comparisons to be made, and what attributes are to be measured) should be based on explicit statements of the objectives (Noss 1990).

While it can often appear efficient to focus monitoring resources on such very specific issues or components of indigenous biodiversity, this approach may be inadequate over the longer term. In New Zealand, historically such an approach has led to inconsistencies in the way monitoring has been organised and funded as different issues and monitoring techniques came in and out of vogue. The true worth of some historical data sets has sometimes been insufficiently recognised, and unfortunate losses of data have occurred during organisational restructuring.

Long-term monitoring is essential if we are to understand and manage indigenous forests. Long-term monitoring data provide insight into natural or human-induced vegetation dynamics that would be impossible if data were only available from one-off vegetation surveys or short-term monitoring programmes. Long-term monitoring data on forest structure or composition can provide a baseline from which future unforeseen changes can be assessed.

Given the range of needs for monitoring data, from local to national, a key step for land administrators is to design and use monitoring systems that can address data needs simultaneously over a range of spatial and temporal scales (Allen et al. 2003; Jackson et al. 2016; Pereira et al. 2017). The requirements of long-term monitoring are best met using systems that collect comprehensive, enduring and interpretable biodiversity data using standardised and consistent techniques (e.g. Allen et al. 2003; DOC 2019a). Where such a system is used, monitoring results are likely to be of interest, use and relevance for decades to come.

1.2 Why use permanent plots to monitor indigenous forests?

Permanent plots are a robust approach for measuring detailed changes in forest structure and composition (Graves 1906; Dallmeier & Comiskey 1998). Composition addresses species richness and diversity, as well as structure – the physical organisation of the forest (Noss 1990; Allen et al. 2003). Long-term monitoring of forests should be based on these characteristics, as most anticipated uses of long-term data will require these fundamental measures.

Where permanently marked plots are resampled over time, between-plot differences are removed from change estimates, thus increasing the ability to detect significant change in vegetation attributes. Permanently marked plots with individually identified trees are also currently the only way to measure fundamental population parameters for tree species, such as recruitment, growth and mortality rates (Bellingham et al. 1999, Coomes et al. 2011, Velázquez et al. 2016), because such data can only be obtained where the fates of individual trees are followed through time. Monitoring systems based on permanent plots measuring these vegetation characteristics are more likely to remain relevant in the face of changing or evolving issues of concern.

In New Zealand, one of the earliest examples of the use of permanent plots are the belt transects established by Cockayne (1898) in mountain beech (*Fuscospora cliffortioides*) forest, subalpine scrub, and red tussock (*Chionochloa rubra*) grassland at Arthur's Pass. From 1950 to 1985 permanent plots were widely established in indigenous forests by the former New Zealand Forest Service (McKelvey et al. 1958; Allen & McLennan 1983; Meurk & Buxton 1991).

The most frequently used types of permanent plots were cruciform (Holloway & Wendelken 1957) and 20 × 20 m plots (Allen 1979, 1993; Allen & McLennan 1983). The purpose of the cruciform plot system (used in the 1950s and 1960s) was to provide permanently marked areas that could be remeasured over time to determine changes in vegetation structure and composition. However, experience showed that the cruciform plot system had limitations: the crosses had a large perimeter-to-area ratio (each arm measured 20 × 5 m), which meant many trees were located on plot boundaries, and many estimates were visual (e.g. for diameter). Also, since trees on these plots were not individually tagged, the demographics of tree populations could not be determined.

Further development of plot systems resulted in reconnaissance descriptions ('Recces'; Allen 1992) and methods using 20 × 20 m permanent plots (hereafter permanent plots; Allen 1993). While Recce descriptions were usually temporary and used in vegetation inventory surveys, by convention they were also undertaken on 20 × 20 m permanent plots to record data on site factors and vegetation composition.

It is now commonplace for permanent plot data to be used to address issues or questions beyond those anticipated when monitoring was originally established, as new lines of enquiry or avenues of research are undertaken (Leathwick 1998; Leathwick et al. 1998; Wiser et al. 1998; Allen et al. 1999; Bellingham et al. 1999; Wardle et al. 2001; Coomes et al. 2002, 2003; Newell & Leathwick 2005; Wiser & Allen 2006; Coomes et al. 2011, Velázquez et al. 2016, Allen et al. 2020). Moreover, syntheses of plot data from different regions are essential for the application of biodiversity indicators at national scales (Lee et al. 2005; Jackson et al. 2016; Pereira et al. 2017).

It is impossible to optimise a monitoring method for every potential question or issue and forest type. For one thing, New Zealand forest types 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 above 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. As with any widely used monitoring method, small sacrifices in appropriateness are often amply repaid by gaining comparability (Gauch 1982).

1.3 Further examples of the use of permanent plots

1.3.1 Assessing introduced animal impacts on forest structure and composition

Assessing the impacts of introduced mammals (e.g. possums, deer and goats) on forest structure and composition has long been a primary use of permanent plots. A common approach has been to compare the vegetation structure and composition of sites with different animal abundances. This approach has been used to:

- compare the structure and composition of forests with introduced herbivore populations to those of forests without such populations (e.g. a comparison of mainland and offshore island sites)
- compare vegetation in fenced plots that exclude animals with that of unfenced plots (e.g. Bellingham & Allan 2003; Husheer et al. 2005)
- examine changes in vegetation structure, composition or demographic patterns along an invasion front of introduced mammals (e.g. Stewart 1992)
- analyse the effect of vegetation structure and composition, abiotic variables and control history on invasive mammal abundance (e.g. possums, Forsyth et al. 2018)

Permanent plots have also been used to relate temporal changes in forest structure or composition to changes in herbivore populations (e.g. Stewart et al. 1987). The above approaches have been used to provide a rationale for animal control, and to monitor the efficacy of wild animal management programmes.

Previous studies in New Zealand suggest there are complex causes of vegetation change. Because of the difficulties in distinguishing natural changes in vegetation from those caused by introduced herbivores, care must be taken when interpreting the results of observational studies. Studies often rely to some degree on our knowledge of which species are preferred or avoided by the introduced herbivore in question (e.g. Forsyth et al. 2002). Appropriate study designs are important so that the effects of specific factors, such as introduced herbivores, can be adequately isolated from potential confounding factors (e.g. differences in light, soil fertility, initial species composition, disturbance history or natural stand dynamics; Allen et al. 2003; Bellingham & Lee 2006).

In part, such issues are addressed by collecting a broad range of interpretive data from permanent plots, but detailed ancillary data may also be required to adequately address such issues. For example, it may be useful to collect ancillary data on animal browse, distribution or abundance using standard methods (e.g. Baddeley 1985; Forsyth 2005; National Pest Control Agencies 2015). Detailed animal browse data collected in conjunction with permanent plots have been used to study both possum (e.g. Urlich & Brady 2005) and deer impacts (e.g. Husheer & Robertson 2005; Duncan et al. 2006), increasing the ability to relate animal impacts to demographic processes such as growth and mortality.

1.3.2 Monitoring species invasion

Changes in the distribution or abundance of plant species, including unanticipated invasions by exotics, can be measured using permanent plots. For example, the invasion of mountain beech forest by the exotic herb *Hieracium lepidulum*, previously only considered to invade grassland, was documented by Wiser et al. (1998) and Spence et al. (2010) using data from 20 × 20 m permanent plots. The long history of plot measurements (i.e. 35 years) and the comprehensive nature of the plot data and supplementary soil fertility data allowed the invasion process to be quantitatively studied in relation to plot environmental factors. Further, extrapolations of model predictions from this data revealed invasion levels to be strongly affected by *Hieracium* persistence as opposed to disturbance frequency (Spence et al. 2010).

1.3.3 Monitoring canopy dieback in tree species

Dieback of forest canopies has been variously attributed to natural forest dynamics and the effects of introduced herbivores, and is sometimes of concern to forest managers. In the mountain beech (*Fuscospora cliffortioides*) forest of the Harper–Avoca catchments in Canterbury, 250 permanent plots have been used to study canopy mortality patterns and changes in forest structure over three decades (Wardle & Allen 1983; Allen & Wardle 1993; Allen et al. 1999; Hurst 2006). Our ability to monitor the spread and landscape-scale impacts of pathogens such as kauri dieback disease (*Phytophthora agathidicida*) and myrtle rust (*Austropuccinia psidii*) is increased with regular monitoring of a national permanent plot network (DOC 2018).

1.3.4 Developing models of forest dynamics

Models are essential if we are to predict the likely outcomes of management activities, and they also contribute to our wider understanding of forest dynamics. In a study on the impacts of multiple species of introduced animals on forest composition and structure in Waitutu Forest, Fiordland, permanent plots provided essential data on recruitment, growth and mortality rates of canopy tree species to parameterise a predictive model of forest dynamics (Forsyth et al. 2015). Similarly, tree recruitment, growth and mortality data from permanent plots in mixed beech forest near Springs Junction have been used to parameterise models to simulate various management strategies and disturbances (Hurst 2014).

1.3.5 Measuring carbon stored in indigenous forests

Plot data have been used to estimate changes in the carbon stocks contained in live biomass in indigenous forests (e.g. Hall et al. 2001; Coomes et al. 2002; Coomes et al. 2012, Holdaway et al. 2017; Paul et al. 2019). Permanent plot methods also form the basis of data collected for LUCAS. This is a programme developed by the Ministry for the Environment to help meet international reporting obligations to monitor carbon (see Coomes et al. 2002; Davis et al. 2004; Payton et al. 2004). The LUCAS plot network consists of over 1,000 permanent plots on an 8 km grid across New Zealand’s pre-1990 natural forest and shrublands, using existing plots where appropriate and new plots in areas where none previously existed (Payton et al. 2004).

1.3.6 Modelling the distributions of plant species or communities

Plot-based vegetation data – used in combination with climatic, land-form, and land-cover data derived from geo-spatial databases and statistical modelling techniques – can answer questions about the actual and potential distributions of both threatened and common New Zealand plant species (Leathwick 1998; Lloyd et al. 2003; Rogers & Walker 2005; Newell & Leathwick 2005), and exotic weed species (Overton & Lehmann 2003). The species composition of plots also permits classification into vegetation associations and alliances (Wiser et al. 2016). More recently, McCarthy et al. 2021 created species distribution models (SDMs) for all New Zealand's native Myrtaceae species based on presence–absence plot data from the NVS Databank. These SDMs were examined against a spatial layer of mean daily myrtle rust (*Austropuccinia psidii*) infection risk to quantify range non-overlap and identify potential refugia where conservation efforts could be prioritised (McCarthy et al. 2021).

1.4 Existing data from permanent plots

More than 121,000 vegetation survey plots have been established across New Zealand and more than 26,000 of these are permanently marked (Hayman et al. 2021). However, existing permanent plots, although widespread, are patchily distributed. Some areas are very well represented (e.g. upland forests, Fiordland, and southern North Island forests), whereas others are poorly represented (e.g. lowland forests, Taranaki and Coromandel forests; Bellingham et al. 2000).

Some more notable gaps in national plot networks have been recently recognised and remedied through the establishment of new local plot networks (e.g. Grove 2005). The use of permanent-plot protocols for LUCAS, the establishment of DOC’s Tier 1 BMRS, and the introduction of monitoring programmes by some regional councils also increased plot coverage, providing the first truly representative plot network across New Zealand’s forests (see Figure 1) (DOC 2019b).

Before considering any new monitoring programme using 20 × 20 m permanent plots, all existing monitoring within the study area should be identified and evaluated. It is important that there be long-term commitment to monitoring programmes to capitalise on the considerable investment required to establish and measure permanent plots.

The remeasurement history of permanent plot data sets varies considerably. Whether some of the existing plot surveys will be remeasured at all is a pressing issue. For example, a large number of plots established in the 1970s and 1980s have not yet been remeasured, and the remeasurement will become increasingly difficult due to missing plot markers and ingrown tree-tags. Where surveys of existing permanent plots are to be abandoned, this should be a conscious decision based on an analysis of scientific value and logistical practicality, rather than an outcome of default or short-term funding imperatives.

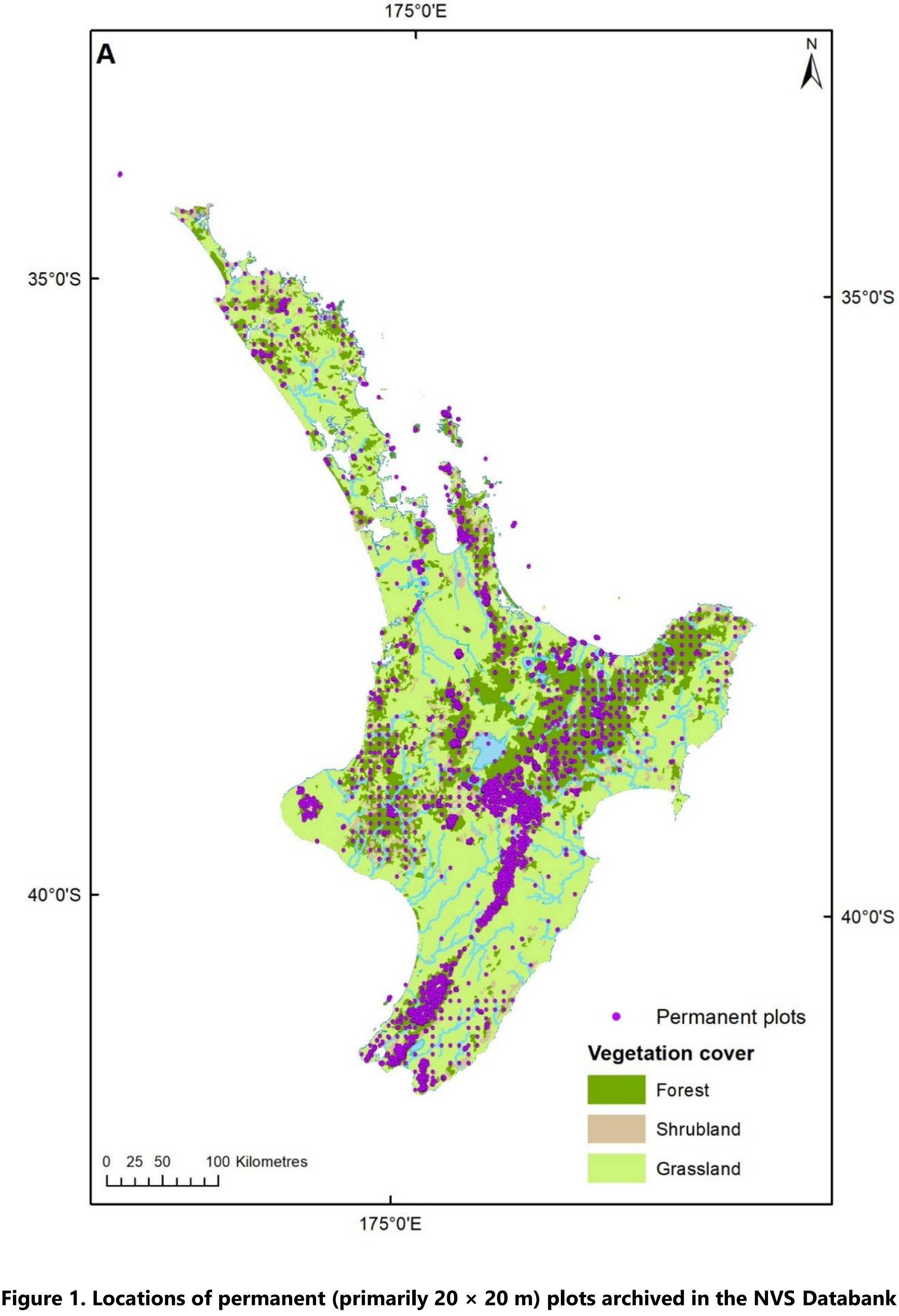


Figure 1. Locations of permanent (primarily 20 × 20 m) plots archived in the NVS Databank for which location data are available: (a) North Island, (b) South and Stewart Island / Rakiura. As of July 2021, the NVS Databank holds data from over 121,000 vegetation survey plots, including over 26,000 permanent plots. Plot locations were overlain onto maps with vegetation cover classified as indigenous forest, shrub and tussock grassland by the Vegetative Cover map of New Zealand from Manaaki Whenua – Landcare Research. Crown copyright reserved.

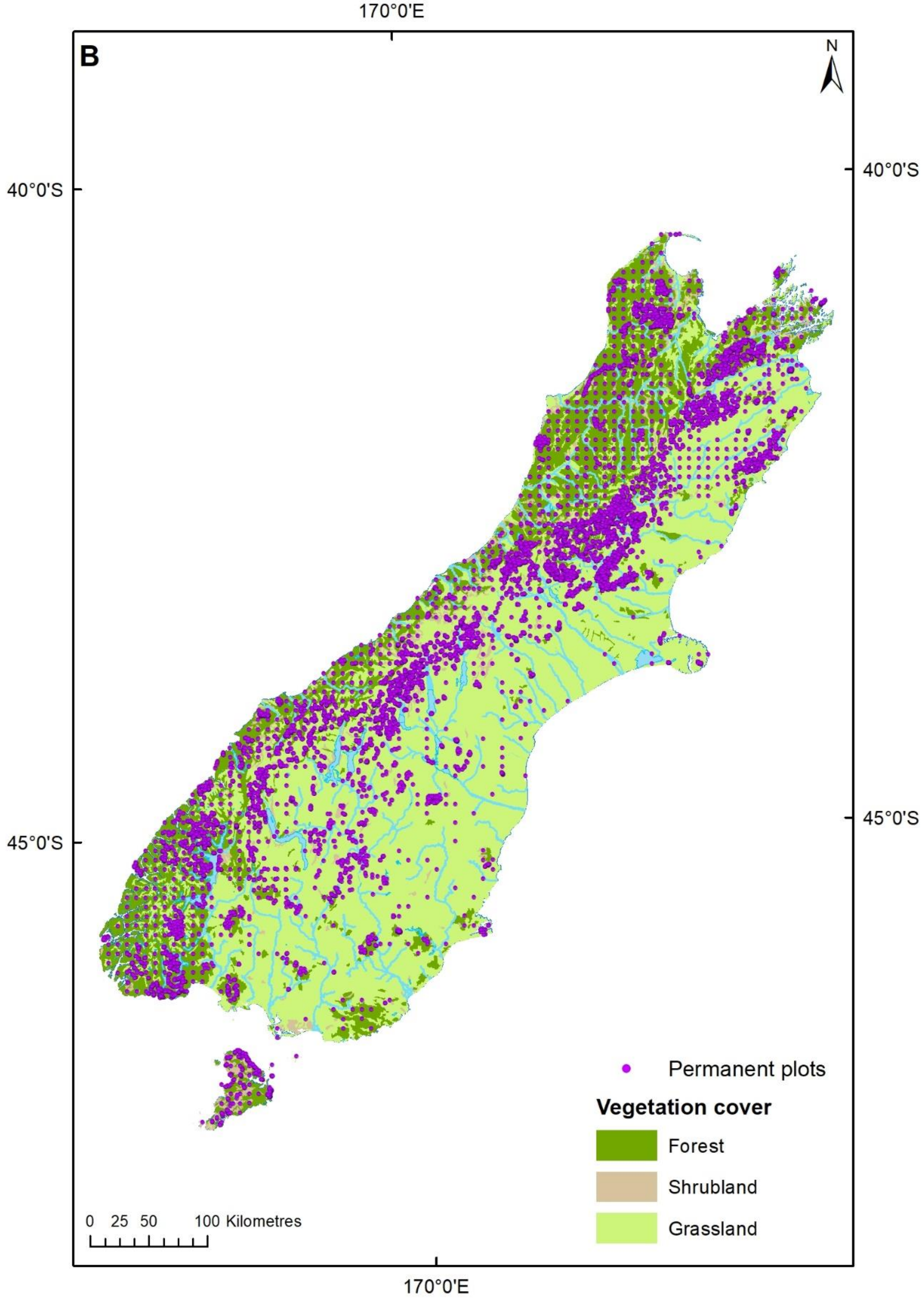


Figure 1. Continued from previous page.

1.5 Why is a permanent plot manual needed?

The importance of standardised and widely accepted protocols for measuring vegetation plots is readily apparent. Standardisation ensures that vegetation patterns detected over time and space really are occurring in nature and are not simply the result of measurements taken in slightly different ways. Standardised monitoring programmes will be credible and more likely to withstand scrutiny. Conversely, without the use of standardised plot measurement protocols, forest management agencies run the risk that data collected are inaccurate, inconsistent and unrepeatable, or are unable to be combined to study vegetation patterns across a variety of spatial or temporal scales. The publication of standard protocols also allows potential data users to interpret data more easily and gauge their suitability for any particular study.

Despite the long history of using 20 × 20 m permanent plots in New Zealand, there are several reasons why standardisation has been problematic. Firstly, changing priorities can lead to the intentional use of non-standard plot measurement methods. For example, a 2006 survey identified nine different methods in use for enumerating tree ferns on permanent plots. Many of the alternative protocols provided compatible data at a simple level (e.g. to calculate stem densities of all tree ferns >1.35 m; as in Allen 1993), but not at others (e.g. to calculate tree-fern mortality rates, as can be done when tree ferns are individually tagged). Intentional deviations to plot measurement protocols may be driven by the need to collect additional data to meet local needs, or to omit certain measurement protocols due to inadequate resources for monitoring. In part, such flexibility is provided for in this manual by promoting standardisation at certain basic levels, while leaving optional those protocols considered less important (e.g. measuring tree-fern stem length; see section 5.5.1).

Use of non-standard measurement protocols can also arise unintentionally. Staff collecting vegetation data may work in isolation from technical support or may not have obtained the full range of skills necessary to implement vegetation surveys to a high standard. There will always be the need for formal training and support to ensure data are of a high quality and collected in accordance with protocols.

1.6 What is the purpose of this manual?

This manual expands upon earlier versions (Allen 1979, 1992, 1993; Allen & McLennan 1983) in order to standardise protocols pertaining to 20 × 20 m permanent plots, and to outline commonly agreed ‘best-practice’ plot measurement procedures. Specifically, this version of the manual is an update of version 4 (Hurst & Allen 2007). No assumptions can be made about the uptake of this revision. Historical versions of this manual will continue to be used both domestically and internationally. As such this revision has been conservative in its nature and attempted to retain as much continuity as possible with earlier versions, whilst clarifying any sources of ambiguity. Several different kinds of data are collected on each plot as part of standard protocols:

- a Recce description
- stem diameter data

- sapling data
- understory subplot data.

These are briefly described below.

1.6.1 Recce description

Each permanent plot measurement includes a general site and vegetation description. The Recce site description includes readily obtainable topographic data (e.g. aspect, slope, altitude). Such data are often required to interpret vegetation patterns. The Recce vegetation description is the most complete record of vascular plant species occurring on the plot, and is important because it will normally include rare species and those of certain growth forms (e.g. epiphytes) that may not be recorded elsewhere in the plot data. Non-vascular plant species can also be recorded in the Recce vegetation description.

1.6.2 Stem diameter data

Within each plot all trees and tree ferns (≥2.5 cm diameter at breast height; DBH) are tagged and the diameters recorded. These data are used to determine the size structure and calculate the stem density of tree and shrub populations. When plots are remeasured, stem diameter data are used to estimate tree demographic parameters such as recruitment, growth, and mortality rates.

1.6.3 Sapling data

Sapling data consist of counts of the number of saplings (≥1.35 m tall and <2.5 cm DBH) of each species within the plot. These data can be used to calculate sapling densities of tree and shrub species in order to evaluate regeneration patterns. Such data have often been used when evaluating the impacts of introduced ungulates on forest vegetation.

1.6.4 Understorey subplot data

Understorey subplots collect occurrence frequency data for all understorey species <1.35 tall, and seedling density data for woody trees, shrubs and tree ferns.

1.7 Organisation of the manual

In section 2 we provide some basic principles of sampling. The development of an appropriate sampling design will depend on the study site and any specific objectives of the survey. Pre-fieldwork planning activities are outlined in section 3, while section 4 provides practical guidelines on locating and marking plots in the field.

In section 5, protocols for measuring permanent plots are outlined, including rules for a coding system for recording species names. Comparability with data from historical surveys is largely maintained in this manual by retaining protocols outlined in previous manuals (Allen 1979, 1992, 1993; Allen & McLennan 1983). Long-term monitoring programmes should not exclude any of the standard plot measurements, since the strength of the method for monitoring long-term forest change rests on the collection of a wide range of interpretive data from each plot.

Section 6 provides guidelines on remeasuring permanent plots. Historical plots were sometimes established using non-standard protocols, and common variations to standard protocols have been provided. Protocols for the establishment and remeasurement of permanent plots are also available in an accompanying field guide (Hurst et al. 2022; see http://nvs.landcareresearch.co.nz/).

Because high taxonomic standards are required when measuring biodiversity patterns through time and space, section 7 provides guidelines on collecting and recording specimens of unknown plants. Section 8 outlines further data quality assurance procedures to follow during the fieldwork planning, data collection, and data management stages of a vegetation survey.

In section 9, steps are outlined for archiving data in the NVS Databank, which provides a number of key benefits to data providers and users, such as the facilitation of data access and quality checks on archived data. Archiving vegetation data in the NVS Databank is now a DOC standard operating procedure.

Objectives for individual surveys may necessitate the collection of ancillary data from plots, in addition to the standard plot measurement protocols, in order to better address specific research or management questions. Some examples of ancillary data are outlined in section 10.

2 Sampling

Given unlimited resources, an entire population of interest would be quantified in any defined survey area. In such cases we would say that 100% of a population had been sampled. However, such an approach is seldom taken, since the resources required and the precision obtained are usually unwarranted. Instead, some form of sampling is used.

Sampling decisions are crucial and will determine both how the data can be used and the feasibility of undertaking the programme. Ultimately, the monitoring design must allow the objectives of the programme to be met. To ensure this, the following questions must be answered:

- What are the population(s)/communities of interest?
- What parameters or characteristics of the vegetation need to be reliably measured, and to what accuracy?

Monitoring designs are often a trade-off between practical constraints, such as the resources available and the nature of the terrain to be surveyed, and the amount and accuracy of data required to meet the objectives of the project.

Some general guidelines are outlined in this section. Our aim is not to review the complete range of alternative designs for monitoring surveys. Monitoring sampling designs have received comprehensive treatment elsewhere, and investigators should consult relevant textbooks for further details (e.g. Mueller-Dombois & Ellenberg 1974; Jongman et al. 1987; Økland 1990; Elzinga et. al. 1998; Newton 2007).

Other considerations when developing a monitoring programme using permanent plots are the plot measurement protocols to be used in the field (section 5), including whether ancillary data are required to better address specific research or management questions (see section 10).

2.1 General guidelines and principles of sampling

Key monitoring design decisions concern the *arrangement* and *number* of sample plots. These decisions affect the statistical properties of the data (e.g. whether formal statistical tests will be valid), and the representation of dominant vs rare species and/or communities. They also have practical implications, such as influencing the number of plots that can be established within a given time frame.

2.1.1 Arrangement of sample plots

(a) Representative sampling and statistical inference

The objectives of a vegetation survey usually require generalisations to be made about a large group of interest (the population), based upon measurements made for a small subset of the group (the sample). This is called *statistical inference*.

Some sort of representative sample should always be used when statistical inference is required. The process of statistical inference allows statistical estimates of vegetation parameters to be produced, along with an estimate of their reliability. Representative samples require that every site within a predefined study area have a known, non-zero probability of being included in the plot network. Statistical inferences can only be made for areas that have a chance of being included in the sample.

(b) Defining the area/population of interest

A fundamental step before determining plot locations is to clearly define and document the boundaries of the areas/populations of interest (the sampling universe). Study areas vary in size and shape – from large, contiguous forest blocks to small and scattered remnants. Forest boundaries can often be defined by reference to aerial photographs, maps, and some initial field reconnaissance.

Sites considered unsafe to sample due to the nature of the terrain or access restraints (e.g. beyond the range of helicopter flight) can be excluded from the sampling universe prior to implementing a sampling scheme, but no statistical inference can then be made about these areas. Furthermore, clear rules about plot rejection must be developed prior to fieldwork and subsequently used to adjust (by proportion) the sampling universe (e.g. if 2 out of 100 plots were rejected during fieldwork due to bluffs, it would mean 98% of the sampling universe was actually sampled).

(c) Stratification in heterogeneous areas

While representative sampling is ideal whenever it is important to know the relative abundance of species or communities, some redundancy may result for very common species or vegetation types, and rare species or vegetation types can be poorly represented, particularly when sampling intensity is low (Økland 1990). In areas that are heterogeneous, stratified sampling (e.g. by vegetation type or a nominated environmental gradient) is often suggested as a way to more efficiently achieve accurate estimates of vegetation parameters, or to more equally sample the range of different conditions present (Jongman et al. 1987).

Prior stratification by current vegetation patterns is usually not recommended for plot networks, which must serve multi-faceted, long-term monitoring objectives (Bellingham et al. 2000; Allen et al. 2003). This is because vegetation strata suitable for one parameter of interest may differ from strata suitable for other parameters of interest, and strata boundaries based on vegetation patterns will change over time (Bellingham et al. 2000). However, stratification by current vegetation type can be an efficient way to supplement representative, unstratified plot networks with additional plots in areas of special concern (e.g. to increase sampling in rarer vegetation types, or to increase the sample sizes of species of particular interest).

There are several strategies during data analysis to overcome bias resulting from sampling some subpopulations more heavily than others (e.g. Bellingham et al. 2000; Hall et al. 2001). Within a vegetation survey, whenever some parts of a study area are sampled more intensively than others, or use a different sampling method, the specific details should be recorded in the metadata for the survey (see section 9.2.3).

(d) Subjective sampling

Subjective sampling (also called selective or preferential sampling) should be avoided whenever statistical inference is required to some larger, non-sampled area. Subjective sampling is the least formal approach to locating plots. It involves locating plots in vegetation that is perceived to be typical, representative or undisturbed. When subjective sampling is done by attempting to sample the range of species assemblages in a study area rather than by selecting sites considered to be in some way 'typical' of the species assemblages, the approach is termed *subjective sampling without preconceived bias* (Mueller-Dombois & Ellenberg 1974).

Subjective sampling has been widely used in descriptive ecology, partly because careful subjective selection of sampling sites often includes greater floristic variation than more formal schemes, and it can be used to efficiently sample along environmental gradients to understand vegetation patterns (see Austin 1985). To ensure good coverage of the study area, subjective sampling may also sometimes be aligned with predetermined points, yet the precise plot positioning will be selected to sample, for example, a uniform land form and vegetation (e.g. British Columbia Ministry of Sustainable Resource Management 2003). Such an approach may be useful where data are to be used for very specific objectives (e.g. to produce growth and yield models for sites with different environmental characteristics). While statistical summaries of data can be made whenever more than one plot is established, it is inappropriate to extrapolate results to the study area as a whole because the data are not representative. When used in such a way, subjective sampling methodologies are easily discredited by critics, and may produce biased, unreliable information.

Although representative sampling designs are strongly advocated for most long-term monitoring projects, this does not mean permanent plot surveys comprising subjectively located plots are completely invalidated. If a plot survey using subjectively located plots already exists, the need for representative sampling must be balanced against the benefits of maintaining an existing long-term data set on forest change. Geographical information systems can be used to determine the adequacy of sampling in existing vegetation surveys (Neldner et al. 1995; see also Husheer 2006).

(e) Summary

Before implementing any particular sampling design, it is strongly recommended that the proposed design receive peer review from other ecologists and/or a statistician. Regardless of the approach taken to place plots, in the metadata for a survey always record details of the sampling approach employed (see section 9.2.3) to ensure the long-term integrity of the survey. In other words, record the rationale for the sampling design used to ensure that in the future it will be clear how plot locations were decided upon.

2.1.2 How to obtain a representative sample of a study area

A representative sample of a study area can be obtained by locating plots using either random or systematic sampling methodologies. For full guidelines on the benefits of alternative representative sampling methodologies, consult detailed texts on the subject (e.g. Økland 1990).

In representative sampling methodologies, plot location in the field is likely to be more time consuming and require greater resources than for subjectively located plots. Plot locations are determined prior to field sampling, and geographical information systems (GIS) are often employed to develop sampling strategies (e.g. Reiter et al. 2003).

(a) Random plot placement

In random survey designs, plot placement is typically determined using a random number generator in conjunction with a coordinate system overlaid onto a topographical map. The boundaries of the study area should first be clearly defined. An effective technique for generating randomly located plots involves overlaying a grid onto a topographical map of the study area. Then *x* and *y* coordinates can be assigned to the grid cells, and a random number table (e.g. as generated from a spreadsheet) used to select grid cells randomly. A second pair of numbers in the range 0–9 can then be used to define the precise location of the plot within each selected cell. This process is continued until the desired number of sample plots has been located.

(b) Stratified random plot placement

While random plot placement is unbiased, it is less efficient than spatially balanced designs if spatial autocorrelation (where values for a variable are correlated at nearby locations) exists within a sampling area (van Dam-Bates et al. 2018). A master sample utilising balanced acceptance sampling (BAS) that in theory can be used to coordinate and scale monitoring designs can permit both sampling consistency and coordination between different agencies (van Dam-Bates et al. 2018). A master sample is essentially a set of points that can be subsampled for different monitoring activities. A BAS master sample can be generated quickly to sample a selected area using a shape file (van Dam-Bates et al. 2018). A master sample can also accommodate existing monitoring networks. For those who are familiar with programming in R, a maintained version of the code used to generate a master sample in New Zealand is available online (https://doi.org/10.5281/zenodo.1193953).

(c) Systematic plot placement

In systematic sampling methodologies (also called ‘regular’ or ‘grid’ sampling), plots are placed systematically across the study area using a grid system. Systematic sampling methodologies are sometimes considered to provide better coverage of the study area than random sampling methodologies, and so they may be particularly suitable for understanding spatial patterns and changes in vegetation over environmental gradients (Økland 1990).

First, the boundaries of the study area should be clearly defined, and the origin of the systematic grid assigned randomly. Because the size of the grid (distance between grid lines) will determine the number of sample plots, the grid size used must be appropriate for the task. An appropriate grid size can be roughly calculated for a study area of known size and for a given sampling intensity. For example, in a study area 10,000 ha in size, in which you want to establish 50 sample plots, there would be one plot every 200 ha (i.e. 2×10^6 m^2). To approximate such a sampling intensity would then require a grid spacing of c. 1,414 m (i.e. the square root of 2×10^6 m^2).

(d) Systematic plot placement along transects

Monitoring projects using permanent plots in New Zealand have typically employed randomly located transects, on which plots are then placed systematically (one-dimensional grid sampling; in the sense of Økland 1990). Transect origins were typically located on a watercourse and finished at the treeline or a ridge-top, with plots located at fixed intervals (often 100 or 200 m). One advantage of this sampling scheme is increased efficiency, especially in mountainous country where a field party may more easily visit more than one plot in a day, compared with simple random or systematic sampling.

To assign plot locations on transects, the boundaries of the study area should first be clearly defined. An effective technique for generating randomly located transects involves overlaying a grid onto a topographical map of the study area (e.g. the 1,000 m^2 map grid on a topographical map), assigning x and y coordinates to the grid cells, then using a random number table (e.g. as generated from a spreadsheet) to select grid cells randomly (the number selected depends on the sampling intensity required). Mark the centre of each selected grid cell and use either a random or a systematic approach to assign transect directions.

Alternatively, where transect origins are to be located on watercourses, identify the point on a watercourse nearest to the centre of each selected grid cell and make this point the transect origin. Flip a coin to randomly assign the transect to one or other side of the watercourse, and draw a line from the origin to the nearest main ridge or treeline (as dictated by the predetermined study area boundaries).

For each transect, the compass bearing used in the field is determined from the line drawn on the map, with correction for magnetic declination. The predetermined distances between the systematically located plots along each transect are typically set at 200 m intervals (Allen 1992).

2.1.3 Plot size and shape

Each plot is a quadrat 20 × 20 m square giving a plot area of 0.04 ha. This size and shape are considered suitable for most temperate forests (Mueller-Dombois & Ellenberg 1974). Plot size and shape represent trade-offs between accuracy, precision, and the costs of a vegetation survey.

(a) Plot shape

The plot shape largely determines the size of the perimeter in relation to the plot area. Circular or square plots have the smallest perimeter per unit area, while rectangular or cruciform plots have the largest. A primary advantage of square plots over circular plots is that boundaries can be easily defined in the field with the use of tapes, making it easier to determine which plants are 'in' and 'out' of the plot.

(b) Plot size

The standard plot size of 0.04 ha is probably too limited for monitoring changes in comparatively low-density canopy tree species. While it is possible to optimise plot sizes for individual vegetation surveys by conducting pilot studies, this adds an additional complication and effort to designing the survey. By anchoring the 20 × 20 m plot within a larger plot and only sampling trees over a given size, it is possible to increase the sample size of large, widely spaced trees (e.g. Payton et al. 2004). In New Zealand this approach has been adopted by LUCAS and the DOC Tier 1 BMRS; the external plot method used anchors the 20 × 20 m square plot within a larger, circular plot with a 20 m radius (approximately 0.13 ha). All large trees and CWD ≥ 60 cm in diameter are measured within the external plot. The DOC Tier 1 BMRS field protocol (DOC 2019a) describes methods for establishing and remeasuring an external plot. Additional time would be needed to accurately establish and measure such plots, so fewer permanent plots could then be established within a given time frame.

Because the precision with which vegetation parameters are determined depends not only on plot size but also on the number of plots established, the advantages of such an approach must be balanced against the use of a greater number of standard 20 × 20 m plots. Estimates of variability among standard 20 × 20 m plots is useful for interpreting structural variation in forests, but variation at this scale may be missed if larger plots are used. For most permanent plot surveys, the use of a greater number of standard 20 × 20 m plots is the preferred option.

2.1.4 Number of sample plots

In many management and ecological studies the number of plots is dictated by resources, with limited consideration of statistical issues. However, compromises in sampling intensity could render the data inadequate for their intended purposes, as too few will not allow conclusions to be drawn about the parameters of interest. Conversely, too many plots will increase the expense of the programme and may mean redundant data are collected.

(a) How to decide on the sampling intensity

When deciding on the sampling intensity required, consider the following questions.

- *How heterogeneous is the vegetation within the study area?* If vegetation is highly variable in composition and structure, then a larger number of plots is required within the study unit to accurately describe this variation, and to estimate vegetation parameters to a given level of precision. Conversely, where vegetation is relatively homogeneous, it may be appropriate to use fewer plots.

- *What vegetation parameters are of interest?* Because species and vegetation attributes differ in terms of how they vary through space and time, different sampling intensities may be required to accurately estimate the abundance of different species, or to accurately determine different vegetation characteristics.
- *What is the desired accuracy of the results?* The accuracy required in parameter estimates directly affects the number of plots required. Note that more plots are needed to make precise estimates of a vegetation parameter at one point in time than are required to measure changes in the parameter with the same precision. Generally speaking, the larger the changes in vegetation over time, the fewer the plots needed to precisely estimate those changes.
- *How will the plots be located?* A greater number of representatively located plots would be needed to sample the complete range of vegetation or sites present, compared with unrepresentative, subjectively located plots (see section 2.1.1).
- *What resources are available?* The higher costs associated with undertaking surveys in increasingly large areas often mean that lower sampling intensity is used. The average cost of establishing plots varies considerably among areas, often as a reflection of the nature of the terrain and ease of access, as well as the complexity of vegetation.

(b) Doing initial calculations

Some preliminary familiarisation with the vegetation of the study area – a pilot study and/or power analysis using existing plot data – is very useful to address these issues. Initial field reconnaissance can help assess the spatial heterogeneity of vegetation within the study area. Initial field reconnaissance can also help define the boundaries of any areas of special interest (as specified in the study objectives). These may include, for example, areas where a species or community of particular interest is present.

Unmarked temporary plots established in a pilot study can allow stem densities and/or size structures for individual tree species of special interest to be estimated. These data can then be used to provide an indication of the likely number of permanent plots required to obtain an adequate sample of the species to estimate demographic parameters (Peltzer et al. 2005). For example, to accurately estimate a mortality rate of c. 1% for trees of a given species over a period of 10 years, approximately 40 individuals would need to be individually tagged; but accurately estimating the same mortality rate over a shorter period would require a much greater number of individuals to be tagged (Peltzer et al. 2005; see Figure 2).

Simple power analyses using plot data from existing studies in comparable forest types can also be used to approximate the number of sample plots required to estimate vegetation parameters to a given precision. For example, Bellingham et al. (2000) used existing plot data to determine the sample size required to estimate national mean kāmahi (*Weinmannia racemosa*) basal area to within an acceptable error limit. Although national estimates of kāmahi basal area stabilised when c. 230 plots had been sampled (Figure 3), c. 4,160 plots would be needed to obtain national estimates of kāmahi basal area to within 5% of the mean, with 95% probability, due to high variation in kāmahi abundance between plots. To obtain a national kāmahi basal area estimate to within 10% of the mean and 95% probability would require only c. 1,040 plots. This analysis was undertaken at a national scale, but the same principles apply when developing sampling strategies for local plot networks.

As mentioned above, larger numbers of plots are required to detect small changes (between treatments or over time) in a parameter than large changes. For example, using data from permanent plots in the Tararua Forest Park, Husheer (2005) found that 108 plots would be required to estimate a 5% change in kāmahi basal area over time, but only 29 plots would be required to detect a 20% change.

Detailed procedures for conducting simple power analyses are available in statistical textbooks (e.g. Goulding & Lawrence 1992), and analytical packages are available for estimating statistical power from both simple and nested plot designs, and for a wide range of data distributions (e.g. the SIMR package; Green & MacLeod 2016).

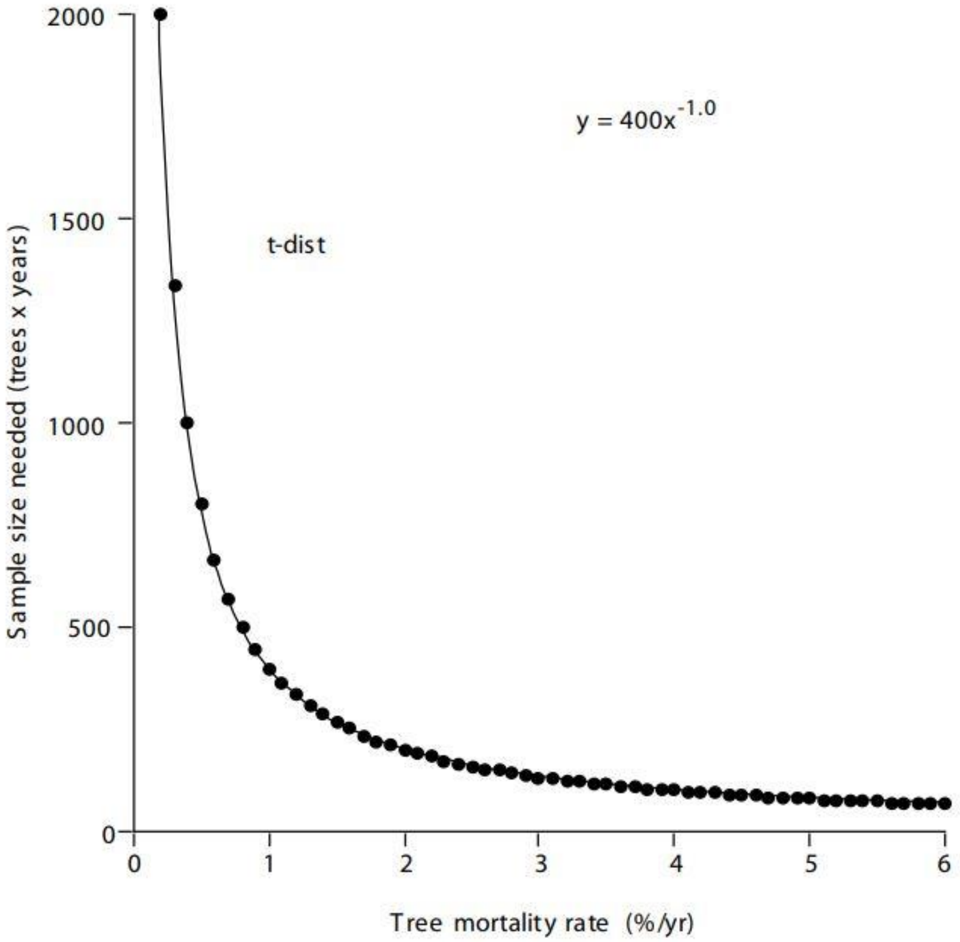


Figure 2. Minimum sample size required (number of trees × years sampled) vs annual tree mortality rate (from Peltzer et al. 2005). This relationship shows the minimum sampling effort in 'tree years' (number of trees × time) in order to detect a given tree mortality rate (%/yr). More samples are required to account for temporal or spatial differences in mortality rates and cumulative tree deaths (i.e. a reduced sample size through time). Sample size is calculated using the minimal detectable effects based on statistical *t* distributions (almost identical results are obtained with chi-squared distributions).

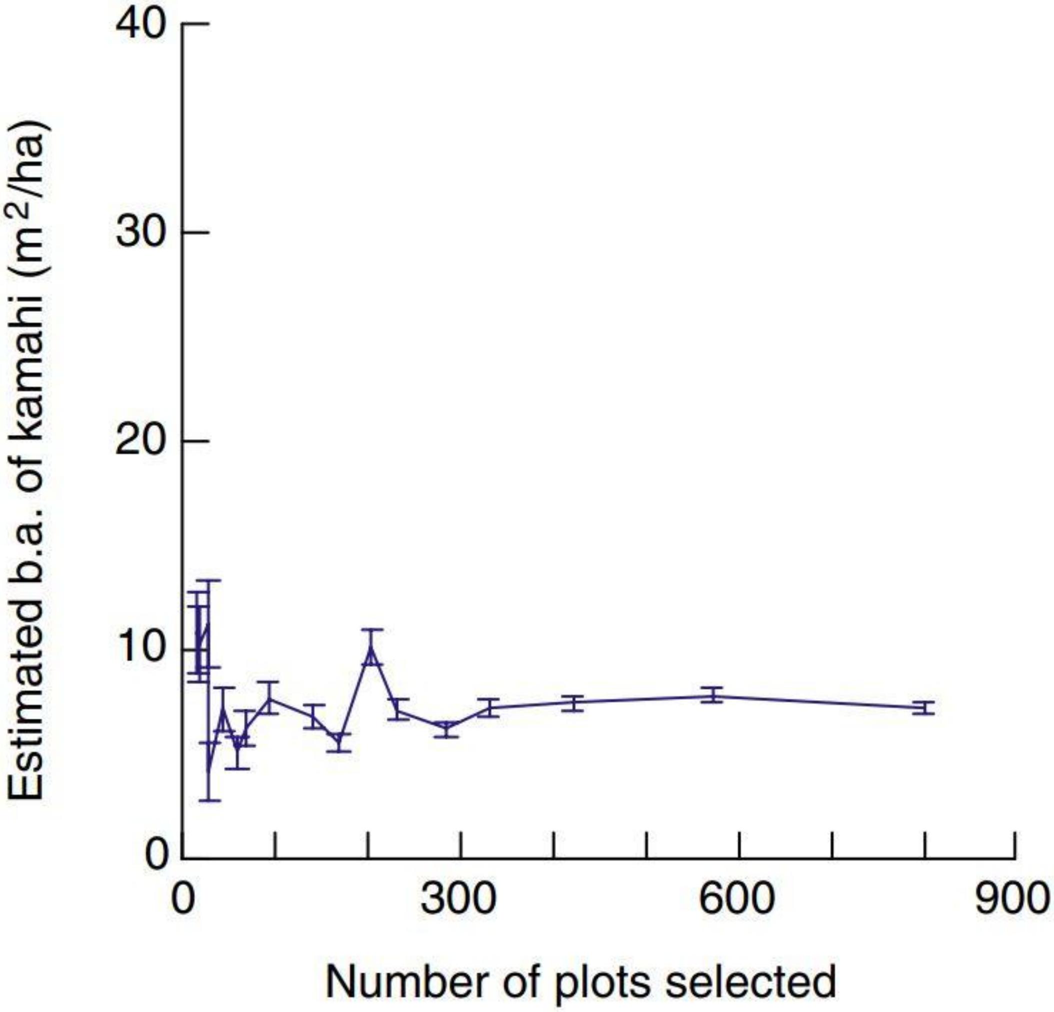


Figure 3. Basal area (b.a.) of kāmahi (*Weinmannia racemosa*) in permanent plots, and associated standard error, for various numbers of plots selected at random from permanent plot networks across New Zealand (from Bellingham et al. 2000). Because kāmahi basal area varies considerably between plots, a large number of plots is needed to obtain a precise estimate of this parameter at a national scale.

3 Pre-fieldwork planning for locating and measuring permanent plots

Pre-fieldwork planning ensures that fieldwork proceeds as efficiently and smoothly as possible, data are of high quality and meet the intended purpose, and the work is completed within budgeted time frames. As part of the overall management of the inventory or monitoring programme, realistic budgets and work plans must be developed, suitable staff selected to undertake the work, and all equipment and resources organised. Quality control procedures should also be considered during the planning phase of a survey (see section 8).

Pre-survey planning includes the following tasks.

3.1 Developing the sampling design

This includes making decisions on the number and arrangement of plots needed to ensure adequacy of sampling to meet specific study objectives. This may necessitate a pilot study, statistical analysis, and/or peer review of the proposed study design.

3.2 Scheduling and logistics

A scoping exercise may be necessary to determine the availability of field skills and the personnel required to measure/establish a plot network. Logistical planning may also be required to determine local service providers (e.g. helicopter transport) and to assess potential access issues (e.g. crossing private land).

3.3 Organising and purchasing equipment.

Equipment required for the completion of permanent plots is detailed in Appendix 2. Obtain all necessary equipment and check that it is in working order before undertaking fieldwork. Ensure spare equipment is on hand in case any is lost or broken.

3.4 Selecting staff

Where required, select a field team coordinator and support staff that have a background in project management and preferably vegetation plot measurement. When selecting staff, consider the fieldwork, vegetation survey, and botanical experience of potential team members and ensure there is a good mix of complementary skills across the team. Accurate identification of plants in the field is a key skill, which underpins all vegetation measures. Therefore, each team needs at least one member with a high level of plant taxonomy knowledge. Selecting appropriate staff will ensure the work runs as smoothly and efficiently as possible without compromising data quality.

3.5 Training staff

This should include instruction in all plot measurement protocols to be followed, with a strong focus on correctly recording and checking data on field sheets. Staff training should also include familiarisation with the use of all field equipment, including GPS receivers, metal detectors, altimeters and other measuring equipment. Training should be provided to ensure all field staff understand health and safety and risk management processes, as well as relevant biosecurity protocols. Additional training in team leadership and coordination should be provided for relevant personnel.

3.6 Pre-season

Before the field season begins, all field staff should be briefed on the logistical and operational processes for field trips.

3.7 Create a detailed field plan

Sufficient time and resources must be available to complete the work to a high standard. The time taken to establish and measure each permanent plot varies considerably depending on the complexity of the vegetation, the difficulty of the terrain, and the experience of the field team, as well as whether any ancillary data are collected.

As a general guideline, a field party of four experienced staff, working in areas with a moderate amount of travel time to get to field sites from base (e.g. several hours' driving or walking), should allow at least one 8- to 10-hour day per plot in relatively species-rich forest types, or half this in less compositionally complex forest types (e.g. beech forest).

When drawing up a field plan, assign potential start and finish dates for each field trip, including extra contingency time for bad weather. If multiple field methods are being undertaken simultaneously, teams should be provided with guidelines on how to prioritise field effort when time is constrained (e.g. due to poor weather). Include in field plans how teams will travel from place to place, and all the associated expenses (e.g. helicopters).

Note that after each field trip a sufficient break should be scheduled in order to deal with collected plant specimens (i.e. arranging pressing and drying; section 7), store field sheets, and restock consumable equipment (see Appendix 2).

3.8 Allocate time for follow up work after fieldwork is complete

Sufficient time must be allocated to identify collected plant specimens and correct field sheets (section 7), and to arrange for data entry, and for the general management and archiving of data (section 9).

3.9 Obtain lists of species likely to be encountered in the survey area

Gather as much information about the vegetation of the survey area as possible, such as the types of plants and communities you are likely to encounter, previous survey reports, species lists (e.g. from botanical societies or the New Zealand Plant Conservation Network; http://www.nzpcn.org.nz/), and (where possible) regional floras. Inaturalist (inaturalist.nz) and the Global Biodiversity Information Facility (gbif.org) are also excellent resources that capture species distribution records. Species lists for surveys archived in the NVS Databank can be obtained via the website (http://nvs.landcareresearch.co.nz).

Compile short field guides and/or keys providing distinguishing features for any genus or species for which identification is likely to be problematic. Compile species lists alongside correct NVS six-letter species codes (see section 5.2). Updated *Flora of New Zealand* taxonomic treatments with excellent images and maps are available as fascicles in PDF format from: http://www.nzflora.info/publications.html

3.10 Obtain permission to cross land and collect specimens

Arrange permission from the landowner or administrator of the land that must be crossed to reach each plot location. Permits must also be obtained from landowners or administrators to collect material such as plant specimens.

For further pre-survey planning specific to the *remeasurement* of permanent plots see section 6.

3.11 Biosecurity

Include mechanisms in logistical planning processes that ensure the field teams are both aware of the biosecurity risks in the areas they are intending to work in and are equipped to deal with those risks. Dealing with biosecurity risks could include developing protocols to abandon or relocate new plots, as well as introducing stringent cleaning and quarantining protocols; the latter, in most cases, will have already been developed by DOC and the Ministry for Primary Industries. As of 2021, access to tracks and forests in several New Zealand regions is restricted because of kauri dieback (caused by the oomycete pathogen *Phytophthora agathidicida*) and myrtle rust (caused by the fungus *Austropuccinia psidii*).

4 Location and layout of new permanent plots

4.1 Overview

When implementing representative sampling designs, the precise plot location in the field must be determined in a truly objective (unbiased) way to ensure data collected are a representative sample of the study area. This can often be facilitated through the use of GPS to locate plot positions. However, note that GPS receivers cannot always be used to determine location, particularly in mountainous terrain or beneath tall or dense forest canopies. On such occasions, alternative procedures to locate the plot must be followed, such as the use of a hip-chain and compass to locate the plot from a nearby landscape feature that may be easily identified on a topographical map.

A predetermined plot location may sometimes fall at a location where it is unsafe or impractical to establish a plot (e.g. bluffs, very steep terrain). Do not establish a plot at the specified predetermined location where doing so would be likely to endanger the field party. For such plots, use the Notes section of a Recce sheet to briefly describe the situation and vegetation, and archive this with the rest of the data from the survey. A plot relocation protocol can be used if a site is unsafe. An example of a plot relocation protocol currently used in New Zealand requires a field team to examine a hierarchical set of 30 alternative plot locations, derived from 10 random bearings at 200 m, 400 m, and 600 m intervals from the original point, sampling the first safe location (DOC 2019a).

4.2 Locating plots at systematic or random sample points

Where plots are to be established at points determined prior to fieldwork, enter the most recent grid reference for each plot into a GPS receiver prior to fieldwork. Check the coordinate system of the grid reference before entering them. If they were collected in New Zealand Map Grid (NZMG) they will need to be converted to New Zealand Transverse Mercator (NZTM).

When GPS reception can be obtained, use it to navigate to within c. 30 m of each plot location. Set the direction function of the GPS receiver to magnetic, and use the GPS waypoint function to obtain a bearing and distance to the plot. Follow the bearing and measure the distance to the plot using a hip-chain or tape. Establish corner P (see section 4.4.1 and Figure 4) at this point. This procedure is recommended because the accuracy with which a GPS receiver can locate any specified point decreases as the point is reached (Burrows 2000).

When GPS reception cannot be obtained, follow a bearing and measured distance using a hip-chain (as above) to locate the plot from a significant nearby landscape feature that can be accurately identified on a topographical map (e.g. stream confluence, high point, bush edge, ridge). Similarly, if there is no GPS reception at corner P, re-fix the position of an identifiable point (e.g. a prominent landscape feature). Use Permolat (painted aluminium strips) to mark each plot position from the chosen significant landscape feature to ensure plots can be easily relocated by future field parties. Where possible, re-fix each plot position with the GPS receiver and record the coordinates on the Recce sheet (see section 5.3.1).

4.3 Locating plots along transects

Where plots are to be located along transects, navigate to the transect origin using a map, compass and GPS receiver (where possible, as outlined above). Mark the transect origin with Permolat. Label the transect origin Permolat markers with the transect number and transect bearing (magnetic), and the distance to the first plot.

When establishing each transect, ensure the compass bearing is accurately followed. Mark the transect using sufficient Permolat so that it will be easily relocated, even if the origin markers go missing. Each successive transect marker should usually be able to be easily seen from the previous one. If a marked transect needs to detour to avoid impassable terrain, ensure accurate distances and waypoints for each leg of the route are recorded.

Using a hip-chain or tape, measure the pre-specified distance along the transect to each plot (typically 200 m). Establish corner P at this point. Where possible, fix each plot position with the GPS receiver and record the coordinates on the Recce sheet (see section 5.3.1). Also, record the transect bearing (magnetic) and GPS reference for the transect origin (where possible) on the Recce sheets of all plots on the transect (see section 5.3).

4.4 Procedure for laying out plot tapes

The layout of a 20 × 20 m permanent plot is shown in Figure 4.

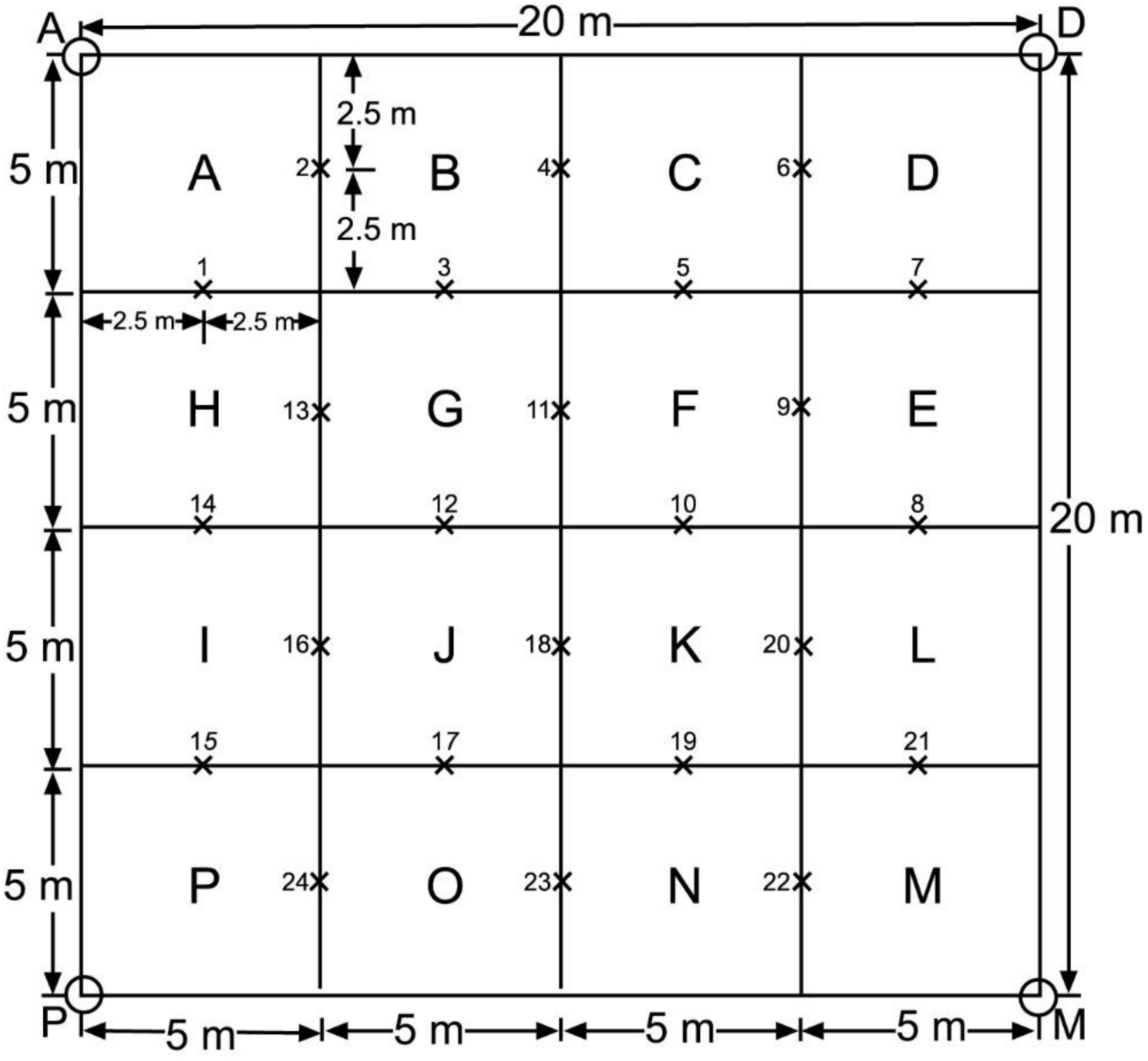


Figure 4. Layout of 20 × 20 m permanent plot (redrawn from Allen 1993) showing location of tapes, corner pegs (A, D, M, P) and understorey subplots (×; 1–24).

4.4.1 Locating plots at systematic or random sample points

When plots are located at *systematic or random sample points*, establish the 20 m plot boundary between corners P and M along the predominant contour of the slope (see Figure 4). While standing at the plot corner, determine the bearing by using a sighting compass to sight on somebody standing 10–15 m away along the contour of the slope.

Take 90° off the compass bearing of the P–M boundary to determine the compass bearing of the P–A and M–D boundaries, and lay out two boundary tapes at right angles to the first. Join the open end along the A–D boundary, with a fourth boundary tape to form a square plot.

When a plot is located on flat terrain (average slope is <5 degrees, see 5.3.2), establish the plot so that the M–P boundary lies in a north–south direction (i.e. corner M is north of corner P).

4.4.2 Locating plots on transects

When plots are located on *transects,* establish the plot so that the P–A plot boundary lies along the transect in the direction of travel. Each plot should be established to the right of the transect (relative to the direction of travel). The P–M and A–D boundaries should be laid out perpendicular to the transect (i.e. add 90° to the compass bearing of the P–A boundary to determine the compass bearing of the P–M and A–D boundaries).

4.4.3 Laying out plot boundary tapes

Use a sighting compass to lay out plot boundary tapes to the correct magnetic bearings. The tapes should be pulled tight when laying out a plot on even ground. When the plot is in a gully or over a ridge, the tapes should generally follow the ground surface. Ignore small bumps or depressions. Where possible take the tape under windfalls, or if that is not possible, pull the tape above them.

Lay boundary tapes out as straight as possible. When trees are located along plot boundaries, include them in the plot when their trunk is predominantly (>50%) rooted within the plot.

Subdivide the plot into 5 × 5 m subplots (*n* = 16) using six internal tapes laid out between opposing boundaries at 5 m intervals to ensure correct shape and area of subplots. Subplots are ordered from A to P, starting in the top left-hand corner (Figure 4). The four plot corners bear the name of their corresponding internal subplot.

Ensure all boundary and internal tapes lie close to the ground to clearly define the plot area and reduce errors during plot measurement. Try to minimise disturbance to the plot area and immediate surroundings to reduce the possibility that changes measured over time will result from measurement activities.

4.4.4 Checking that the plot size and shape are correct

Check that boundary tapes meet at right angles at each plot corner, as follows.

Check that the compass bearings of plot boundary tapes are correct using a sighting compass.

Use a 3–4–5 triangle: measure 3 m along one tape from a corner and 4 m along the adjacent tape, and mark these points. The distance between the two points should be 5 m.

Where practical (i.e. on very open plots with even ground), check that the length of a tape placed between diagonally opposite corners (i.e. A–M and D–P) is 28.3 m.

Check that each boundary tape is 20 m. Note that due to topographic variation across the plot area it will not always be possible to make each boundary tape exactly 20 m, even when the corners are at right angles. This is acceptable if the bearings of the tape lines differ by 90°.

Record the dimensions of the plot (i.e. tape distances) and bearings (magnetic) of boundary tapes on the Recce sheet (see section 5.3). The bearings of plot boundary tapes provide useful information during plot remeasurement, particularly where plot corners cannot easily be re-established due to damaged or missing plot markers.

4.5 Permanently marking the plot

Adequate plot marking is absolutely essential to ensure plot boundaries can be accurately re-established during future plot measurements.

- Mark the centre and each plot corner with a large strip of Permolat attached to an aluminium peg (e.g. 7 mm diameter, 45 cm long) placed in the ground. Ensure you scratch or stamp onto the Permolat strips the appropriate letter i.e. 'C' (centre) or 'A', 'D', 'M', 'P' (corresponding corner; Figure 4). Do not use permanent marker pens. The aluminium peg should be bent at the top to reduce the likelihood of the Permolat falling off.
- At each corner peg, select the nearest live tree outside the plot on which to nail a strip of Permolat and provide corner location information. Label each Permolat strip with the measured distance along the ground, the magnetic bearing *from* the centre of the base of the tree *to* the corner peg, and the appropriate corner letter (e.g. 'Corner A 1.6 m @ 205º'). Nails should protrude by at least 2 cm to allow for tree growth. Adequate Permolat marking near corners is invaluable when plots are to be remeasured, as corner pegs can be lost over time.

Additional means of more permanently marking the plot are recommended, where practical. For example, at easily accessible study sites, wooden or aluminium stakes or waratahs (steel standards) can be used to mark plot corners.

5 Measuring permanent plots

Always thoroughly document plot measurement protocols in the metadata for a survey (see section 9.2.3), and outline in detail any intentional variations to standard plot measurement protocols.

Equipment required for measuring permanent plots is detailed in Appendix 2. Plot data are recorded on Recce, stem diameter, and understorey subplot sheets (Appendices 3–5). Standard field sheets are also available from the NVS website (http://nvs.landcareresearch.co.nz). Print field sheets onto both plain and waterproof paper or card for use in the field.

Note that collecting data over extended periods in wet or cold weather is not advisable, as data quality generally suffers. When the ground is wet, measurement activities can also cause considerable damage to the vegetation on the plot, especially on steep terrain.

5.1 Order of data collection and division of labour

The speed and efficiency with which a team can establish and measure each permanent plot are determined to some extent by the allocation of people to tasks. The following division of labour works well on the majority of plots, but it can be adapted depending on the nature of the vegetation and the skills of the field staff.

1. On arrival at the plot, all field-party members locate plot corners and lay out boundary tapes, working in pairs when necessary to ensure all tapes are correctly laid out (see section 4).
2. Two people are usually needed to measure and record understorey subplot data. This task should be completed early in the plot measurement sequence so that the understorey is as little disturbed as possible. The recorder should also label any collected plant specimens (see section 7) and transcribe species onto the Recce vegetation description sheet as they are encountered.
3. At least two people are needed to measure and record stem diameter and sapling data. On plots with a very dense overstorey it can sometimes be efficient to work in groups of three, with two people taking measurements (e.g. by splitting the tree-tagging, measuring, or sapling counts, into separate tasks).
4. The Recce site and vegetation description can be completed by the team finishing first, who should communicate with all field-party members to ensure all species present on the plot are recorded and assigned the appropriate cover class in each height tier.
5. Before pulling in boundary and internal tapes, the field party should check that all tasks are complete using the quality control checklist (Appendix 9), field sheets are complete to the required standard (Appendices 3–5), and that equipment has been accounted for.

5.2 Plant species nomenclature and coding system

5.2.1 Naming species

The recommended nomenclature authority for New Zealand is Ngā Tipu o Aotearoa – New Zealand Plants database (**https://nzflora.landcareresearch.co.nz/**). The database annually releases date-stamped species lists, which are available from https://datastore.landcareresearch.co.nz/organization/plant-names-database-reports . The use of a date-stamped species lists permits a work programme to achieve taxonomic consistency over a specified time period. The Biota of New Zealand portal (https://biotanz.landcareresearch.co.nz/) can be used to search nomenclatural details in the database (filter the record source to Names_Plants to improve search outcomes).

Plant species should be identified and recorded to a level of taxonomic resolution that the field botanist can confidently recognise as a unique taxon. Where appropriate, record taxon identifications below species level (i.e. to subspecies or variety if relevant). While subspecies and varieties are sometimes raised to species level during data analysis, recording the most accurate identification possible can capture valuable distribution data for subspecies and varieties that are threatened, and also future proofs data against potential taxonomic changes (e.g. a subspecies becomes recognised as a distinct species).

5.2.2 Using the coding system

Plant species must be recorded using a standard species-coding system to guarantee that data can be interpreted in the long term. Key requirements of the species coding system are that:

- each taxon is recorded using a unique code that applies *only* to that taxon
- codes used for each taxon are *consistent* within and between surveys.

Before beginning fieldwork, all survey participants should be familiar with the species-coding system, be aware of potential non-intuitive species codes, and know how to check that the species codes used are correct. Rules for constructing species codes are outlined as follows.

(a) Coding species

- Each plant species is represented using a unique six-letter NVS code on field sheets and in electronic data once the data are entered. The species code usually consists of the first three letters of the plant genus (upper case) followed by the first three letters of the species name (lower case). For example, *Pseudopanax crassifolius* is recorded as PSEcra on all field sheets. The current catalogue of species codes is maintained by the NVS Databank team and is directly linked to Ngā Tipu o Aotearoa – New Zealand Plants Database (https://nvs.landcareresearch.co.nz/Resources/NVSNames).
- Where only the genus is able to be determined due to a lack of identifying features (e.g. *Parsonsia*), use the first six letters of the generic name (written in upper case on field sheets; e.g. PARSON).

- Some taxa have not been formally described (e.g. *Coprosma* sp. (d)) but are generally recognised as distinct and are listed on the Ngā Tipu o Aotearoa – New Zealand Plant Database (http://nzflora.landcareresearch.co.nz/). For such species the code should consist of the first three letters of the genus (upper case) followed by the letter used to identify the informal species (lower case) (e.g. COPd).

(b) Non-intuitive species codes

- The simple species-coding system outlined above provides a unique code for most taxa. However, following this coding system, some six-letter codes could denote more than one taxon. For example, the intuitive code for both *Pseudopanax colensoi* and *Pseudowintera colorata* is PSEcol. To ensure each taxon receives a unique code, non-intuitive codes are used for some species (e.g. the code for *Pseudopanax colensoi* is NEOcol).

- Be aware of any non-intuitive codes for species you are likely to encounter during the survey. A list of some common non-intuitive codes for vascular plants in the New Zealand flora is given in Appendix 6, but others may be devised as a result of ongoing taxonomic revisions.

- *Do not* use *ad hoc*, non-standard plant species codes, because at a future date these are likely to be misinterpreted by people unfamiliar with the data set. Where there is any possibility of ambiguity, or if you are in doubt about the correct six-letter species code, write out the plant name in full.

(c) Coding subspecies and varieties

- For subspecies and varieties, various methods have been used to construct unique species codes. The species code usually consists of the first three letters of the plant genus (upper case), followed by the first letter of the species name (lower case), followed by either an 's' or 'v' (to denote subspecies or variety), followed by the first letter of the subspecies or variety name (lower case).
- For example, *Polystichum neozelandicum* subsp. *zerophyllum* is denoted as POLnsz on field sheets, while *Ascarina lucida* var. *lanceolata* is denoted as ASClvl. These conventions ensure the intended taxonomic concept is clear and unambiguous. In contrast, note that if a plant was identified in a wider sense (i.e. to species level), then, for the previous examples, *Polystichum neozelandicum* would be recorded as POLneo, and *Ascarina lucida* as ASCluc.
- Because of the potential for duplicate species codes, the codes used for some subspecies and varieties do not follow the standard system (e.g. *Olearia virgata* var. *lineata* is denoted as OLEvli). Always refer to the list of six-letter species codes to check that the species code recorded is correct.

(d) Coding hybrids

- For hybrids with a recognised hybrid name (e.g. *Coprosma cunninghamii = Coprosma propinqua* × *C. robusta*), the code consists of the first three letters of the genus (upper case) followed by an x (to denote the hybrid status of the plant) and the first two letters of the hybrid name (e.g. COPxcu for *Coprosma cunninghamii*).

- For hybrids without a recognised hybrid name (e.g. *Fuscospora cliffortioides* × *F. truncata*), the code should consist of the first three letters of the genus (upper case) followed by the first letter of each putative parent (lower case) separated by an × (e.g. FUScxt for the mountain x hard beech hybrid).

5.2.3 Checking that species codes used are correct

- Before starting fieldwork, obtain an up-to-date list of all species codes currently used in the NVS Databank from the NVS website (https://nvs.landcareresearch.co.nz/Resources/NVSNames), and use this list during and following data collection to check that each six-letter code used is correct.
- Also, before starting fieldwork, reconcile any lists of plant species that are expected to be encountered on the survey (e.g. regional flora lists or plant identification books, species lists compiled by botanical societies, species lists from nearby vegetation surveys) against the correct six-letter species codes. Species lists for surveys archived in the NVS Databank can be obtained via the website (http://nvs.landcareresearch.co.nz).
- Because of ongoing taxonomic revisions, at any point in time there may be recognised published species that have not yet been incorporated into the list of species codes used in the NVS Databank. Use the search functions on the New Zealand Plant Names Database (Ngā Tipu o Aotearoa – New Zealand Plants; http://nzflora.landcareresearch.co.nz/) to check that each species name is current or recognised.
- When a species name does not yet have an assigned six-letter species code, contact the NVS Databank manager (email nvs@landcareresearch.co.nz), who will arrange for the species to be added to the NVS Databank list and provide you with the new NVS code for the species. *Do not* assign *ad hoc* six-letter codes to any species without checking with the NVS Databank manager, as the code could conflict with a six-letter code already assigned to another vascular or non-vascular species.
- If a formally recognised species is not listed on the New Zealand Plant Names Database, use the feedback function on the New Zealand Plant Names Database website and/or contact the NVS Databank manager.

5.2.4 Documentation of plant species recorded in metadata

Despite the general rules outlined above, achieving consistency in the use of species codes within and among surveys has proven difficult. Ongoing taxonomic revisions mean that historical data normally include out-of-date species codes, and the uptake of taxonomic name changes can be slow. The following 'best-practice' guidelines are recommended to help ensure species codes are used consistently within a vegetation survey, and that the intended meaning of each species code used in a survey is documented.

- During the survey, maintain a list of the full taxonomic names of every species recorded, along with the six-letter codes used on field sheets. An easy way to create and maintain this list during fieldwork (e.g. at the field base) is to mark species off on

the master list of species codes currently used in the NVS Databank as they are recorded in the survey.
- Document the basis of nomenclature followed for individual species or logical groups of species (e.g. ferns, grasses), preferably conveyed by reference to a standard authoritative work. In lieu of an authoritative reference for each species, plant identification texts can be referenced, where used to identify all species within certain groups of plants (e.g. all fern species). Include information on the edition and year of publication.

5.3 Recce description

A Recce description should be completed on each permanent plot at every remeasurement. The site description data provide essential information for many analyses, while the vegetation description provides the most complete record of the composition of the plot, as it will include rare or epiphytic species that may not be included in the stem diameter, sapling, or understorey data. In addition, it provides an indication of the dominance of lianas in subcanopy and canopy tiers. Recce descriptions undertaken on 20 × 20 m plots should be 'bounded' to the plot area; in other words, they should include only those species present within the plot boundary.

Plot identification information and descriptive data on the site and vegetation (sections 5.3.1–5.3.4) are recorded on the front side of the sheet. An example of a completed Recce sheet is provided in Appendix 3a. Take the following steps when measuring and recording the plot identification and site data.

- Limit data to constrained categories (where these are supplied). For example, do not record drainage as 'okay'; always record it as 'good', 'moderate', or 'poor'. Use the Notes section where justification or further detail is required.
- Confer with other field-party members if you are at all unsure of the value for a data field. This applies especially where subjective visual assessments are required (e.g. surface characteristics and ground cover).
- Ensure data are legible. Neatly record data to minimise any possibility they will be misread or unable to be interpreted.
- Do not leave any field on the data sheet blank. Where data are intentionally not recorded in a data field (e.g. the sub-catchment in which the plot is located is unnamed), record a dash ('—') or 'none' to ensure the data are not interpreted as missing. Record 'not measured' where data were not measured for whatever reason.

5.3.1 Plot identification information and location

Plot identifier:	Record the unique identifier for the plot (including the transect line number where appropriate). Ensure the unique identifier is recorded on both sides of the Recce sheet in case it is photocopied onto separate sheets.
Survey:	Record the name of the survey (e.g. Kokatahi).

Region:	Record the region (e.g. Westland).
Catchment:	Record the name of the catchment in which the plot is located (e.g. Whitcombe River).
Sub-catchment:	If the plot is located in a named river or creek running into the main catchment, record this as a sub-catchment (e.g. Vincent Creek).
Measured by:	Record the *full* name of the person(s) doing the plot measurement (e.g. Larry Burrows).
Recorded by:	Record the *full* name of the person(s) recording the descriptive data (e.g. Susan Wiser).
Permanent plot:	Circle Y (yes) or N (no) to indicate if the plot is permanently marked.
Date:	Record the day, month, and year in *full* (e.g. 3 March 2005). For plots that take more than 1 day to measure, record both the first and final days of plot measurement.
Topographical map:	Record the topographical map series, map sheet number, and name (e.g. Topo 50, BV18 - Kokatahi).
GPS reference:	Record the make and model of the GPS receiver (e.g. Garmin 64S). Where possible, a GPS reference should be recorded using a GPS receiver, for consistency this should be taken at corner P of the plot. This provides accurate location information (important for some data analyses, as well as to facilitate future plot re-location). Record the Easting and Northing in the space provided, preferably using seven-figure NZTM coordinates (e.g. (Easting) 1652112, (Northing) 5319823).
GPS fix:	Circle whether a single position was measured or if the position was averaged (see GPS accuracy below). Circle if it was 2D or 3D fix, this is relevant for older model receivers only – a 2D fix requires only 3 satellites and cannot measure altitude (i.e. assumes sea level). It is important to ensure the GPS receiver is set to the datum relevant to the topographical maps used. Early topographical maps (1972-2000) used the New Zealand Map Grid (NZMG) projection, defined in terms of the New Zealand Geodetic Datum 1949 (NZGD1949). Contemporary topographical maps (e.g. NZTopo50, 2001 onwards) produced by Land Information New Zealand use the New Zealand Transverse Mercator (NZTM) projection, based on the New Zealand Geodetic Datum 2000 (NZGD2000). Circle which geodetic datum was used to obtain the GPS reference (i.e. NZGD1949 or NZGD2000). Be aware that older GPS references (pre-2001) were likely taken using the NZMG projection (NZGD1949) and will differ substantially in position when plotted onto contemporary maps that use the NZTM projection (NZGD2000) (see http://www.linz.govt.nz/).

Ensure the plot location is correctly marked on a topographical map and, if applicable, on an aerial photograph (where available). Note that there will be times and places (e.g. mountainous terrain) where it is very difficult to obtain a GPS fix at a plot location. In these instances, try to obtain a reading from the nearest high point or canopy gap where good reception can be found. Record this position in the approach notes and mark it on the location diagram. Measure the distance and direction to the plot using compass and hip-chain or tape, and record this information in the approach notes. More detailed information on using GPS receivers can be found in Burrows 2000.

GPS accuracy: For Garmin GPS receiver units that are 60 series or older, average a waypoint, allowing 30 measurements. For Garmin 62 units or newer, use the multi-sampling averaging function. The unit will display 100% once the averaging process is complete; circle Y (yes) on the plot sheet to confirm 100% averaging. To obtain the accuracy displayed in metres, immediately scroll through to the satellite page after averaging. For greater accuracy, average the waypoint twice, waiting for a minimum of 90 minutes between. Record the accuracy obtained (e.g. ±4 m).

GPS location: Circle CORNER P if this is where the GPS reference was taken (preferred) or record the GPS reference location.

Approach: Record detailed instructions on how to get to the plot. Include information on the location of the plot in relation to prominent features of the landscape or vegetation. Record any important GPS waypoints along the approach route. Where plots are located on transects, record the compass bearing of the transect and the GPS or map reference for the transect origin. Also record if you found the line start, how this was marked, if you followed a Permolat line to plot, record the colour of the Permolat.

Accurate and detailed approach notes are very important for the future re-location of plots. *Do not* assume that GPS references will be completely adequate for re-location purposes. The description should be sufficiently detailed to enable people who have not previously been to the plot to locate it without extensive searching. Do not copy previous approach notes but ensure that any points of confusion or misleading notes from the previous measurement are clearly explained.

Location diagram: Sketch the route to the plot, emphasising prominent landscape or vegetation features (e.g. ridges, gullies, streams, slips, bluffs, roads, large tree-fall gaps). Indicate all features for which GPS grid references are provided in the approach notes.

Location diagrams should always have an arrow indicating north (magnetic), and the direction of flow of any streams or rivers should be indicated.

Plot layout: Measure and record the bearings (magnetic) and tape distances of the four boundary tapes (e.g. A→D, D→M, M→P, and P→A). Record each bearing to the nearest degree using a sighting compass, and each tape distance to the nearest 0.1 m.

Vegetation description and notes: Provide a short description of the vegetation on the plot and any additional observations or impressions, such as evidence of erosion, disturbance, pest impacts or notable features of the topography. Information recorded here should provide a general impression of what the plot looks like (see example in Appendix 3a).

5.3.2 Site description

Site data collected provide important information on abiotic factors that may influence vegetation structure and composition. As a minimum, a set of basic, readily obtainable measures is required, as outlined below.

Altitude: Determine the altitude using a barometric altimeter, or use the GPS coordinates to determine the plot position on a topographical map (or the map loaded onto the GPS receiver) and then use the map contour lines to determine the altitude. Record altitude to the nearest 10 m. If using a barometric altimeter, it should be calibrated from a known spot-height on the topographical map each morning before work starts, and more frequently in changeable weather.

Altitude should not be directly read from GPS receivers because the reading can be inaccurate. Some models of GPS receiver contain in-built barometric altimeters: check the specifications of the GPS receiver used.

Physiography: Circle the applicable option from: ridge (including spurs), face, gully, or terrace. When more than one category could apply, circle the predominant physiography and record any major change in physiography within a plot in the Notes section.

Note that in addition to the standard methodology, more detailed landform classifications have sometimes been used in studies focused on relationships between vegetation composition and landform (e.g. Myers et al. 1987; Rose, Harrison et al. 1988; Whitehouse et al. 1990). For example, Dalrymple et al. (1968) developed a general nine-unit land surface model that has been used with Recce descriptions (see Selby 1982 for details).

Aspect: Determine the physiography of the plot before measuring the aspect.

Use a compass to measure the predominant aspect at right angles to the general lie of the plot, to the nearest 5° (magnetic). Aspect cannot be determined on flat or almost-flat plots (slope <5°) and should be recorded as 'X'. Do not use zero to record aspect on flat plots, as this will be misinterpreted as a northerly aspect. Where there is a major change in aspect across the plot, record the predominant aspect.

Slope: Use a clinometer (or equivalent instrument) to measure the average slope of the plot along the predominant aspect, to the nearest degree. From the middle of the plot, sight the clinometer on an object at eye level near the upslope and downslope boundaries of the plot, and average the two readings.

Parent material: Identify the predominant bedrock type or parent material. This can often be determined prior to fieldwork from geological survey maps. Copies of geological survey maps are available in libraries and can be obtained from GNS Science (http://www.gns.cri.nz/). Where available, the QMAP geological map series at 1:250,000 scale should be used, which supersedes the Geological Map of New Zealand (GMNZ) 1:250,000 ('four miles to the inch') series.

Where the field party contains staff with expertise in the identification of rock types, any disagreement with the broad map classifications can be noted in the field, particularly when there are extrusive/intrusive rocks. Circle the relevant option to record whether parent material was derived from the mapped classification or was observed in the field. If you are unaware of the parent material while in the field, record 'Unknown'.

Drainage: Circle the applicable option from good (fast runoff and little accumulation of water after rain), moderate (slow runoff, water accumulation in hollows for several days following rain), or poor (water stands for extended periods).

This subjective, point-in-time drainage assessment will probably identify extremes in soil drainage only. Several other soil drainage scales have been used previously on Recce descriptions (e.g. Taylor & Pohlen 1962), but they do not overcome this limitation.

Mesoscale topographic index: Use a clinometer (or equivalent instrument) to measure the angle from the centre of the plot to the horizon at eight equidistant (45°) magnetic compass bearings. Record whether each angle is above (+) or below (−) the horizontal. Move around the plot if necessary. When the horizon angle is obscured (e.g. by low cloud or dense vegetation), estimate the horizon angle and make a note that the recorded value is an estimate (e.g. −8° (est)). An estimate of the horizon can be made by projecting ridges using your knowledge of the plot based on your observations as you travel to and around the plot (lowest visible light is not necessarily the horizon). If measuring or estimating the horizon is impossible, then record 'obscured'. When all eight values are averaged, the resulting value provides an indication of the relative protection (e.g. high values) or exposure (e.g. low values) of the site (McNab 1993). It is also possible to calculate a metric of plot protection in the landscape using a Digital Elevation Model in a geographic information system.

Terrain shape index: Use a clinometer (or equivalent instrument) to measure the angle from the centre of the plot to eye-level 20 m from the centre of the plot at eight equidistant (45º) magnetic compass bearings. Record whether each angle is above (+) or below (−) the horizontal. The index is a quantitative description of surface shape and is used in forestry as an explanatory variable for metrics such as tree height (McNab 1989). It would be useful to have a second person and an extra 20 m tape for measuring terrain shape index. To save time, measure the terrain shape index while measuring the mesoscale topographic index.

Surface characteristics: Record the following for the plot.

Percentage bedrock, percentage broken rock: estimate the percentage of the plot ground surface comprising bedrock and broken rock (>2 mm) to the nearest 5%. Include all rock that is evident, even if covered by vegetation, moss, or a thin layer of litter.

Size of broken rock (>2 mm): record whether rocks greater than 30 cm (>30 cm) or less than 30 cm (<30 cm) form the predominant cover of broken rock by circling the relevant option. If there is no broken rock, cross out both options.

Mode of transport of broken rock: classify (if possible) whether broken rock was mostly deposited as a result of alluvial (river deposits), colluvial (erosion debris), moraine (glacial deposits), or volcanic activity.

Note that previous versions of the Recce description method (Allen 1979, 1992; Allen & McLennan 1983) also required the presence or absence of rock and bedrock to be recorded. In this manual the modes of transport ('Description' in previous manuals) include the range of deposition modes likely to be encountered.

5.3.3 Vegetation parameters

Note that the following vegetation parameters are estimated visually, and as such they are relatively subjective. They are included because of their use in demonstrating marked differences between plots or through time, and provide a data user with a better impression of what the plot looks like. These variables have been used in studies of vegetation dynamics (e.g. Harcombe et al. 1998; Wiser et al. 1998).

Ground Estimate the percentage of the plot area (to the nearest 5%), below

cover: 1.35 m, that is covered by the following.

Vascular vegetation: live, vascular vegetation, including foliage, tree trunks and exposed roots. Note that tree trunks and exposed roots normally comprise only a very small portion (usually <1%) of vegetative cover. As this estimate is of actual vegetation cover, any gaps in the vegetation are excluded from it.

Non-vascular vegetation: all non-vascular vegetation, including mosses, liverworts, hornworts, lichens (including crustose species) growing on soil, litter, coarse woody debris, and rock, and non-vascular plants growing as epiphytes on other living plants, stems and roots, and on dead-standing stems.

Litter: visible dead plant material that is detached from the live plant (including leaves, dead logs, and branches) that is in contact with the ground. This includes litter among low-growing vegetation.

Bare ground: exposed soil not covered by litter, vegetation, moss, or rocks.

Rock: exposed rock, either broken rock or bedrock, not covered by vegetation, moss or litter.

The above five values must sum to at least 100%, but because of multiple layers of overlapping cover they will normally sum to more than 100%. As plots are not flat (e.g. there may be hollows or cliffs present), it is best to imagine flattening these features and estimating ground cover as a proportion of the entire flattened surface. Note that in some historical Recce data, percentage ground cover estimates may have only included the top intercept, so that the sum of cover in all classes was 100% (Allen 1979; Allen & McLennan 1983).

Average top height: Estimate the average top height of the dominant vegetation on the plot, to the nearest metre. For low-statured communities (i.e. where average top height is <1 m), these are recorded to the nearest 0.1 m. Here the dominant vegetation is defined as all vegetation in the tallest tier (as recorded on the Recce vegetation description; see section 5.3.5) with an overall cover of >25% (i.e. overall cover class of ≥4). Where none of the tiers have cover >25%, average top height should be averaged across the entire plot.

Height estimates should be calibrated regularly, with heights measured using a tape (e.g. 8 m builder's tape), height pole, hypsometer or equivalent instrument.

Note that in previous manuals (Allen 1979, 1992; Allen & McLennan 1983) this parameter was termed 'mean top height', a term that may be confused with more formal definitions used in forestry literature; and that in structurally complex vegetation, the vegetation to be included was at the discretion of the observer.

Canopy cover Visually estimate the total canopy cover of the plot above 1.35 m, to

(%): the nearest 10%. Canopy cover is the vertical projection over the plot area of all vascular and non-vascular live or dead material (leaves, trunks and branches) >1.35 m above the ground. This measure reflects how much light to the ground surface is blocked. Use the Canopy Cover Scale (Appendix 7) to help arrive at this estimate. In plots with a dense subcanopy, several estimates may need to be made from different positions around the plot (e.g. the centre and four other points, halfway between the centre and each of the plot corners) and then averaged.

Alternative, less subjective estimates of canopy cover can be obtained using a canopy densitometer. This instrument consists of a mirror that when held horizontally below the canopy, reflects the view of the canopy. Cover can be assessed at evenly distributed points across the 20 × 20 m plot area. Each point where the marked crosshairs at the centre of the mirror appears to be covered by canopy is counted, and the proportion of canopy-covered points out of all those sampled is converted to a percentage. Note that the accuracy of the overall canopy cover estimate obtained depends on the number of points assessed (see Stumpf 1993).

5.3.4 Additional biological information

Cultural: Record direct evidence of human interference within the plot boundary using the categories provided (logged, burnt, tracked, cleared, mined, grazed [by domestic stock], none). Use the Notes section to justify your choice(s), where necessary, or to record indirect evidence of human activity.

Treatment: Has a treatment been applied to the plot (e.g. 'fenced' or 'not fenced' for plots that are part of a grazing exclosure trial). Record not applicable (NA) when plots are not part of an experimental trial.

Fauna: Record the presence of any mammalian, bird, reptile, or invertebrate species that can be positively identified by sight or sound. Note that only birds may have been noted on historical Recce descriptions (Allen 1979, 1992; Allen & McLennan 1983).

Browse: Record conspicuous browsing damage in all height tiers to plant species on the plot using the following categories.

Light (L): browse on one or two shoots only, on only a few of the plants of the species present.

Medium (M): browse on more than one or two shoots, but most plants of the species not browsed.

Heavy (H): browse on most accessible shoots on most plants of the species.

Record the animal responsible where this can be reliably determined (e.g. ungulate, goat, deer, tahr, chamois, possum, insect, rabbit, hare), or record 'unknown'. If necessary, use binoculars to closely observe canopy foliage. Possum-browsed leaves often have torn edges and jagged leaf stubs, while insect damage typically consists of holes and wavy, clean-edged browse or straight, finely milled edges (Payton et al. 1999). Refer to Payton et al. 1999 for examples of typical insect and possum browse on some common tree species.

General observations on animal impacts can also be recorded in the Notes section (e.g. bark stripping and the height of browsing).

There are more detailed, quantitative and repeatable methods to monitor animal impacts on vegetation (see section 10), and to monitor animal distribution and abundance (e.g. Baddeley 1985; Forsyth 2005; National Pest Control Agencies 2015). Such methods may be used in conjunction with permanent plots, depending on the objectives of the monitoring programme.

5.3.5 Recce vegetation description

On the reverse side of the Recce sheet, vegetation structure and composition are described in height tiers (strata) using cover classes (Appendix 3b). When establishing new permanent plots, 'bounded' Recce descriptions are undertaken that survey only the 20 × 20 m plot area.

In the past, Recce vegetation descriptions undertaken on permanent plots were often not restricted to vegetation occurring within the 20 × 20 m plot area, and species may have been included that only occurred outside the plot boundary tapes (i.e. 'unbounded' Recces). In bounded Recce plots, all vegetation within the three-dimensional plot is included in the vegetation description, including any foliage overhanging the plot from plants rooted outside the plot boundary tapes.

Observe the following guidelines when completing the Recce vegetation description.

(a) General guidelines

- *Apply high taxonomic standards:* reporting changes in plant biodiversity over time and between areas requires consistent, accurate taxonomic standards. Follow the rules for assigning standard six-letter species codes when recording data (section 5.2) or record species' names in full. When a species is not known, collect a specimen for later identification at the field base or office (section 7).
- *Make a thorough attempt to record all live vascular species present on the plot:* where identifiable, dead annual species or browned-off geophytes (i.e. terrestrial orchids) are to be included in height tiers. To capture these, record the species as present (cover score of 'P') against the relevant height tiers. Record a note 'dead' to the left of the species code. (Appendix 3b). Do not include dead plants of other perennials.

- Record the following readily identified non-vascular species and genera when present: *Atrichum androgynum, Cyathophorum bulbosum, Dawsonia superba, Dendroligotrichum dendroides, Dicranoloma, Leucobryum candidum, Ptychomnion aciculare, Sphagnum*, *Weymouthia cochlearifolia* and *Weymouthia mollis*. More detailed data on non-vascular species composition can also be collected as an addition to the standard protocol (see section 10).

(b) Cover classes and height tiers

- *Use the standard fixed-height tiers* (Figure 5): fixed-height tiers provide standardised and repeatable data that are readily comparable between plots within a survey and between surveys. Fixed-height tiers follow a contour that is perpendicular to the ground surface, the tiers occupied by a plant are relative to its rooted position (Figure 6). Plot boundaries are defined vertically with respect to the ground surface (Figure 6). For foliage overhanging the plot from plants rooted outside the plot boundary tapes, estimate the height tier relative to the plants rooted position. Note that these tiers differ from those used on standard grassland Recce descriptions (Wiser & Rose 1997).
- Use the standard cover-abundance scale (Table 1) to assign a cover class to each species with live foliage in each tier (tiers 1–7): the standard cover-abundance scale is modified from the Braun-Blanquet cover-abundance scale (Mueller-Dombois & Ellenberg 1974). Several other cover-abundance scales exist, of which those of Bailey & Poulton (e.g. Leathwick 1987) and Braun-Blanquet (e.g. Allen et al. 1991) have been used to collect Recce description data in New Zealand. The standard cover-abundance scale should be used (Table 1), as it is simple and comparable with most data previously collected from Recce descriptions in New Zealand.
- The use of a cover-abundance scale, rather than recording continuous percentage canopy cover estimates, allows rapid data collection and speeds up fieldwork considerably, is more repeatable, and affords greater ease of training. In contrast, recording continuous percentage-canopy-cover estimates gives a false sense of precision, and different observers will rarely agree. The use of roughly logarithmic cover-abundance scales provides greater precision for species that are comparatively small and uncommon, and also improves consistency; for example, it is easier to tell the difference between 1% and 2% than between 51% and 52%.
- The cover class assigned to each species in each tier represents the percentage of the plot area covered by a vertical projection downwards of the outermost perimeter of the crown of each plant (Daubenmire 1968; Jennings et al. 1999). Small openings within the crown of each plant are included in cover-class estimates, and care should be taken not to bias the estimate because of high or low foliage density. Cover class estimates are less susceptible to seasonal variation in leaf phenology than indices that take foliage density into account.
- Plant species are deemed to be present in a height tier only when they have living foliage within that tier. For example, if a thin layer of *Rubus cissoides* only occurred c. 10 m above the ground, it would be recorded in tier 3 (5–12 m); and if a *Weinmannia racemosa* had foliage in each of tiers 1 through 6, then it would be recorded in all these tiers.
- Use the canopy cover scale in Appendix 7 to help determine percentage canopy cover and assign cover classes.
- An exception to the living foliage rule is if a species is rooted in the 20 × 20 m bounded area but all the foliage is outside the plot (leaning out). To capture this, record the species as present (cover score of 'P') for tier 6 only (regardless of the height of the foliage outside of the plot). Record a note 'leaning out' to the left of the species code (Appendix 3b).

- Note that cover estimates represent the absolute rather than relative proportion of vegetation present in a stratum. For example, if mountain beech formed a monospecific canopy, with a cover of 40%, it would be recorded with a cover-class of 4, not as 100% of the stratum (cover-class of 6).
- *For parasitic plants with no foliar cover* (e.g. *Gastrodia* spp.): record the species as present, and record a cover score using the standard cover-abundance scale for the corresponding height tiers where plant parts occur (excluding reproductive material).
- *Fallen dead trees* (i.e. logs) are considered ground substrate as they are touching the ground surface, and any plants growing on these should be recorded in the appropriate tiers 1-6.
- *The epiphyte tier (tier 7)* includes any plant growing on another living or dead standing plant/branch that is suspended off the ground surface. Parasitic plants (e.g. mistletoes), where present, are also recorded in the epiphyte tier. Plants growing on live roots of other plants should also be listed as epiphytes if they are growing on the root itself, not in soil or litter that has accumulated around it.
- *Lianas* are recorded in all tiers in which their foliage occurs.
- *Use the standard cover-abundance scale (Table 1) to assign an overall cover class to each tier (tiers 1–6)*: for each height tier the overall cover class is the total canopy cover of all species collectively in that tier (*not* the sum of the cover classes for each individual species). The overall canopy cover of each tier will therefore never exceed 100% (cover class of 6), but must always be equal to or greater than the highest of the cover classes recorded for any individual species in the tier. For each tier, record the overall cover class in the row labelled ‘Overall cover’ (see Appendix 3b).

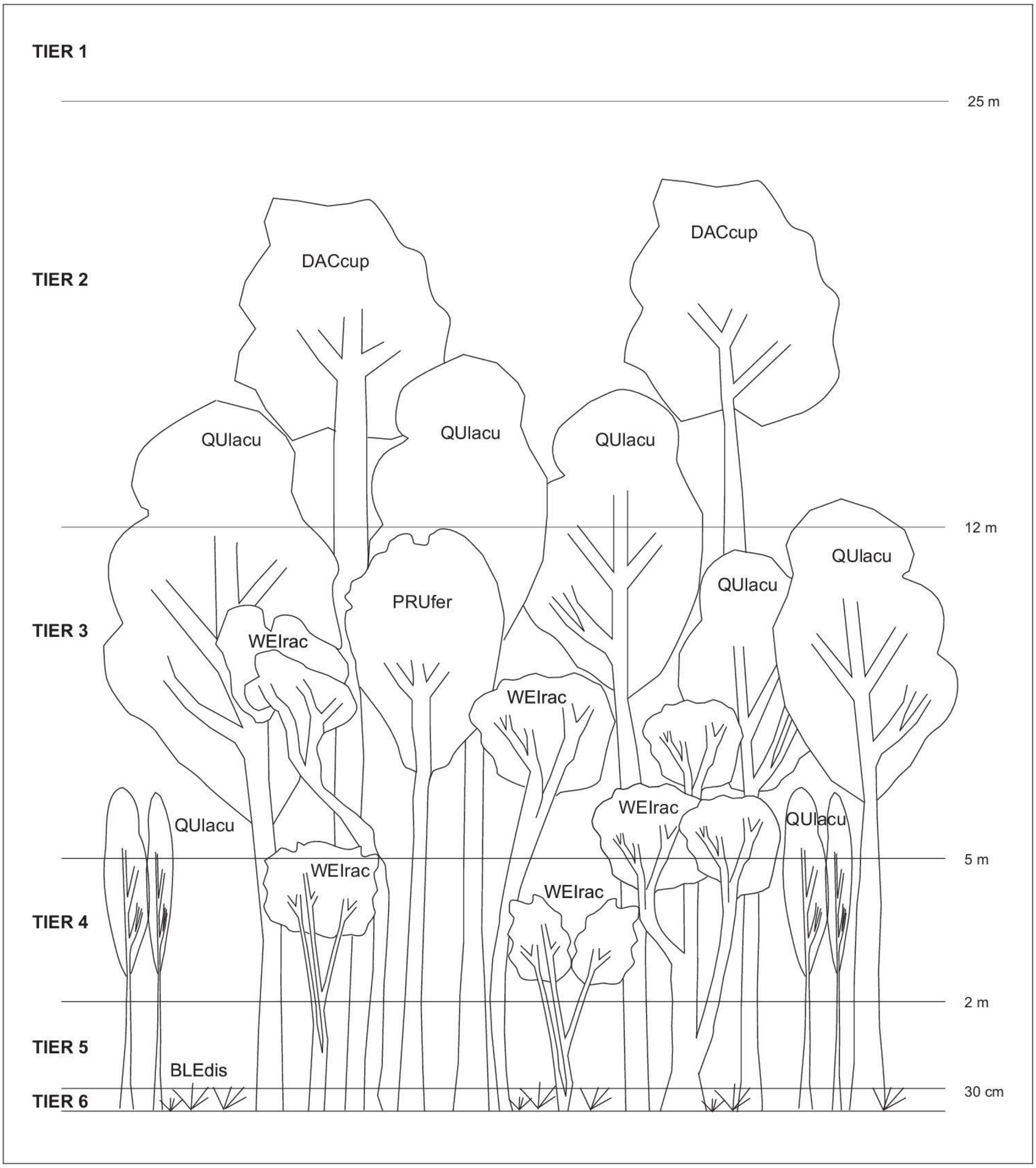


Figure 5. Height tiers used for Recce descriptions on permanent plots. A seventh 'tier' includes all epiphytes (not shown). In this example, *Quintinia acutifolia* (QUIacu) would be recorded in tiers 2 (12–25 m), 3 (5–12 m) and 4 (2–5 m) as it has cover in all of these tiers. By contrast, miro (*Prumnopitys ferruginea*, PRUfer) would be recorded only in tier 3 (5–12 m), and rimu (*Dacrydium cupressinum*, DACcup) only in tier 2 (12–25 m). Crown fern (*Blechnum discolor*, BLEdis) would be recorded in both tiers 5 (0.3–2 m) and 6 (<0.3 m).

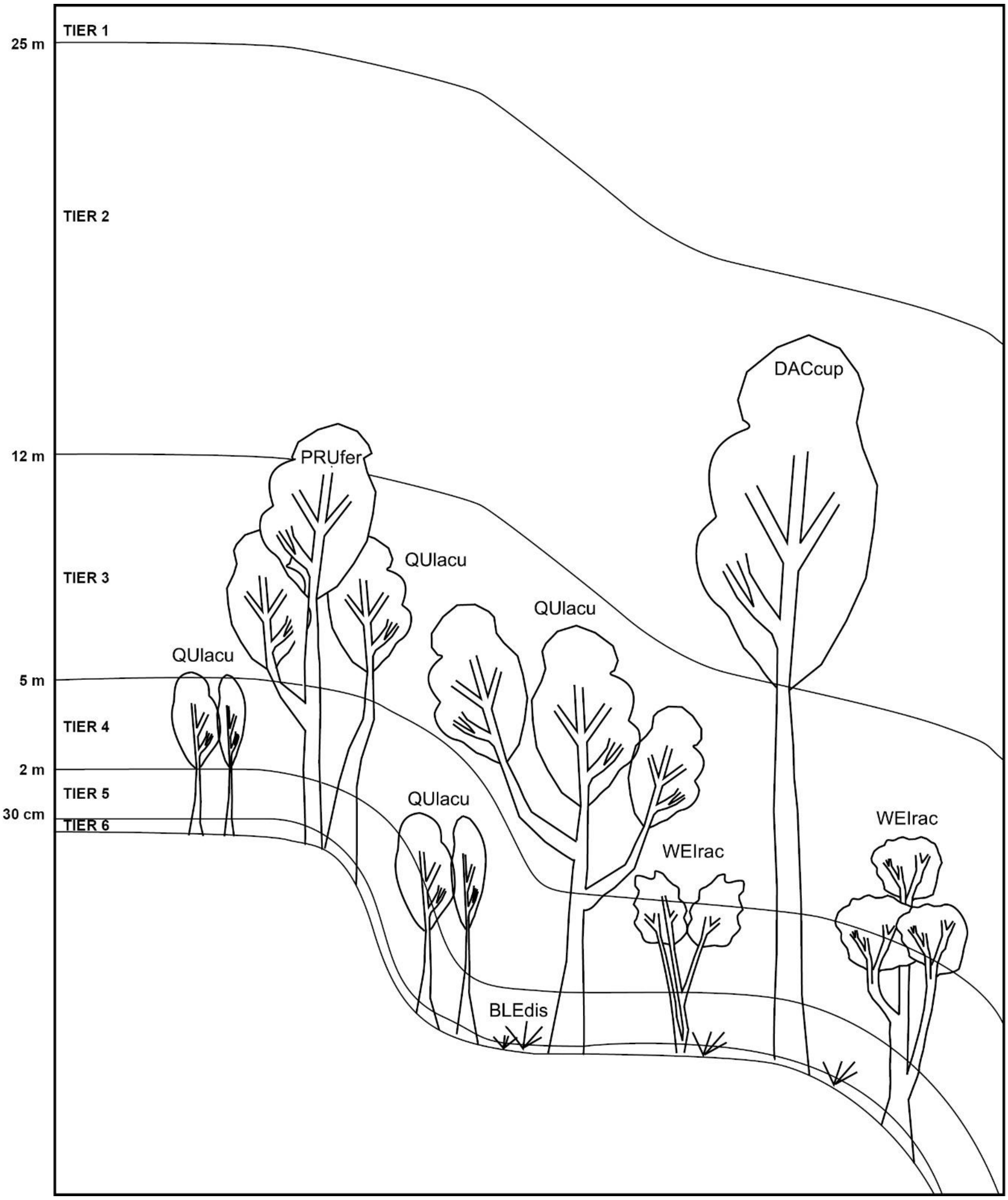


Figure 6. Fixed-height tiers follow a contour that is perpendicular to the ground surface, whereas plot boundaries are defined vertically with respect to the ground surface.

Table 1. Cover classes applied to the species present in each height tier on the Recce vegetation description. Cover classes are modified from the Braun-Blanquet cover-abundance scale (see Mueller-Dombois & Ellenberg 1974). Equivalent areas of a permanent plot are given (see also Appendix 7).

Cover class	Percentage canopy cover	Equivalent area of a 20 × 20 m plot	
1	<1	< 2 × 2 m	(i.e. <4 m2)
2	1–5	> 2 × 2 m and < 4 × 5 m	(i.e. 5–20 m2)
3	6–25	1–4 (5 × 5 m) subplots	(i.e. 21–100 m2)
4	26–50	4–8 (5 × 5 m) subplots	(i.e. 100–200 m2)
5	51–75	8–12 (5 × 5 m) subplots	(i.e. 200–300 m2)
6	76–100	12–16 (5 × 5 m) subplots	(i.e. 300–400 m2)

(c) Practical tips for completing the Recce vegetation description

- When recording data, each species occurring should be allocated one row on the field sheet, so that if the species occurs in more than one height tier it can be ticked on the same row (see Appendix 3b). Use a dash (i.e. '–') where a species does not occur in a shorter tier (see Appendix 3b), to allow the field sheet to be readily checked for completeness before finishing the plot.
- Where the number of plant species present exceeds the number of rows on the Recce field sheet, use a second sheet, and ensure that both sheets contain the same header information (e.g. unique plot identifier, date) and that they are cross-referenced (e.g. Page 1 of 2).
- Work in pairs, where possible, particularly if field staff are new to the method.
- If a species has been collected for identification, record a collected symbol (©) in the empty cell to the immediate left of the species name. If the species occurs in tier 1 or tier 7, and there is no empty cell to the immediate left, record the collected symbol (©) in the same cell as the species name, in the upper right corner of the cell (see Appendix 3b).
- Adopt systematic procedures when completing the Recce vegetation description to ensure that species present are not missed. Take the following steps.
  - Start by listing species present in the uppermost (tallest) height tier and work your way down through to the lowermost (shortest) tiers.
  - Once all obvious species are recorded, traverse the plot, subplot by subplot, recording additional species in each tier as you see them. It is usually necessary to move around to gain better vantage points of the canopy, particularly in dense or complex vegetation.
  - For small or cryptic canopy foliage, gain a good vantage point and use binoculars if necessary to help ensure each species is correctly identified.
  - Ensure all species recorded in the tree, sapling and understorey subplots are also recorded on the Recce vegetation description. The recorder of the understorey subplot data may start transcribing species onto the Recce sheet as they are encountered on understorey subplots to help ensure all species are recorded.

  When transferring species from understorey subplots to the RECCE vegetation description, beware the risk of inflating species richness. Do not transfer genus-level observations based on seedlings (e.g. *Fuscospora* sp) when this taxon has already been resolved to species level (e.g. *F. truncata* and *F. fusca*) in the RECCE vegetation description, unless you believe the observation represents an additional distinct species not already recorded.

  - Small and rare species are important to record. Be aware that in the understorey tiers, uncommon and small species can be easily overlooked. At the conclusion of the Recce vegetation description, before winding in any tapes, conduct a systematic search of the entire plot area to ensure that all species present have been recorded.

- Develop straightforward approaches to arrive at your estimates of cover for each species in each height tier.
  - In each tier, mentally move plants of each species to a corner of the plot, and then estimate what proportion of the plot they cover. Equate cover classes with the equivalent areas of a 20 × 20 m plot (see Table 1), and use the Canopy Cover Scale (see Appendix 7) and the 5 × 5 m subplots (which each represent 6.25%) to help arrive at accurate cover estimates.
  - When the cover of a species within a tier is very high, it may be easier to estimate the proportion of the plot area *not* covered by the species.
  - For species with very few individuals present on the plot, estimate the proportion of the plot covered by each individual in each tier, add these together within each tier, and assign a cover class.
- Visualise the canopy of each species squashed into a flat plane, and then estimate the proportion of the plot area covered by the species (i.e. avoid biasing cover estimates because of high or low foliage density).
- Take care to ensure that species are assigned to the correct height tiers. Observers should calibrate height estimates frequently against heights measured, using a tape, height pole, hypsometer, or equivalent instrument.
- Observers should regularly compare their cover class estimates with one another. As a balance between the repeatability and accuracy required for cover estimations, trained field staff should generally be able to estimate cover classes consistently and repeatedly to within one class of each other.
- Note that viewing the cover of trees obliquely rather than vertically can result in overestimation of cover. Move around as necessary when making cover estimates.

5.4 Stem diameter measurements

Stem diameter data are used in a number of ways. The stem diameter data collected on each plot provide information on the size structure of tree populations. Over time, tagged tree stems on remeasured permanent plots allow the recruitment, growth, and mortality rates of tree populations to be calculated. Stem diameter data also form the basis of the allometric equations used in carbon calculations.

Stem diameter measurement involves measuring all previously tagged stems and tagging all new stems that have reached the minimum tagging threshold of 2.5 cm DBH at 1.35 m along the stem from the base of the stem.

To allow stem diameter data to be used in these ways, it is important to follow some general principles for data collection.

- *Collect stem diameter data in a repeatable manner.* If the collection of stem diameter data is less than fully repeatable, small changes in plot measurement can lead to large differences in results. Stem diameter is often unreliable for a small subset of stems of woody species (e.g. epiphytes originating high in the canopy, lianas), which necessitates excluding these individuals from standard plot-measurement protocols.
- *Follow the fate of each tagged tree stem accurately through time.* This means that at each plot, each stem must be uniquely identified using a tree tag, and this tag number should remain the same indefinitely. The data record the recruitment into the tree size classes, growth, and death of each stem. Because annual mortality rates are generally low for many tree species (e.g. typically c. 1% per year), even small errors in tracking individual tree stems through time can cause large inaccuracies in analyses.
- *Ensure diameter measurements are accurate.* Because diameter measurements record each stem's size and hence growth, measurements must be made accurately and at the same place on the stem at each plot remeasurement (by convention each diameter measurement is made 1 cm above the tree tag, which is placed 1.35 m along the tree stem).
- *Apply high taxonomic standards.* Reporting changes in plant biodiversity over time and between areas requires consistent, accurate taxonomic standards.

Additional data have sometimes been collected for tagged trees on permanent plots to meet specific study objectives. For example, in a survey in Tararua Forest Park, data on possum browsing of fuchsia (*Fuchsia excorticata*) were collected for trees on permanent plots in order to help judge the effectiveness of possum control in protecting fuchsia (Urlich & Brady 2005). General guidelines for collecting browse data from permanent plots are provided in section 10.2.

Some forest monitoring protocols also include height measurements, which are usually made to establish height–diameter relationships and improve forest biomass estimates over those that can be obtained using DBH data alone (Goulding & Lawrence 1992; Harcombe et al. 1998; Coomes et al. 2002; Beets et al. 2012). For example, plots established as part of LUCAS include height measurements for a subset of trees on permanent plots (Payton et al. 2004). Further rationale for including height measurements are provided in section 10.1.

Height measurements are not recommended on standard permanent plots; however, a rationale for making tree fern height measurements is provided in section 5.5.1, with an optional protocol that can be followed, where relevant to the survey's objectives and if time and resources allow.

Section 5.4.1 outlines which stems are tagged and measured on standard permanent plots. Key 'best practice' procedures for measuring tree stems and recording the data are outlined in sections 5.4.2 and 5.4.3.

5.4.1 Stem diameter measurement protocol

(a) Which stems to tag and measure

- Tag and measure the diameter at breast height (DBH; 1.35 m) of all live trees (≥2.5 cm DBH over bark) and tree ferns (with stems ≥1.35 m long) rooted within the permanent plot (Figure 7a).
- A tree or tree fern is defined as being within the plot if at least 50% of its trunk is rooted within the bounded plot area.
- Lianas or descending aerial roots of hemi-epiphytes or stranglers (e.g. *Griselinia lucida*) do not need to be tagged or measured on standard permanent plots. Lianas are difficult and time consuming to include and the measurements are often unrepeatable. Cover of all liana species is estimated and recorded on the Recce vegetation description (section 5.3.5). The only exception is when a clearly defined *Metrosideros robusta* stem can be tagged and measured in a repeatable manner (as a guide: when it has nearly encompassed the whole host tree, has a tree-like form, and no longer has a descending root or vine form). If data on liana stem density or demographics are required to address specific study objectives, they can be enumerated as an addition to the basic plot protocols. Always document the protocol followed in the metadata for the survey.
- Fallen logs are considered 'substrate'. Tag and measure trees growing on fallen logs unless it is unsafe to do so.

(b) Multi-stemmed trees and epicormic shoots

- For multi-stemmed trees (Figure 7a) that fork below breast height, treat each stem as an individual, tag each stem individually, and record as attached to other stems belonging to the same tree. Use square brackets in the right side of the tag number column to denote this (Appendices 4 & 8). When square brackets are not practical record the associated tagged stem in the notes column (e.g. Att. to AF1983).
- Epicormic shoots (also known as coppice or sucker shoots) originating below breast height (1.35 m) are treated as stems (i.e. tagged and measured) when their DBH at 1.35 m from the base of the stem is ≥ 2.5 cm (Figure 7c). Record as attached to other stems belonging to the same tree. Epicormic shoots originating below breast height (1.35 m) with a DBH < 2.5 cm are not counted, tagged or measured. Epicormic shoots originating above breast height are treated as branches and are not counted, tagged or measured.
- If stem division occurs at breast height, tag and measure the stem/s at the closest practical point either above or below breast height (Figure 7b). Tag height would be recorded in the Notes column if not at 1.35 ±5cm (e.g. tagged @ 1.2m due to branching; refer to Table 2).

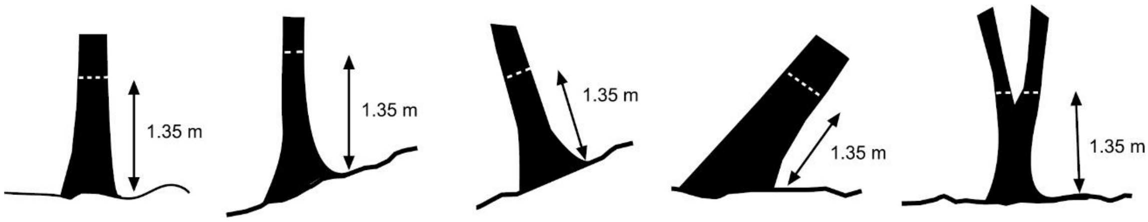
(c) Leaning, prostrate and fallen live stems

- Leaning, prostrate and fallen live stems that are rooted inside the plot should be tagged and measured 1.35 m along from the base of the stem (Figure 7a, c). Be careful not to miss stems rooted inside, but leaning out of, the plot.
- Record the note ‘fallen’ for live stems that have fallen over, such as after a windthrow event (Appendix 8). Where a live tree has fallen but is rooted in the plot, tag and measure the main stem at 1.35 m from the base; any living branches or epicormic shoots that originate <1.35 m along the stem should be tagged if they are ≥2.5 cm in diameter 1.35 m along from the base of the fallen stem. Use square brackets to denote that these are attached. (Figure 7c).
- Tree ferns that have fallen after snapping off at their base (detached) but hold live foliage should be measured as live stems. Tag, measure and record the DBH and make a note about the status (fallen, snapped at base). Tree ferns can survive being snapped off at their base.

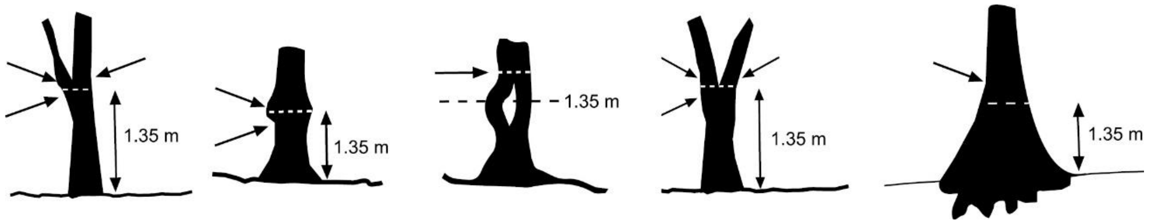
(d) Stems with irregular diameters at breast height

- Diameter irregularities at breast height can result from bulges, large wounds, splits, and stem enlargement due to buttressing (Figure 7b).
- Tree stems with diameter irregularities at breast height should be tagged at the nearest practical point above or below breast height where the diameter becomes more regular (Figure 7b). Record a note in the Notes column of the field sheet whenever a stem cannot be tagged and measured in a position unaffected by diameter irregularities (e.g. too dangerous to reach – overhanging cliff).
- Whenever a stem is tagged at a position other than 1.35 m along the stem, note the tag position and reason for the departure in the Notes column of the stem diameter sheet (see Table 2, Appendix 8).

(a) Vertical, leaning and multi-stemmed trees: tag stems 1.35 m along the stem.



(b) Stems with irregular diameters at breast height due to malformation, stem division or buttressing: tag each stem at the closest possible point(s) either above or below breast height where the diameter becomes more regular.



(c) Epiphytes, fallen live stems and epicormic shoots, and trees on stilts: tag each stem if ≥2.5 cm in diameter 1.35 m along the stem.

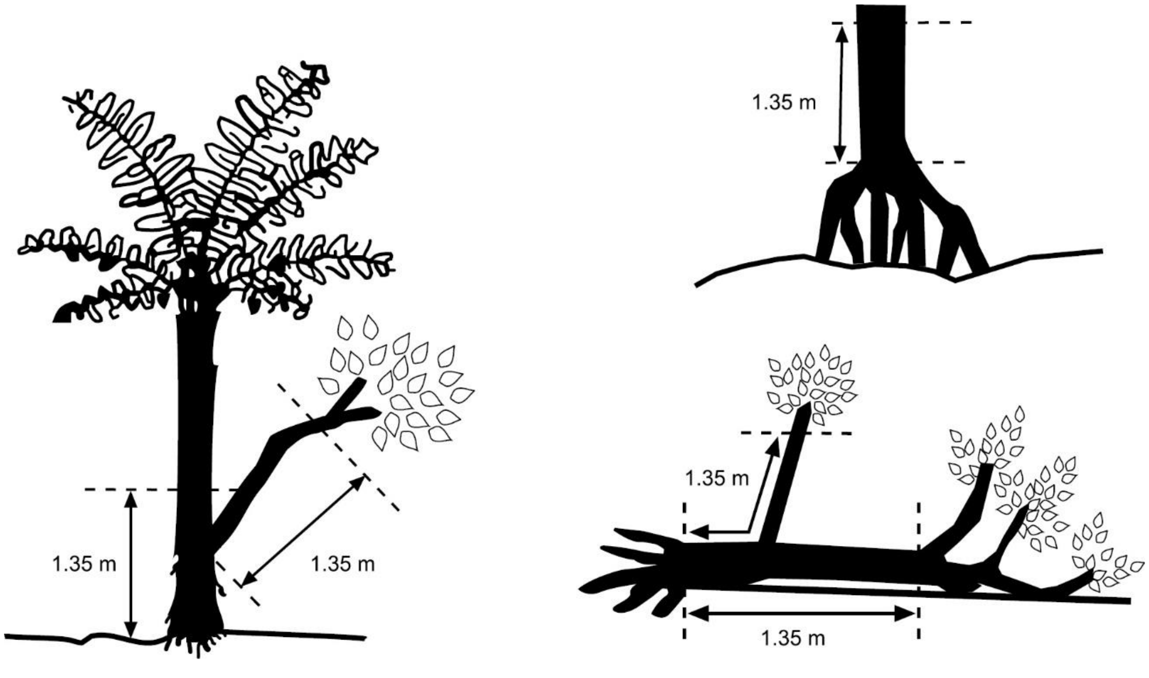


Figure 7. Tag and measurement positions for tree stems. Trees are tagged and measured 1.35 m along the stem, unless stem division, stem malformation or buttressing occurs at this position.

(e) Epiphytic trees and saplings

Epiphytes are plants growing on other living plants and dead standing stems. Plants growing on fallen dead trees (logs) that are touching the ground surface are not epiphytes, as such logs are considered ground substrate. Enumeration of epiphytic stems on plots is problematic because they can be out of reach. It is usually only practical and repeatable to collect size structure and demographic data for a subset of the epiphytic trees or saplings that are present. One practical subset of epiphytes to sample are those rooted below 1.35 m on a host tree. When only a subset is sampled, this should be noted on the relevant plot sheet (e.g. *only measured saplings rooted below 1.35 m on host trees*). All epiphytes are included in the Recce vegetation description (section 5.3.5).

- Epiphytic stems originating below breast height are treated as trees (i.e. tagged and measured) when they are >1.35 m in length and their diameter 1.35 m along their stem is ≥2.5 cm. These stems should be tagged 1.35 m along their stem (Figure 7c). Where this is not possible, the stem should be tagged within reach, and the distance along the stem to the tag recorded in the Notes column (e.g. 'tag @ 0.9 m – unable to reach') (see Appendix 8).
- Epiphytic stems originating below breast height are treated as saplings (i.e. counted) when they are >1.35 m in length and their diameter 1.35 m along their stem from where they originate is <2.5 cm (see section 5.6).
- For all tagged epiphytic stems, record 'epiphyte' in the Notes column, along with the species and tag number of the host tree (e.g. 'epiphyte, growing on DICsqu AB1234') (Table 2; Appendix 8).
- Epiphytes originating above breast height are not tagged or measured, but are included in the Recce vegetation description.

(f) Situations where stem diameter must be estimated rather than measured

- It is always preferable to measure diameters using a DBH tape, but this is not always possible.
- Where stem diameter cannot be accurately measured with a diameter tape (e.g. fallen stems lying on the ground, individual stems that have become fused together, or large trees with lianas fused to the trunk), tag each individual stem (e.g. fused stems) and record the best possible estimate of the diameter. To estimate a DBH, use a normal centimetre measuring scale (e.g. as found on the reverse side of some diameter tapes), and make two diameter measurements perpendicular to one another. These are called orthogonal measurements.
- In the Notes column of the stem diameter and sapling sheet record whenever a stem diameter is estimated rather than measured e.g. '10x13 ortho' and a reason (see Table 2, Appendix 8.

(g) Dead trees

- Dead trees (standing dead and fallen) should not be tagged or measured during plot establishment. If there is doubt over whether a tree stem is dead, check the inner bark (cambium) for any sign of living tissue.

5.4.2 Procedure for tagging and measuring

- Adopt a procedure to ensure that stems are not missed. Where necessary, use extra tapes, string or flagging tape to divide subplots into smaller areas.
- For trees growing on sloping ground, breast height is determined from the uphill side of the tree, this is usually consistent with the A–D boundary (Figure 7a). Note that this may differ from the ground level when dealing with perched root bases (Figure 7c).
- The stem diameter measurer should be aware of the 1.35 m height on their body. This allows the correct tag positions of vertically growing stems to be quickly identified. A tape should be used for trees for which it is difficult to use the height on the body (e.g. leaning trees).
- Tag stems in a logical order through the plot (e.g. ascending alphabetically from subplot A to P) using aluminium tree tags sequentially numbered in ascending order. Sequentially numbered tags placed on neighbouring trees helps relocate all trees during subsequent plot remeasurements. Finish tagging all trees in each 5 × 5 m subplot before moving on to the next subplot.
- Tag trees facing one direction (e.g. the A–D boundary) to ensure ease of measurement and ease of relocation.
- Use a galvanised flathead nail (e.g. 30–50 mm, but select a size that is appropriate to the stem, e.g. a 30 mm nail for a small stem) to attach the aluminium tree tag to each tree stem. Ensure the nail protrudes at least 2 cm to allow for stem growth, and leans slightly upwards so the tag sits flush against the stem). This helps ensure the tag will remain intact for a long time.
- When measuring tree ferns (which have 'squeezable' stems), the diameter tape should be pulled moderately tight without crushing frond bases that make up the stem. Clear away dead fronds and loose material from the stem before taking a measurement. Don't measure over the dead fronds. Also, use a longer nail (e.g. 75 mm) to attach the aluminium tree tag, and ensure the nail reaches the hard stele of the tree fern caudex.
- To increase the repeatability of diameter measurements of very large trees (e.g. >100 cm), or irregular or buttressed stems, additional nails can be placed around the diameter measurement circumference. Before nails are installed, place and hold the diameter tape in the correct measurement position to ensure accurate placement of the guide nails. Whenever such additional nails are used, note this in the Notes column of the field sheet. Nails should be used with caution on plots established in forests managed for timber production.
- Do not place tree tags in positions where they are likely to become overgrown (e.g. between two stems that might fuse as they grow).
- Before measuring the diameter, remove any moss or other debris from the stem where it is to be measured. This should be done around the full circumference of the stem. Lianas growing up the stem should be carefully loosened and excluded from the DBH measurement. Take care not to damage the bark.
- Measure the diameter 1 cm above the tree tag with a diameter tape, pulling the tape firmly when taking the measurement. The diameter tape converts a measurement of the circumference into a diameter measurement. Ensure you are reading measurements from the correct side of the diameter tape, as some diameter tapes have a normal metric scale marked on one side. Measure and record diameter to the

nearest millimetre. Ensure the diameter tape is positioned at right angles to the axis of the tree stem.

5.4.3 How to record stem diameter data

- Stem diameter data are recorded on the stem diameter data sheet (see Appendix 4), which can be downloaded from the NVS website (http://nvs.landcareresearch.co.nz/).
- On each stem diameter sheet, record the unique plot identifier (e.g. survey, location and line/plot number) as recorded on the Recce sheet. Record the names of the people measuring and recording the data in *full* (e.g. Elaine Wright) and the date in *full* (e.g. 27 February 2006). Ensure this information is recorded on both sides of every field sheet, as double-sided field-sheets may later be photocopied onto separate sheets. Also, ensure each page is cross-referenced (e.g. Page 1 of 5).
- For each stem, record the subplot (A–P), six-letter species code (see section 5.2), *full* tag number (including any alphanumerical prefix) and diameter (to the nearest 0.1 cm).
- Leave a blank line between each subplot to ease the job of the data-entry operator and minimise the possibility of data being ascribed to the wrong subplot.
- For subplots where no tagged stems are present, record 'none'.
- Record appropriate comments in the Notes column, wherever necessary, to provide extra information (see Table 2). *Do not* use symbols or non-standard abbreviations, as these can be difficult to interpret.
- For multi-stemmed trees, ensure all stems are linked with square brackets in the right side of the tag number column (see Appendices 4 and 8). When attached stems span more than one page or are not recorded in sequence, record these as attached in the Notes section (e.g. 'Att to AF1983') (Table 2, Appendix 4). Ensure that notes refer to the tag number of the attached stem. When one attached stem is on the pre-printed stem diameter sheet and the other on a new stem diameter sheet, record that they are attached in the Notes column of each.
- Ensure all data and notes are legible.

Table 2. Examples of some standard comments used on stem diameter and sapling sheets. Note that more detailed comments are required whenever there is a possibility of ambiguity. Note also that comments recorded can be entered during data entry, making it possible to print these comments onto pre-printed stem diameter sheets for use at the next plot measurement.

Example of comment	Description
Ortho. (record reason)	Use the Notes column to identify any stem diameters that were estimated and any orthogonal measurements that were made. Record the note 'Ortho.' and the reason for the estimation (e.g. 'Ortho.' – tree has fallen and stem is lying on ground'). Data users may decide to exclude such data from certain analyses.
Att. to '____' (record tag number)	Ensure that attached stems (i.e. multi-leader trees) are clearly noted or bracketed. Use the Notes column whenever the use of a bracket could be ambiguous (e.g. if stems of multi-leader trees are not recorded in sequence on the stem diameter sheet or are recorded on different pages).
Tagged '__' m along stem (record distance along stem to tag)	Record a note when a tag position is unintuitive (i.e. other than 1.35 m along the stem) capturing the distance along the stem and the reason. These data will assist subsequent field parties to relocate tags.
Epiphyte on '____' (record species and tag number of host tree)	Use the Notes column to identify epiphytic stems, and link them with the host tree. It can sometimes be difficult to find all previously tagged epiphyte stems, so these data will assist subsequent field parties to relocate tags.
Leaning '__'°	If tree fern height is being measured (see section 5.5.1), estimate the angle of the lean to the nearest 10° for all tree ferns leaning >20° and record as a note in the Notes column.

5.5 Optional data on tree fern size and growth

The recommended minimum protocol for tree ferns (i.e. tagging and measuring when ≥2.5 cm DBH; section 5.5.1) provides data for calculating tree fern recruitment and mortality rates, basal area, and stem density. Since tree ferns do not accrue radial growth in the way that most tree species do, simple DBH measurements do not provide data on each individual tree fern's size or growth rate.

An optional addition to standard permanent-plot protocols is to measure the stem length of each tagged tree fern. These data can be used to define the size structure of tree fern populations and to calculate growth rates. The following protocol may also be used for other species that do not exhibit radial diameter increments, such as nīkau (*Rhopalostylis sapida*), where this is relevant to the survey objectives.

The species code, tag number, and diameter of each tree fern are recorded as before. Record the tree fern stem length in the Notes column of the stem diameter sheet. Note in the metadata for the survey that tree fern heights were measured.

5.5.1 How to measure tree fern stem length (height)

- *The stem length measurement* should be from the ground to the base of the living fronds, as accurately as possible to the nearest 0.1 m.
- *Relatively short tree ferns* (e.g. those <7 m) can be measured with a large builder's tape (i.e. 8 m) or height pole. It is essential that you be able to see the top of each tree fern stem to obtain accurate measurements. This method will usually require two people to work together (e.g. the measurer and the recorder). One person (e.g. the recorder) should stand several metres away from the tree fern to obtain a good view of the top of the stem.
- *Taller tree ferns:* the most direct and efficient way to measure taller tree ferns (e.g. those ≥7 m) is to use a Vertex or Suunto hypsometer. Follow the instructions for the hypsometer make or model to obtain the height measurement. This method usually also works best if two people can work together, with one person holding the transponder at breast height (1.35 m along stem) on the tree fern while the other moves to a point where both the top of the tree fern and the transponder are visible. The optimal angle for measuring tree height is <45° (0–55° is acceptable) from the measurer to the top of the tree. Clinometers can also be used to measure tree fern height (see Goulding & Lawrence 1992; Goulding 2005).
- *Leaning tree ferns:* where a hypsometer is used to measure heights, any leaning tree fern should be measured at right angles to the direction of the lean halfway between the top and the base of the tree. Take three measurements and record the average. When using a hypsometer, the vertical distance to the longest point of the tree fern is measured for leaning tree ferns rather than the stem length. Estimate the angle of the lean to the nearest 10° for all tree ferns leaning >20° and record as a note in the Notes column of the stem diameter and sapling sheet e.g. leaning 70° (see Table 2). Where the tree fern height measurement cannot be made at right angles to the direction of lean, measure from the best vantage point and record the angle of lean as plus (+) when it leans towards the observer, and minus (–) where it leans away from the observer.
- *Where an accurate measurement of stem length cannot be obtained*, record a note in the Notes column of the stem diameter and sapling sheet.

5.6 Sapling counts

Sapling counts are used to provide data on the regeneration of tree and shrub species. These data should be collected from all permanent plots. It is usually efficient to count saplings in conjunction with collecting stem diameter data. The term 'sapling' applies here to any woody plant (excluding lianas) or tree fern >1.35 m tall but <2.5 cm DBH. Saplings are counted by species but are not tagged.

- In each 5 × 5 m subplot, count the number of saplings of each species. Adopt a procedure to ensure saplings are not missed, subdividing each subplot into smaller areas with string or tapes where necessary, or using chalk to mark stems once they have been counted.
- Stems of the same plant that fork at or above ground level are counted as a single stem (stems that *may* be joined below ground level are counted as separate stems). Where this is not clearly visible, you may need to gently feel under loose litter at the

base of stems to determine if they are joined above ground. Epicormic shoots or branches joined to tagged tree stems are not included in sapling counts.

- Record the number of saplings per species in each subplot on the stem diameter and sapling sheet. To distinguish sapling records from stem diameter data, denote them with the symbols '< >' for each subplot (e.g. '<A>'; see Appendix 4). For subplots where no saplings are present, record 'none'. Leave a blank line between each subplot to ease the job of the data-entry operator and to minimise the possibility of data being ascribed to the wrong subplot.
- For woody tree species, the measure of height is taken as the plant naturally stands – 'natural height' (rather than measuring the pulled-up or extended height) – and is measured on the true vertical axis, not perpendicular to the slope. Natural height includes living vegetation only.
- Tree ferns are counted as saplings when they have a natural frond height (i.e. not pulled-up or extended height) of >1.35 m and a stem length of <1.35 m.
- Epiphytic stems originating below breast height are counted as saplings when they are >1.35 m in length, and their diameter 1.35 m along their stem from where they originate is <2.5 cm. They must possess live foliage above 1.35 m. Tally epiphytic saplings separately from normal saplings of the same species (i.e. on a separate line of the stem diameter and sapling sheet), with a note in the Notes column indicating that the plants are epiphytes (Appendix 4).
- Lianas, vines and climbers should not be included in sapling counts on standard permanent plots. Lianas are difficult and time consuming to count, and the measurements are often unrepeatable. Cover of all liana species is estimated and recorded on the Recce vegetation description. If data on liana stem density are required to address specific study objectives, they can be counted as an addition to the basic plot protocols. Always document the protocol followed in the metadata for the survey.
- Saplings growing on dead logs and stumps are not epiphytes, as dead logs and stumps are considered substrate.

5.7 Understory subplots

Understorey subplots should be measured on every permanent plot. These measurements collect plant species frequency data (i.e. the number of times a species occurs within a given area) from 24 subplots, each 0.75 m^2, located on a regular grid across the plot area (Figure 4). The data are collected in height tiers, allowing assessments of structural changes in understorey vegetation to be made. Frequency data are generally considered reliable and repeatable measures of plant abundance and dispersion (Daubenmire 1968). In this manual, numerous understorey subplots are used that are small enough to ensure they are practical and relatively quick to measure in all forest types.

The following protocol only samples understorey vegetation that grows on the ground surface. Understorey sampling on other establishment substrates has also been undertaken on permanent plots as an addition to standard plot measurement protocols. For example, as a means of quantifying epiphytic regeneration of deer-palatable species, Stewart and Burrows (1989) selected the two tree ferns (>2 m tall) nearest each understorey subplot and enumerated epiphytic seedlings growing on these. Such a method may be adopted in addition to standard protocols.

Each understorey subplot is marked with a numbered marker inserted into the ground (conventionally a numbered Permolat marker attached to an aluminium peg). Permanently marked understorey subplots assist with future plot re-establishment, as these additional markers can help with accurate re-establishment of plot boundary tapes, and in particular the internal tapes dividing up the plot into 5 × 5 m subplots.

Permanently marked understorey subplots also provide the opportunity to apply repeat-measure statistics to the data. Because some subplots are likely to be lost between plot remeasurements, accurate data must be recorded on which subplots were relocated at each plot remeasurement. Considerable time is often spent relocating understorey subplots to allow subplots to be treated as repeat measurements; however, relocating subplots should be considered a relatively low priority compared with ensuring that accurate and consistent taxonomic standards are applied, and that subplots are carefully measured.

5.7.1 Understorey subplot measurement

- On each permanent plot, record understorey vegetation on 24 understorey (or seedling) subplots (each 0.75 m^2). Understorey subplots are circular (radius of 49 cm) and are located midway between the intersection points of the tapes that divide the 20 × 20 m plot into the sixteen 5 × 5 m subplots (see Figure 4).
- Data are recorded on the understorey subplot sheet available from the NVS website (http://nvs.landcareresearch.co.nz/; see Appendix 5).
- Each understorey subplot should be permanently marked with an aluminium peg and a numbered Permolat strip (i.e. 1–24; Figure 4) or other suitable permanent markers. The aluminium peg is bent over at the top and inserted through two holes at either end of the Permolat strip to hold it securely in place on the peg.
- Where it is impossible to insert a peg into the ground at the specified location (e.g. because the subplot location falls on a tree root, solid log or rock slab), shift the subplot to the nearest point up to ±1 m along the tape at which the peg can be inserted. To assist with relocation of understorey subplots during plot remeasurement, record a note on the understorey subplot sheet whenever a subplot deviates from the specified location.
- Where it is impractical to insert, or not possible to replace, a subplot peg (e.g. in deep, soft mud), record ‘unmarked’ and measure the understorey subplot as usual.
- When overlapping substrate is available at the specified location, insert the peg on the lowermost substrate (e.g. in the ground under any suspended logs).
- Use a piece of string to define the area of the subplot. Make a loop in one end of the string and tie a knot 49 cm along the string. For efficiency, ensure the loop is large enough to pass freely over the understorey subplot peg. Check the length of the string before measuring each plot.
- Place the loop over the understorey subplot peg. The subplot area is defined using the string (pulled tight but following the contour of the ground surface) to measure a 49 cm radius from the base of the peg, to indicate the subplot boundary.

- The subplot is used to sample the ground surface, and includes any dead standing stems, stumps and logs lying in contact with the ground surface. For this method, epiphytes (plants growing on other living plants or dead suspended plants) are not included.
- For each plant rooted within the subplot, the measure of height is taken vertically (not perpendicular to the slope) from the base of the plant to the uppermost foliage (not flower or seed heads) and as the plant naturally stands (rather than measuring the ‘pulled-up’ or extended height).
- Layering plants, lianas and sometimes tree seedlings often have roots both inside and outside an understorey subplot. Any individual plant that is rooted within the subplot (regardless of the extent of rooting outside the subplot) should be included in the measure.
- Record all woody species <15 cm tall by presence (tick in that height tier) only. For woody species (not lianas) and tree ferns >15 cm tall, count and record the number of plants within each of the following height tiers: 16–45 cm, 46–75 cm, 76–105 cm, 106–135 cm.
- Do not record saplings or trees (including tree ferns) >1.35 m tall or epicormic shoots.
- Woody plants with stems that fork visibly at or above the ground surface are counted as a single plant. Those that fork below ground are counted as separate plants. As with sapling counts, the observer should feel under loose litter at the base of plants to determine if they are joined above or below ground, but should not dig up or disturb the ground.
- As with sapling counts, some woody species are harder to count than others due to habit (e.g. layering or rooting from multiple positions) or where seedling numbers are very high. Effort must be made to count species as accurately as possible. To aid counting, the seedling plot can be subdivided with an additional tape. After completing counts for species, if the confidence in count data is not high (challenging/hard), then note these species as ‘hard to count’ on the data sheet.
- The presence of each non-woody species (e.g. forbs, graminoids, herbaceous ferns, lianas) is recorded with a tick in each height tier containing foliage. Individuals are not counted. For example, a seedling plot with *Carex uncinata* that was 37 cm tall would receive ticks in the <15 cm and 16–45-cm tiers. Non-woody species rooted in the seedling plot that are taller than 135 cm and have live foliage in the lower tiers are ticked as present in those tiers containing live foliage.
- Do not record cotyledonous seedlings that are not identifiable to at least the genus level (i.e. due to a lack of identifying features).
- Where identifiable, dead annual species or browned-off geophytes (i.e. terrestrial orchids) are to be included in understorey plot measurements, but do not include dead plants of other perennials. Record the species, tick its presence in the corresponding height tier, and record ‘(dead)’ in the same row.
- For subplots where no vegetation is present, record ‘none’.
- Leave a blank line between each subplot to ease the job of the data-entry operator and minimise the possibility of data being ascribed to the wrong subplot (see Appendix 5).

6 Remeasuring permanent plots

Experience across a range of forest types suggests that a 5–10-year interval is generally suitable for monitoring the demographics of tree populations and changes in forest structure and composition. Note that remeasurement of permanent plots may be prompted by objectives that differ from those of the original survey. Before embarking on plot remeasurement, critically assess the survey design and quality of previous measurements to ensure the work is justified and will meet objectives. Changing objectives, new information, or limited resources may dictate that only a subset of plots should be remeasured, but carefully consider any long-term implications. Permanent plots require ongoing maintenance (e.g. to ensure tree tags do not become overgrown), and when left unvisited for long periods it becomes increasingly difficult to undertake accurate remeasurements.

When permanent plots are to be remeasured, develop a lineage of the vegetation surveys to be remeasured, summarising what plots and what measurements were made in each previous survey. Determine the number of plots originally established and their distribution. Note that some plots may not have been measured in every survey, and not all sampling methods (e.g. Recce, stem diameters, sapling counts and understorey subplots) may have been undertaken at every plot measurement. Previous surveys may have been spread over more than 1 year and may be archived as separate data sets. At times a vegetation survey encompasses remeasurement of plots that, when originally established, were part of different vegetation surveys. Always clearly document in the metadata for the survey what plots were measured, and clarify any links to other vegetation surveys.

Where possible, plots should be remeasured in the same order and over the same months as the historical measurements. Relocating and remeasuring all of the permanent plots in an existing vegetation data set within the same field season keeps analysis of vegetation change over time as straightforward as possible.

6.1 Pre-fieldwork planning for locating and remeasuring permanent plots

Pre-fieldwork planning is essential to ensure the fieldwork proceeds as smoothly and efficiently as possible. In addition to the pre-survey planning activities outlined in section 3, obtain all existing information about the vegetation survey stored locally and/or archived in the NVS Databank (nvs@landcareresearch.co.nz), including the following.

- *Metadata for the survey:* obtain copies of any previous survey reports produced from the original data. These may contain important documentation on any variations to standard plot-measurement protocols, as well as lists of species recorded and other background information on the area.
- *The best available information on the relocation of plots:* note that the most detailed relocation information for plots located on transects is often recorded on the Recce sheet for the first plot along the transect. Recce sheets from the first measurement of a plot often have the best relocation information.

- *Maps of transect or plot locations and aerial photographs (where available):* where necessary, transcribe transect or plot locations from imperial or outdated maps onto new topographical maps. Ensure original survey maps are securely archived, and never take the only known copy of a survey map into the field.
- *High-quality photocopies of all field sheets from previous measurements:* do not write new data on photocopies of the old data sheets, because it is difficult to interpret, especially when photocopied. *Never* take original field sheets from previous plot measurements into the field.
- *Pre-printed stem diameter sheets* (i.e. computer printouts listing the old stem diameter data; see section 6.2.4 and Appendix 8.
- *A list of all species previously recorded in the vegetation survey, as well as plot-by-plot species lists:* species lists from vegetation surveys can also be accessed through the NVS website (http://nvs.landcareresearch.co.nz/).

6.2 Plot remeasurement procedure

Permanent plot protocols have changed slightly over the years, and some plot surveys have used non-standard measurement protocols. It is usually important to follow the original protocols when plots are remeasured to maintain the integrity of the time-series data, as small changes in measurement protocols can cause large changes to results.

For surveys that previously used non-standard plot measurement protocols, relevant details on the protocols followed will ideally be in the metadata for the survey. If not, plot measurement protocols sometimes become apparent when looking through old field sheets, or may have been recorded in any report or publication that used the data.

Make every effort to determine exactly what measurement protocols were followed in the original survey. Potential differences between plot measurement protocols are highlighted in the following sections. When remeasuring plots, always record any known variations to standard plot measurement protocols in the metadata for a survey.

6.2.1 Plot relocation and layout

- Use the Recce description sheet from the previous plot measurement, map, and aerial photograph (where available) to relocate each plot.
- Access routes to plots (e.g. transect origin and transect markers) must be re-marked with Permolat where they are difficult to follow or relocate.
- Record accurate GPS fixes for existing waypoints along the route to verify against those originally recorded and add new ones if required.
- Record new approach notes and location diagrams, as information must be periodically updated to ensure the plots will never be lost.
- Re-establish plot corners and boundary tapes as accurately as possible using the remaining plot markers. Replace any damaged corner markers and pegs, and record in the Notes section of the Recce sheet which corner locations were re-established (where the original corner peg was not found). Note that the location of existing tagged trees can often help with the re-establishment of a plot boundary where the corner Permolat and/or a corner peg is missing. Where the corner Permolat is no

longer visible, the writing is illegible or the label is incorrect, replace it or correct the inscription. Record the direction and distance of plot boundaries on the Recce sheet (as outlined in section 5.3). Use the understorey subplot pegs to guide the layout of the internal tapes.

- Permolat that has become illegible because it is covered by plants or mould should be cleaned.
- Where a plot cannot be relocated after an exhaustive search, do not establish a new plot. Record detailed notes in the metadata for a survey outlining the area that was searched and the time spent. Plots have sometimes been relocated during later surveys.
- Previous experience suggests that plots will frequently change in size and shape (e.g. due to tectonic activity and/or landslides). Do not realign plot boundaries, as this will invalidate comparisons with earlier remeasurements. Use the Notes section on the front side of the Recce sheet to describe any major deviation in plot size and orientation, and record the direction and distance of plot tapes (as in section 5.3).
- Bowed boundary tapes can occur on plots. Some existing plots may have plot boundaries that are not straight. If a plot boundary on an existing plot is bowed, do not straighten the side (and thereby change the original plot layout).
- More extensive damage to a plot may occasionally occur (Allen et al. 1999; Monks et al. 2006), and most original plot markers or vegetation may have been disturbed or destroyed. Re-establish the plot in the original location, using map and altitude data to guide your decision. Record detailed information in the Notes section on the front side of the Recce sheet to provide data users with an idea of the nature and magnitude of the disturbance to the plot and surrounding vegetation, including what plot markers were relocated. Do not re-establish the plot if none of the original plot markers or tagged trees could be found, unless you are quite certain where the plot should be located.

6.2.2 Potential differences in plot layout

Note that differences may occur in:

- *the size of the plot* – some permanent plots are not 20 × 20 m in size, but instead may be 10 × 10 m or some other non-standard size
- *the labelling of corners* – corners may have been marked 'A', 'B', 'C', and 'D', rather than 'A', 'D', 'M', and 'P': retain the original labelling of corners, and use the Notes section of the Recce sheet to describe the corner labelling system
- *the number and size of the square subplots the plot is divided into* **–** plots were sometimes divided into four 10 × 10 m subplots instead of sixteen 5 × 5 m subplots; on such plots, superimpose the standard layout of 5 × 5 m subplots
- *the labelling of 5 × 5 m subplots* – retain the original labelling of 5 × 5 m subplots and use the Notes section of the Recce description to describe the subplot labelling system
- *the orientation of plots with respect to transect or slope contours* **–** retain the original plot layout and use the Notes section of the Recce description to describe the plot orientation

- *the number of understorey subplots and their size* – retain the original understorey subplot system, and record details in the Notes section of the Recce description and in the metadata for the survey
- *the placement and numbering of understorey subplots* – retain the original understorey subplot layout, and use the Notes section of the Recce description to describe the layout; some examples of non-standard understorey subplot numbering systems are provided in Figure 8.

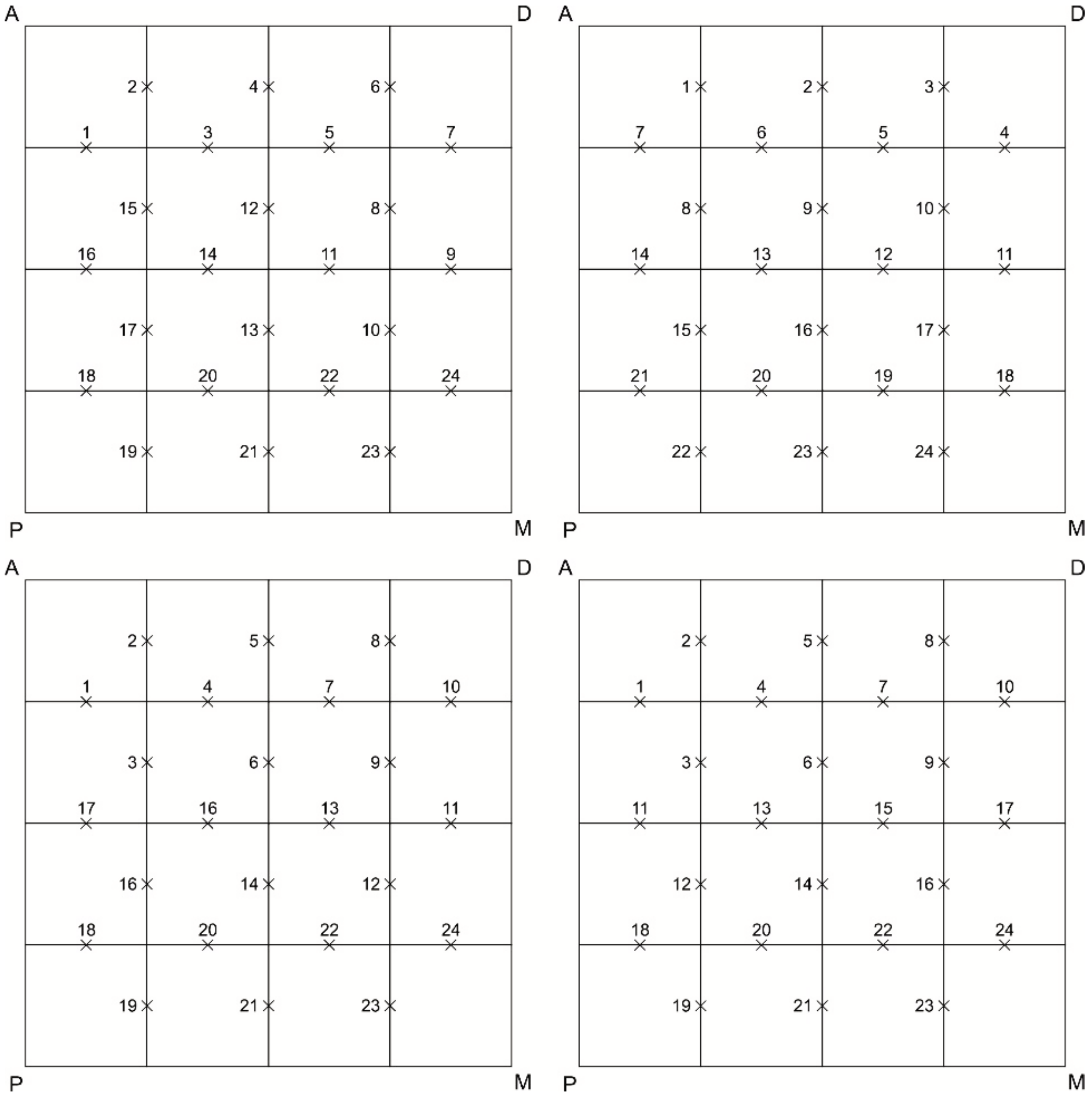


Figure 8. Alternative understorey subplot layouts found on some existing 20 × 20 m permanent plots. Retain the original numbering system and record details in the Notes section of the Recce description and in the metadata (see section 9.2.3) for the survey.

6.2.3 Recce description

(a) Plot identification information

- Use the same plot identification information (e.g. survey name, unique plot identifiers) as recorded in the previous measurement and/or under which the data are archived in the NVS Databank.
- Obtain an accurate GPS fix where possible (see section 5.3.1).
- Always record new location notes and draw a location diagram when remeasuring plots.

(b) Site description, vegetation parameters and additional biological information

- Always record all Recce description site and vegetation parameters during plot remeasurements (following the protocols in section 5.3), including topographical data (e.g. aspect, slope). Note major points of difference from the previous Recce description in the Notes section.

(c) Recce vegetation description

- *Conduct the Recce vegetation description (section 5.3.5).* Note that in some historical permanent plot surveys there may have been differences in the area described by the Recce, and/or the location of the Recce in relation to the plot. Recce descriptions in some historical surveys were sometimes not bounded to the 20 × 20 m plot area, so species may have been recorded that did not occur within the plot boundaries. Compositional data from historical Recce descriptions have also varied greatly in quality.
- *Bounded' Recce descriptions should be used* when remeasuring historical plots, since they will allow future changes in structure and composition through time to be more accurately quantified. Note that where historical plots were unbounded or bore no relationship to the 20 × 20 m plot area, explicit comparisons of Recce data between plot measurements may be inappropriate.
- *Taxonomic name changes:* taxonomic names for some species present may have changed since the last plot measurement. When remeasuring plots, always record data using current nomenclature and NVS codes (see section 5.2).
- *List of species previously recorded:* use the printout of species previously recorded on each plot, and in the survey as a whole, to assist the search effort for additional species and to identify ambiguities (e.g. potential errors in previous data).
- *Height tiers:* note that historical permanent plot protocols used different definitions for tier 1 and tier 2 (Allen 1979; Allen & McLennan 1983). The standard height tiers should now be used, and data should be collected following the guidelines in section 5.3.5.

6.2.4 Stem diameters

Stem diameter remeasurement involves relocating and measuring all previously tagged stems and tagging all new stems that have reached the minimum tagging threshold of 2.5

cm at 1.35 m along the stem. Remeasuring stem diameters allows mortality, growth, and recruitment rates of tree populations to be calculated. Very high-quality data are required to produce accurate estimates of these parameters, so field staff must take a conscientious approach to relocating *all* previously tagged trees and tagging *all* new tree stems. Field staff should be aware of the range of problems that can occur in stem diameter data, how to correct them, and what documentation is required. Relevant information can be found in Wiser et al. 1999; Newell & Baldwin 2000; and Hurst et al. 2006.

(a) Relocating and remeasuring existing tagged stems

- *Adopt a systematic approach* to measuring and recording stem diameter data (as outlined in section 5.4). For *every* stem, check the subplot (A–P), species code, tag number, and stem status (alive or dead), and measure the diameter.
- *Record remeasured stem diameter data on pre-printed stem diameter and sapling sheets* (i.e. computer printouts of stem diameter data from the previous plot measurements). If data are archived in the NVS Databank, formatted datasets for creating pre-printed plot sheets can be downloaded directly from the NVS website (https://nvs.landcareresearch.co.nz/Data/Search). Alternatively contact the NVS Databank manager in advance of undertaking fieldwork (email: nvs@landcareresearch.co.nz). These sheets allow any obvious errors in previous data to be identified, and assist with the relocation of all previously tagged trees. *Never* write new data on photocopies of the old data sheets as it can be difficult to interpret when photocopied. Use new stem diameter sheets for newly tagged stems and saplings. For subplots where no new tagged stems are present, record 'no new stems' in the species column. Print all field sheets onto waterproof paper prior to fieldwork.
- *Tag numbers:* tag numbers listed on the pre-printed stem diameter sheets may only be four digits long due to historical data-entry constraints. Amend the pre-printed data with the full tag number of each stem to provide a better record of each tag number used. Accurate records of the full tag numbers used become increasingly important over time as more different tag series are used during successive plot remeasurements.
- *Adopt a procedure to ensure that every previously tagged stem is relocated* (e.g. use pre-printed stem diameter sheets and photocopies of previous plot measurements to keep track of which stems have been found). Where a previously recorded tree stem is missing, conduct a thorough search both inside the plot and immediately outside. Land movement can result in trees moving outside the plot boundary. Note that it is possible to use the metal detector to search for swallowed or concealed tags on trees; this is useful where there are vines, moss or rapid growth on plots.
- *If a previously tagged stem cannot be found after a thorough search,* record 'not found' next to the tag number on the pre-printed stem diameter sheet. These data will be entered into the database, providing an indication to data users that a stem was specifically searched for (and is probably dead) rather than being simply missed.
- *Check all previous stem diameter measurements for obvious errors.* When the remeasured diameter of a stem varies considerably from the previous measurement (e.g. recorded as 21.2 cm in 1996 but only 13.5 cm in 2006), double check your measurement, then either record 'double checked' in the notes or record a double tick (✓✓) to the immediate right of the diameter measurement (see Appendix 8). Unless

the double check has been recorded, it is impossible to determine later which data are correct. Note that while recording data, the recorder has an active role in checking all data against previous records. The recorder is responsible for making sure no trees are missed and all are accounted for in every subplot. They should also help to check that the DBH tape is correctly aligned around the circumference of a stem (particularly of large trees).

- *If a stem has a smaller DBH than the previous measure* due to rot, decay or damage, then record a relevant note (e.g. 'Stem rotting'). If a stem has a smaller DBH than the previous measure due to the previous team's measurement error (potentially a recording error, data entry error or measurement error), record a note, 'Previous meas. Error'.
- *Check the identity of every previously tagged stem.* Where the species of a tagged stem was misidentified at a previous plot measurement, correct the species code and ensure it is clear that the new species code has been checked and is correct. Write a short note to confirm that the change in identification is a conscious decision and not a measurement or recording error (e.g. 'tag AD 1234 is a WEIrac, but was incorrectly recorded as MELram in 1996'). Where applicable, update stem identifications to subspecies or variety level if the taxon can be confidently further resolved. Note that while recording data, the recorder has an active role in checking all data against previous records.
- *At each plot, resolve any problems previously identified in stem diameter data.* If data are archived in the NVS Databank, potential problems may be identified on the pre-printed plot sheets. When a problem can be resolved, write a detailed note on the stem diameter sheet, outlining any action taken and detailing (where applicable) any back data to be corrected. Actions required may include (but are not limited to):

– checking the species identification of tagged stems

– replacing a duplicate tag (where two trees on a plot have the same tag number) with a new tag number

– checking the diameters of stems that grew or shrunk substantially between previous plot measurements.

- *If a previously tagged tree is dead,* do not measure the DBH but record write 'dead' beside the tag number (Appendix 8). *Do not* use symbols or abbreviations. Only record a tree as dead when there is positive evidence of tree death. Leave tags in place on standing dead stems but fold them in half. Remove from the plot any loose tag that has been dislodged from a dead stem or is on a fallen dead stem.
- *Replace damaged or overgrown tree tags* to make sure the tag number will remain intact and visible until the next plot measurement. Stems that need replacement tags must be tagged with *exactly* the same tag number as used previously. This ensures that each individual stem can be accurately followed through time. Use a Dymo tape-writer (or equivalent instrument) to create replacement tree-tags. Nail the replacement tag at the same position along the stem as the existing tag. Identify in the Notes column of the stem diameter sheet any stems that have had their tags replaced. If new tag numbers *must* be used to replace tags (e.g. because of a lost or broken Dymo tape-writer), then it is essential to record both the new and old tag number and to back-correct old tags in the electronic data of all previous measurements.

- *If the diameter was measured over lianas at the last measure* (e.g. lianas are fused to the stem), then remeasure the diameter over lianas again and record 'over lianas' and the measurement in the notes. If it is possible to measure beneath the lianas, then do so. If not, also measure orthogonal diameters, record these in the diameter column.
- *Lianas or descending aerial roots of epiphytes* have sometimes been tagged during historical plot measurements. You should attempt to relocate these and confirm species identification. Do not remeasure the diameter, but do record the stem status (alive or dead) and the nature of the stem in the Notes column (e.g 'Aerial roots' in the notes).
- ***Never** reuse a tag from a dead stem to identify another stem.* Doing so makes it impossible to track the fate (i.e. recruitment, growth, and death) of individual trees through time.
- *Notes:* where necessary, record additional information for each tree in the Notes column of the field sheet (see section 5.4.3). Clear notes will ensure the data can be correctly interpreted by data users and during future plot remeasurements.
- *Change in subplot:* where a tagged stem is listed on the pre-printed stem diameter sheet under a different subplot from where it is currently located, amend the stem diameter sheet and write a short note highlighting the change. Where a subplot change is a marginal call that could result from internal tapes being laid out slightly differently, leave the subplot as listed.
- *No tree tag:* where a stem is likely to have been large enough to tag at the last plot measurement but has no tree tag, check that the stem would have been definitely rooted within the 20 × 20 m plot area. Attempt to identify the stem on the pre-printed stem diameter sheet using species, subplot, diameter, and neighbouring tagged stems to highlight potential matches. Where the correct tag number can be ascertained with confidence, retag the stem with *exactly* the same number using a Dymo tape-writer (or equivalent instrument). If the stem cannot be matched against any previously tagged stem with certainty, assign the stem a new tag and note that the tree was assigned a new tag number because the old number could not be determined. Where you suspect that the stem was missed during the previous measurement (i.e. because it was likely to have been large enough but has no tree-tag, and cannot be matched against old tags as above), write a note in the Notes column of the stem diameter sheet (e.g. 'No existing tag – possibly missed in 1994').
- *Diameter measured where no tag was present:* occasionally a stem is found to have a single tree tag at a height other than 1.35 m (e.g. 0.8 m) and has previously been measured at both this tag height as well as at another height (e.g. 1.35 m). The latter is called tag-less breast height, as a diameter is recorded but no tag marks the location. In this situation, only measure the diameter at the tag and ignore any historical tag-less diameter measures. In the Notes section record 'tag @ 0.8m'.
- *Incorrect tag height:* occasionally some or all trees on a plot have tree tags at a height other than 1.35 m (e.g. 0.8 m). When this variance in tag height is greater than the range 1.35 cm ± 5 cm, measure the diameter at tag height (1 cm above the tag) and record the height of the tag in the Notes column if this was not measured and recorded at last measure. If the tag height is within the range of 1.35 cm ± 5 cm, measure the diameter as normal and make no notes regarding tag height. If tree tag

height is consistently beyond the range, make a note in the metadata for the plot/survey. Do not re-tag stems with new tags at 1.35 m.

- *For multi-stemmed trees:* check that stems that are attached have been previously recorded as attached. If formatted datasets from the NVS databank have been used for creating pre-printed plot sheets, attached stems will be indicated by a column of numbers which capture the square bracketing from the previous measure (Appendix 8). Correct any attachment mistakes on the pre-printed plot sheets.
- *Stems with multiple tree tags:* very occasionally a stem is found to have more than one tree tag. The measurement history of each tag can often be seen on the pre-printed stem diameter sheets. Retain the tag with the longest measurement history (unless it was incorrectly placed on the stem; see section 5.4.1) and remove the other. In the Notes column record that the stem has multiple tags, record the tag number of the other tag, and record which tag has been removed (e.g. 'Double tagged with KL1979, removed KL1979'). Where the measurement history cannot be determined (e.g. where the pre-printed stem diameter sheet does not contain data from every historical measurement of the plot), measure both diameters and the height of each tag. In the Notes column record that the stem is double tagged, record the tag number of the other tag and the height of the tag (e.g. 'Double tagged with KL1979, tag @ 1.2 m'). Record any other information that will help describe the situation so that historical data can be checked and the problem resolved at a future plot measurement.
- *Tagged trees outside plot boundaries:* previous experience shows that where plots change in size and shape in tectonically active regions, trees can migrate downslope as a result of landslides or earthquakes. Tagged stems that migrate out of the plot, but are still alive, should continue to be remeasured. Use the Notes column of the stem diameter sheet to indicate which tagged stems are outside the 20 × 20 m plot boundaries, and to record accurate relocation information for each (i.e. a measured distance and direction from a corner peg). Any trees migrating into plots should be tagged and measured following standard protocols, and the situation described in the Notes section of the stem diameter sheet.
- *Tagged living trees outside plot boundaries that are due to previous plot layout error:* some plots have trees well outside the expected plot boundary, which cannot be explained by natural disturbance or soil movement and are clearly mistakes made at the previous measure. Check if the previous measure re-established any corners to determine if the current layout is correct. If after careful checking you are confident the stem(s) should not be within the plot area, remeasure these trees (i.e. stem status and diameter) and record their distance from the plot boundary. Use the Notes column of the stem diameter and sapling sheet (Appendix 4) to clearly indicate which tagged stems are outside the 20 × 20 m plot boundaries (e.g. 'Out—prev. meas. error').

(b) Tagging and measurement of new stems

- *Minimum tagging threshold:* note that although most historical permanent plots have used 2.5 cm as the minimum tagging threshold, some have used larger minimum tagging thresholds (e.g. 3.0 cm or 10 cm). Such plots should be upgraded to meet standard protocols and all stems >2.5 cm tagged. This change to plot protocols should be documented in the metadata for the survey so that data users can account for the change in their data analyses. Tag and measure all new stems with a DBH > 2.5 cm at 1.35 m along the stem and record these on a new stem diameter and sapling sheet (see section 5.4 and Appendix 4).

- *Tag numbers:* ensure tag numbers used for new trees do not overlap with any tag series previously used on the plot. Note that because in historical data only the last four digits of tags could be entered, neither the alphanumerical nor the number sequence of the tag series used should overlap with historical data.
- *Tree ferns:* tree ferns were not traditionally tagged on most plots established before about 1990, but should now be tagged and measured following the standard plot protocols (section 5.4). This modification to original plot measurement protocols for a survey is easily accounted for during data analysis. Note the change in the metadata for the survey.
- *For multi-stemmed trees with new recruits:* on new stem sheets indicate the attachment of new stems to previously tagged stems by recording the associated tagged stem in the notes column (e.g. Att. to AF1983).

6.2.5 Sapling counts

Repeat sapling counts following the protocols in section 5.6. Record sapling counts on a stem diameter and sapling sheet (Appendix 4). Note that variations in sapling count protocols used in historical plot data may include the following.

- *Differences in the treatment of tree ferns:* in most (but not all) permanent plot surveys undertaken before 1990, all tree ferns >1.35 m tall have been classed as saplings (see Allen 1979, 1993; Allen & McLennan 1983). Tree ferns should now be treated either as saplings or as trees when meeting criteria outlined in sections 5.4 and 5.6. This will allow tree fern population demographics and structure to be more accurately quantified in future. Where this protocol change is a modification to original plot measurement protocols for a survey, it can be relatively easily accounted for during data analysis. Note the change in the metadata for the survey.
- *Differences in the treatment of lianas:* historical permanent plot surveys have often included lianas in sapling counts (see Allen 1979, 1993; Allen & McLennan 1983). Use discretion when remeasuring plots, and re-count liana stems only where this is relevant to survey objectives. If lianas are counted as saplings, in the metadata for the survey clearly document the protocols followed.
- *Differences in the treatment of epicormic shoots:* epicormic shoots<2.5 cm DBH are not counted as part of these standard protocols, but in some permanent-plot surveys epicormic shoots have been counted as saplings (e.g. Payton et al. 2004). Where it is known that epicormic saplings were counted in the previous measurement of a vegetation survey, follow the original protocol where this has been documented. Using the Notes column of the stem diameter sheet, clearly distinguish epicormic saplings from other sapling stems. In the metadata for the survey clearly document the protocols followed.

6.2.6 Understorey subplots

- *Note any differences in the understorey subplot numbering system* (section 6.2.2) in the Notes section of the Recce sheet. Be aware that, although uncommon, understorey subplots in existing permanent plot surveys may also vary in number and size. Record such information on the Recce sheet and in the metadata for a survey. Ensure the understorey subplot numbering system in use on the plot has been identified before replacing missing pegs or beginning understorey subplot measurement.
- *Use a metal detector to search for understorey subplot pegs:* understorey subplot pegs can become buried below the current ground surface, and on steep or unstable plots they frequently fall out or move downslope. It can sometimes be efficient for one person to systematically search for all understorey subplot markers using a metal detector while another person or team works behind them doing the measurements.
- *Understorey subplot pegs that are relocated* in their original positions, as far as this can be determined (i.e. they remain in the ground within the vicinity of their correct location), should be remeasured following the standard protocols. Note on the understorey subplot sheet that the subplot has been 're-found' (see Appendix 5).
- *Replace any pegs that are missing with a new peg,* and re-establish any pegs that have been dislodged from their original position. Ensure each subplot is established at the correct position and is in line with any existing subplot pegs and/or the internal tape. Note on the understorey subplot sheet that the understorey subplot peg has been 're-found', 'replaced' or 're-established' (see Appendix 5).
- *Repeat understorey subplot measurements* as described in section 5.7.
- *When more than 24 understorey pegs are found* (e.g. two pegs labelled number 5), retain and remeasure the original peg, if this can be identified. When this is not possible, retain the peg that conforms most closely to the plot layout. Remove the other peg from the plot and make a note on the understorey subplot sheet to this effect.
- *Understorey subplot pegs that have shifted:* previous experience suggests that, on occasion, understorey subplots may move around or out of a plot as a result of disturbance events (e.g. landslide). Where understorey subplot pegs have moved but remain clearly inserted into the ground, they should continue to be remeasured. Note on the understorey subplot sheet any understorey subplot that is outside the 20 × 20 m plot boundaries, and record accurate relocation information for each (i.e. a measured distance and direction from a corner peg or other relocatable point).
- *Ephemeral seedlings:* note that when referring to historical data sheets, you may see the letters 'eph' written next to understorey subplot data. This was a historical convention indicating that seedlings were considered ephemeral (e.g. short-lived cotyledons). The letter 'c' was also sometimes used. These historical conventions should no longer be used.

7 Collecting and recording unknown plants

Reporting changes in plant biodiversity over time or between areas requires consistent, accurate taxonomic standards. Whenever you are unsure of the identity of a plant species on a plot, collect it and have the identity of the plant properly checked at the field base or office. Adopt a systematic approach to collecting and storing specimens, recording specimens on field sheets, and correcting field sheets once the specimen identifications are resolved.

Prior to fieldwork, field staff should become familiar with the range of species likely to be encountered within the survey region. This will help guide staff on the important identifying features that must be included when collecting specimens. Be aware of any provincially or nationally threatened species that may be encountered, and ensure that collecting activities do not contribute to the decline of populations at risk. Before making collections, ensure you have the necessary permission or permit from the landowner or administrator.

7.1 Collecting unknown plant specimens

- A specimen should be collected whenever the identity of a species on a plot is unknown or uncertain. Collect specimens from outside the plot where possible. Do not collect a specimen if doing so would eliminate the species from the plot and immediate surroundings. Do not collect plant specimens from understorey subplots.
- Aim to collect as much of the vegetative and floral parts as practical. The specimen should include (where appropriate and available) root, stem, leaves, flowers, fruits and seeds, and should provide an adequate example of the overall habit of the plant.
- Give each collected species a provisional 'tag name' that reflects a notable feature of the plant or a potential genus or species. Each tag name should be considered specific to the plot at which it was created. When you are confident of the genus, include this in your tag name. If you have some confidence about the species, use the six-letter NVS code for that species. If you are collecting multiple taxa within a genus, combining the genus code with a notable feature of the plant can help generate distinct tag names for all specimens collected at the plot (e.g. ASTgrey).
- EVERY time a collected unknown species occurs on the field sheets, annotate the tag name record with the symbol '©' to indicate that a specimen was collected. At each plot, check that tag names are used consistently throughout all field sheets (e.g. between Recce, stem diameter, and seedling field sheets). When the tag name is assigned to more than one individual plant, ensure the plants really are the same species. Where there is any doubt whatsoever, collect an additional specimen and assign it another unique tag name.
- While *at the plot*, label the plant specimen using a suitable label (e.g. a plant nursery label). Record the tag name (*exactly* as it appears on field sheets), survey name, plot number, collection date, and collector's name, as well as any notable features of the plant's habit, height or substrate. It is also useful to write on the label which subplot(s) the species was recorded at and the tree tag number (where applicable). Attach the

labels to the specimens and ensure they cannot be separated during transportation back to the field base.

- Use a portable plant press (e.g. hard-covered book with absorbent pages, or a smaller version of a standard plant press) or plastic bags to temporarily store collected specimens until arrival at the field base.

7.2 Storing unknown plant specimens

- At the field base, transfer each collected specimen into a plant press as soon as possible. A plant press can easily be constructed using plywood, sheets of corrugated cardboard (and/or corrugated aluminium sheet), and absorbent paper (e.g. newspaper), held together using belts or straps.
- While transferring specimens, systematically check that all collected specimens were recorded on the field sheets, and that the tag name recorded for the species was used consistently across all field sheets, *and was annotated with a '©' symbol every time it occurred.*
- Carefully place each specimen within a folded piece of plain newsprint, and separate specimens using sheets of cardboard and additional paper. Ensure the natural habit of each plant is retained and that features important for the specimen's identification are not obscured. Fold large specimens neatly so that they fit inside the plant press. Place seeds or other loose material in a labelled envelope.
- Change the paper in the plant press regularly to prevent specimens from going mouldy, particularly in damp climates or where specimens were wet when pressed. Specimens will dry most quickly when the plant press is stored in a well-ventilated, sunny location.

7.3 Identifying unknown plants and correcting field sheets

- Once dry, sort the specimens into logical groups, such as by genus or life form. Use identification books and taxonomic keys to identify specimens to species, subspecies or variety level. Don't assume the genus or species used as the tag name is correct. Seek help from a botanist or herbarium to identify specimens and/or to validate each identification.
- Record clearly the new, correct identity on the nursery label attached to each specimen, and cross out the tag name (ensuring it remains legible). Check that all species names used are current and correct (see section 5.2).
- Create a spreadsheet or list of unknown plants. For each collected specimen, list the unique plot identifier, tag name initially recorded on field sheets, resolved identity, and name of the person who resolved the identity. The spreadsheet or list of unknown plants ensures the connection between the tag name and the resolved identity of each specimen is clearly documented, so that if dubious species occurrences are later queried, specimens can be rechecked and field sheets amended where necessary. Print this list and file it with the field sheets.
- Use the list of unknown plants and take a systematic approach to ensure tag names on all field sheets are corrected (where necessary). Each collected species may have

been present on more than one subplot at a permanent plot, and on more than one type of field sheet (e.g. Recce, understorey subplots and stem diameter data). Do not rub out the '©' symbol, but put a line through it to indicate that the identity of the specimen was resolved.

- Keep all specimens until any report or publication using the data has been completed. Consider lodging specimens of each species in a regional herbarium, especially species that are taxonomically difficult, rare, or outside their documented geographical range. Links to the major public herbaria in Australasia can be accessed at https://avh.chah.org.au/. Herbarium curators can provide detailed information on the data required when lodging specimens.

8 Quality control procedures for permanent-plot surveys

Quality control procedures are an essential part of any monitoring programme. Quality control should consist of internal systems of routine technical activities and procedures to ensure data consistency, comparability, and completeness, and so that inventory and monitoring programmes are efficient and will ultimately satisfy the requirements of data users. In this case, the aim of the recommended quality control procedures outlined below is to ensure that reliable data on forest composition and structure are collected from permanent plots.

In addition to using a quality control checklist, data quality limits (DQLs) can be used to provide feedback to field teams when plots are audited, and to guide training processes. A concurrent remeasure of a subset of plots in the national network generated a number of recommendations. Of relevance here is the suggestion of a two-stage solution that first minimises error through comprehensive training programmes, and then accommodates remaining error through quantifying and integrating measurement error into reported measures (Mason et al. 2015). DQLs for the methods described in this manual are reported and critiqued in Mason et al. 2015 and are available here: https://nvs.landcareresearch.co.nz/Content/Mason%20et%20al%20Quantifying%20uncertainty%20in%20forest%20plot%20data.pdf

A suite of DQLs informed by Mason et al. 2015 has been adopted by the DOC Tier 1 BMRS and can be found in the appendices of their field protocol (DOC 2019a).

8.1 Routine quality control procedures

Routine procedures should be followed before and during a permanent plot survey to help ensure quality data are collected. Before starting fieldwork, check that:

- field staff have sufficient training, supervision and/or skills to undertake the work to a high standard
- field staff are informed of measurement protocols for the survey – field teams should be provided with written documentation on any intentional, planned deviations from standard plot measurement protocols
- all equipment (see Appendix 2) is available and in good working order, and field staff are familiar with its use
- work plans for the survey are sufficient to enable high-quality data to be collected, and will not force field staff to leave out certain measurements or undertake them to a low standard
- if the survey is a remeasurement of existing plots, copies of plot sheets from the previous measurement and lists of problems previously identified in data-checking exercises are taken to the plot and resolved, where possible.

Before completing fieldwork on each plot, field staff should undertake the following.

- Methodically check that all data are correct, complete and legible. An example of a checklist that can be used for this purpose is provided in Appendix 9. This checklist may be extended when collecting ancillary data in addition to the standard plot measurement protocols.

- Recheck that unknown plant species have been collected, labelled and correctly recorded on field sheets (section 7).

For the duration of each field trip and on return to the field base or office, ensure the following tasks are completed.

- Securely store data: during fieldwork, suitable data storage consists of envelopes or bags and box files to file the field sheets in a logical order. On return to the main base, ensure safe interim storage of field sheets until the complete set of data from the survey is ready to be properly archived. You should scan or make a back-up photocopy of field sheets.
- Ensure collected plant specimens are properly pressed and dried (see section 7).
- Ensure all gear is in working order and that sufficient supplies of consumable items are available (see Appendix 2).

At the end of the fieldwork for a survey, ensure that:

- the identities of unknown plant specimens are resolved and checked, and field sheets are corrected (see section 7)
- computerisation of data is arranged
- data are securely archived (see section 9).

9 Data management and storage using the NVS Databank

Agencies that collect vegetation data are increasingly aware of the need for systematic data storage to ensure data are easily accessible and safeguarded against loss. Storage of permanent plot data is facilitated by the NVS Databank which is recognised as New Zealand's primary repository for data on the structure and composition of indigenous vegetation.

The NVS Databank's primary function is as a national archive, where data can be deposited with confidence that it will be safeguarded. The NVS Databank is both a physical archive, holding hard-copy records of vegetation plot data in secure, climate-controlled, insect- and fire-proof storage facilities, and a digital databank, storing electronic copies of data.

Many of the vegetation survey data previously collected in New Zealand are stored in the NVS Databank, including vegetation surveys carried out by the former New Zealand Forest Service, by the Protected Natural Area (PNA) surveys, and more recently by DOC, Manaaki Whenua – Landcare Research, regional councils, and universities.

9.1 Benefits of the NVS Databank for data providers and users

There are many benefits of a national repository for vegetation inventory and monitoring data. The NVS Databank enhances data availability to data users while protecting the interests of data providers. It has become invaluable as policy makers and researchers increasingly seek to address questions at multiple scales, requiring more data than one team or agency could collect (Wiser et al. 2001).

Following are some of the direct benefits to data providers and users.

- Data collected using standard methods are systematically archived in both hard-copy and electronic formats.
- Archived data are kept up to date with available technology (e.g. data originally deposited in older, highly coded file formats have now been migrated to a relational database). Ongoing updates ensure that data can continue to be deposited and retrieved in formats that meet the needs of data providers and facilitate ease of data use.
- Systematic error-checking and correction exercises undertaken by NVS staff have improved the quality of data archived in the NVS Databank, benefiting both data providers and users.
- Metadata associated with each vegetation survey ensure that relevant information about the data are archived, safeguarding information for the future and allowing data users to assess whether data are appropriate for any particular purpose.
- Online search facilities provide data users with quick summaries of what data sets are archived, their geographical location, and what taxa were recorded. Links with other databases (e.g. the New Zealand Plant Names Database: Ngā Tipu o Aotearoa – New Zealand Plants; http://nzflora.landcareresearch.co.nz/), and the Ecological Traits of New Zealand Flora (http://ecotraits.landcareresearch.co.nz/), allow potential data users to access information on the taxa recorded.

9.2 Depositing data into the NVS Databank

Before depositing data into the NVS Databank, organise hard copies of field sheets, electronic data (where available), and any other relevant documentation about the survey (i.e. metadata; see below). For further information on depositing data into the NVS Databank, refer to the NVS website (http://nvs.landcareresearch.co.nz/) and/or contact the NVS Databank manager (nvs@landcareresearch.co.nz).

9.2.1 Hard copies of data sheets

Archive all original data sheets (preferable) or high-quality photocopies. Photocopies of data sheets should ideally be done on acid-free paper at 95% the original size and one shade darker than usual, to ensure all data are legible and complete. Check the quality of all photocopies before archiving them in the NVS Databank. Maps and aerial photographs showing plot locations should also be archived in the NVS Databank. If hard copies of maps are not available, scan maps and archive the electronic files in the NVS Databank.

9.2.2 Data in electronic form

Copies of electronic data should be supplied to the NVS Databank manager when these are available. Alternatively, data can be entered in the NVS Databank by staff who specialise in entering vegetation data. There are benefits to arranging for data to be entered straight into the NVS Databank; for example, automated checks are conducted at the point of data entry and throughout the process, ensuring data are of high quality, errors are minimised, and potential errors or problems are highlighted. NVS Express is a freely available purpose-built Windows tool for entering and summarising vegetation data compatible with the NVS Databank and can be downloaded from the NVS website (https://nvs.landcareresearch.co.nz/Data/dataentry). Requirements and costs associated with data entry can be discussed with the NVS Databank manager (nvs@landcareresearch.co.nz).

9.2.3 Metadata

Metadata are data *about* the data. Metadata provide information essential for the long-term use of the data set, as well as information required for plot remeasurement. Metadata can be submitted via the NVS website (https://nvs.landcareresearch.co.nz/Data/Contribute). Metadata must be submitted for all data sets that are deposited into the NVS Databank, and should include (where applicable):

- instructions regarding access to data – the interests of data providers are protected through written agreements that determine access rights to specific data sets within the NVS Databank (refer to the NVS website for further information on access levels)
- what data were collected and the objectives of the survey
- the sampling methodology used to determine plot placement, including study area boundaries

- the plot measurement protocols that were followed – any deviations from standard plot measurement protocols should be documented in detail
- the full names of all people involved in data collection
- the sources of nomenclature usage followed for a survey for either each group of taxa, or (where necessary) for each individual taxon – this information will help ensure nomenclature used remains unambiguous over time (see section 5.2)
- any problems found during data entry or checking that cannot be resolved, or problems to address at the next plot measurement
- any notes regarding data quality (e.g. problems identified during data collection, data checking or data entry)

If the vegetation survey involved remeasuring existing permanent plots, errors and problems may have been found in the original data (e.g. duplicate tags or incorrect species codes for tagged trees; see section 6.2.4 for further examples). Errors in historical data should be corrected, where possible, and any changes made to archived data must be documented (see Newell & Baldwin 2000; Hurst et al. 2006; http://nvs.landcareresearch.co.nz/).

9.3 Retrieval of data from the NVS Databank

Hard copies of data, electronic data and documented metadata can be readily retrieved from the NVS Databank. The NVS website (http://nvs.landcareresearch.co.nz/) provides online access to detailed information (i.e. metadata) about groups of vegetation plots that are stored in the NVS Databank. In the NVS Databank, data from vegetation plots are curated as components of particular surveys or projects.

There are a number of ways the NVS website can be used to locate particular vegetation surveys or search for data, such as:

- conducting a search for a particular survey name, person, known geographical area or species
- viewing interactive maps that show NVS plot locations and species distributions.

If a data set cannot be satisfactorily located, or where a more general type of request is required, then a 'search data request' can be sent using the form provided on the website, and the NVS Databank staff will then help locate the relevant data. Metadata about surveys can be viewed to determine whether a data set will serve your needs. For any given data set, the metadata will state whether there are electronic data available and what access restrictions might apply to the data.

The facilities on the NVS website can be used to locate and compile a list of requested data sets, which can then be automatically requested through the website. If a data user requests a data set that has restricted access, approval from the data owner must be obtained by the person making the request for the data (this is an automated process).

Data can be provided in a variety of electronic formats (e.g. delimited ASCII text files, MS Excel spreadsheets, or that required by PC-Analysis packages). There will usually be no cost associated with reasonable data-retrieval requests. Data users are asked to be conscious that the NVS Databank team do have other work priorities, and responses to requests are unlikely to be immediate. For further information on retrieval of data from the NVS Databank, refer to the NVS website (http://nvs.landcareresearch.co.nz/), or contact the NVS Databank manager (nvs@landcareresearch.co.nz).

10 Ancillary data

The field methods so far outlined in this manual have emphasised data on a restricted set of compositional and structural attributes of vegetation, and a relatively simple set of site variables useful for interpreting these vegetation attributes. Where time, funding and expertise permit, ancillary data may be collected. Additional biotic attributes and environmental variables that may be necessary for specific objectives are addressed below.

10.1 Biotic attributes

10.1.1 Other biota

Historically the emphasis for plot data has been on plants, but recent studies have included soil invertebrates (e.g. Wardle et al. 2001), canopy invertebrates (e.g. Wardhaugh & Didham 2006), fungi (e.g. Allen et al. 2000), and bryophytes (e.g. Dickinson & Mark 1994; Burns & Leathwick 1995), which are specifically considered further below.

'Non-vascular' is a general term for those plants without a vascular system, including the mosses, liverworts and hornworts, lichens, green algae and fungi. Such organisms play important roles in terrestrial ecosystems (e.g. DeLucia et al. 2003), yet relatively little is known about non-vascular plant species in New Zealand. There are knowledge gaps in terms of where they are found, including their wide-scale distributions (e.g. Renner 2003), and, for many species, their conservation status (e.g. de Lange et al. 2015; Rolfe et al. 2016).

Methods for determining and monitoring changes in non-vascular communities have yet to be carefully assessed. Where the objective is a full inventory of non-vascular species on a plot, they may be recorded on the Recce description. Where the objective is monitoring changes in non-vascular communities, then species can be recorded on a fixed area that may be a sub-sample of the plot area. For example, methods for detecting changes in non-vascular communities on permanent plots were developed as part of biodiversity monitoring protocols for LUCAS (Payton et al. 2004). In Payton et al. 2004 the most abundant species occurring on a subset of understorey subplots, and on the entire 20 × 20 m plot, were recorded.

For some conservation purposes it may be appropriate to undertake a more complete inventory of non-vascular species on each plot. DOC attempts a complete inventory of liverwort, moss and lichen species across their Tier 1 BMRS plot network, and their field protocol outlines a plot-based method for systematically searching a plot and managing the collection (DOC 2019a).

Initially, we advocate recording a subset of readily identified species or genera as part of routine permanent plot monitoring programmes. These are listed in section 5.3.5 and are considered to be relatively easily identified by field staff. When including non-vascular plants in inventory and monitoring systems, high taxonomic standards must be applied. For non-vascular species, this will often necessitate the collection of specimens and referral to an appropriate taxonomist for identification. Collection and storage of non-vascular specimens should be undertaken with care to ensure that specimens retain features important for identification, and to limit the impact of collection activities on the non-vascular communities on the plot. Each non-vascular species is assigned a unique six-letter species code, as for vascular plants (see section 5.2). If in doubt as to the correct species code, record the name in full.

10.1.2 Vegetation function

Given the increasing interest in the functional role of vegetation in terms of nutrient cycling, determining above- and below-ground links, and habitat for biota, data on additional vegetation attributes are sometimes collected. For example, carbon (e.g. Davis et al. 2003) and nutrient (e.g. Allen et al. 1997) storage have been estimated in stands of varying age; leaf chemistry has been examined along soil fertility gradients (e.g. Richardson et al. 2004) and linked to herbivore palatability (e.g. Forsyth et al. 2005), and the decomposability of litter of different species has been examined (e.g. Wardle et al. 2002). Two attributes widely useful for quantifying vegetation function are further described below.

(a) Coarse woody debris (CWD)

Dead wood forms a major structural feature of natural forest ecosystems and performs many ecological functions (Harmon et al. 1986). For example, the threatened long-tailed bat (*Chalinolobus tuberculatus*) requires roost sites in standing dead trees (Sedgeley & O'Donnell 1999), while in south Westland, O'Donnell and Dilks (1986) found that standing dead trees are vital foraging sites for kākā (*Nestor meridionalis*). For plant species, dead wood on the ground can be important sites for seedling establishment, growth and survival (Stewart 2002). Dead wood supports diverse saprophytic fungal communities (Allen et al. 2000) that can play a key role in the cycling of nutrients and carbon.

Despite its functional importance in natural forests, coarse woody debris (CWD) has been quantified by very few studies in New Zealand, and these show high variability in the quantity of CWD among different forests (e.g. Stewart & Burrows 1994; Allen et al. 1997). Data on CWD can be collected as an optional addition to standard permanent plot protocols (e.g. Coomes et al. 2002). Protocols for CWD data form part of standard monitoring protocols used for LUCAS (Payton et al. 2004), and these can be adopted on permanent plots to provide data on CWD from local plot networks.

Where CWD is to be measured on permanent plots, all dead standing trees, tree stumps and fallen logs/branches with a diameter ≥10 cm are included, where located within the permanent 20 × 20 m plot boundaries (DOC 2019a). Each item is allocated a 'decay class' and where possible identified to genus or species level (Allen et al. 1997; Payton et al. 2004). For each item of CWD, the length and orthogonal widths are taken so that volume estimates can be calculated. Items of CWD of most decay classes are uniquely tagged so that they can be relocated and remeasured when the plots are revisited. For full details on the methodology, see DOC 2019a.

(b) Tree heights

Accurate measures of tree biomass are required to quantify both stocks and changes in forest biomass and carbon. Because sampling entire tree biomass is both labour intensive and causes significant disturbance, we rely on allometric relationships between easily measurable metrics of tree dimensions and total biomass to quantify biomass and carbon stocks (Coomes et al. 2002; Beets et al. 2012; Marden et al. 2018). Allometric relationships or biomass regression relationships are commonly site or species specific and in New Zealand we only have a good understanding of these relationships for a small number of species (Coomes et al. 2002; Beets et al. 2012). Tree height is not exactly proportional to stem dimension, especially across sites, therefore estimates of total biomass can benefit from the measurement of tree height (Coomes et al. 2002; Beets et al. 2012). Soil fertility, moisture balance, and wind exposure all have an impact on tree height (Coomes et al. 2002). For research projects that require the quantification of total biomass across sites, or across an abiotic gradient, the inclusion of plot level measurements of tree height can improve these estimates. Coomes et al. 2002 trialled an approach in New Zealand forests which included the measurement of 20 trees in a 20 × 20 m plot, these were selected non-randomly to represent a range in tree heights per plot. The DOC Tier 1 BMRS have adopted this approach and their field protocol details methods for selecting species and trees for height measurement, the protocol also describes how to consistently measure tree height (DOC 2019a).

(c) Plant traits

For ecological studies, the classification and grouping of plants based on taxonomic affinities has limitations when it comes to answering certain ecological questions (e.g. Grime et al. 1997). In response, ecologists sometimes group the large number of plant species into much fewer entities based on functional grounds (e.g. Diaz et al. 2002). Functional traits have been associated with plant responses to environmental change or gradients (e.g. leaf nutrient concentrations along gradients of nutrient availability; see Richardson et al. 2004); competitive strength or defence against herbivory (e.g. Forsyth et al. 2005); and plant effects on biogeochemical cycles and disturbance regimes (e.g. leaf nitrogen content as a measure of decomposability; see Wardle 2002).

The most favoured plant traits collected in routine inventory or monitoring programmes are usually those that are relatively easy and cheap to measure and have well-known roles. Detailed guidelines for the collection of plant trait data can be found in Pérez-Harguindeguy et al. (2013).

Data on plant leaf traits are usually obtained using specimens of sunlit foliage, collected in the middle of the growing season. This can present sampling difficulties; in tall forests, canopy foliage may need to be shot down using a firearm, and for understorey species in dense vegetation, specimens must usually be chosen from the least-shaded sites. Recommended sample sizes of individuals and specimens that are likely to be needed to accurately measure various leaf traits, and the collection, storage and processing of specimens, are discussed by Pérez-Harguindeguy et al. (2013).

10.2 Environmental variables

Allen et al. (2003) define a set of factors that drive compositional, structural and functional variation in vegetation. Numerous variables can be used for each of these factors. Below we consider those that can be measured at each plot or determined through often broader-scale environmental patterns.

10.2.1 Point data from plots

Variables measured on an individual plot can represent a mean over the whole plot area, or can capture variability across the plot area. Which option is used depends on the objectives, but also has major consequences in terms of the cost of obtaining the data. Some studies have measured light because of its influence on regeneration (e.g. Coomes et al. 2005), disturbance severity because of its influence on recovery processes (e.g. Stewart & Rose 1990), and animal abundance because of its influence on vegetation dynamics (e.g. Husheer & Robertson 2005). Two factors more often quantified in New Zealand that can drive vegetation patterns or change are soils and browsing by introduced herbivores.

(a) Soils

The chemical and physical properties of soils have a strong influence on vegetation. Soil data collected from vegetation plots in New Zealand have been used to help interpret patterns of vegetation composition and structure (e.g. Stewart et al. 1993), understand patterns of plant invasion (e.g. Timmins & Williams 1991; Wiser et al. 1998; Standish et al. 2004), determine the impacts of introduced herbivores (e.g. Rose, Harrison et al. 1988), relate soil fertility to forest dynamics (e.g. Coomes et al. 2005), and measure carbon storage in soils (e.g. Davis et al. 2004).

Clearly, the choice of soil parameters to measure depends on the questions to be addressed. For detailed guidelines on describing soil profiles, soil sampling, processing and analysis, refer to Milne et al. 1995. However, the collection of a standard set of minimum soil attributes in long-term vegetation monitoring programmes would allow synthesis and comparison between data sets.

An example of a plot-based soil sampling protocol involves the collection of the top 10 cm of mineral soil from the nine internal tape intersections on a 20 × 20 m plot (Figure 4), this collection is aggregated and a sample is then analysed for nitrogen, phosphorus and carbon concentrations (DOC 2019a). Care is taken to sample the mineral soil that is found below the litter layer and the organic horizon (FH, O, or OH horizon).

(b) Browse

Quantifying and understanding herbivory by introduced animals has been a long-term focus of vegetation inventory and monitoring in New Zealand. Incidence of animal browse is recorded as part of standard Recce measurement procedures (see section 5). Where the impacts of introduced mammals on forest composition and structure are a primary concern, more detailed data on browse occurrence can be a helpful addition to the standard plot measurements.

A wide variety of methods have been advocated or used for monitoring the effects of animal browse, including various forms of imagery (e.g. Beadel 1987; Rose, Pekelharing et al. 1988), various types of browse indices (Wardle et al. 1971; Rose & Burrows 1985), vegetation structural gaps (e.g. Sweetapple & Nugent 2004), and the demographics of target plant species (e.g. Allen et al. 2003). Many of the observational methods fail to link animal impacts with the demographic maintenance of the plant species of concern (Allen et al. 2003). We outline methods below for foliar browse and understorey browse by introduced herbivores.

Browse data can be collected from permanent plots using the Foliar Browse Index (FBI) method (Payton et al. 1999). This method uses visual assessments of individually marked trees to determine trends in foliage cover, and possum damage to the leaves and stems of the selected species. Advice on the choice of indicator species, criteria for selecting target sample trees to monitor, and guidelines on appropriate sample sizes and the recommended frequency of measurement are provided in Payton et al. 1999. Linking browse to canopy tree recruitment, growth, and (particularly) mortality is desirable but often requires large sample sizes or many years of monitoring because of the low rates of mortality observed (see Peltzer et al. 2005; Urlich & Brady 2005).

Browse index methods using uniquely tagged individuals have also been used to monitor ungulate browse on understorey plants. Note that studies taking this approach have generally reported differences in seedling demographics between fenced and unfenced plots, or between ungulate treatment areas, rather than the effects of browse on seedling demographics *per se* (e.g. Husheer & Robertson 2005; Duncan et al. 2006). This may be because assigning browse scores to small seedlings is inherently difficult and subject to an unknown amount of error, which highlights the importance of a well-thought-out experimental study design.

When monitoring impacts in forests where more than one ungulate species is present, it is impossible to distinguish between browse from the alternative species present. When the full range of demographics (recruitment, growth and mortality) are monitored under a range of management regimes, for example, it is possible to model and predict long-term consequences of management for the target plant species (e.g. Duncan et al. 2006).

10.2.2 Geospatial data

Rather than the actual measurement of point data on plots, it is also possible to use interpolated or modelled values from geospatial databases to help interpret vegetation patterns. Spatial data on geology or climate that may be used for such purposes can be derived from the Land Environments of New Zealand (LENZ) database (see http://www.landcareresearch.co.nz/databases/). Such data have been used to explore the potential distribution of threatened native plant species (Rutledge et al. 2004; Rogers & Walker 2005), weed species (Overton & Lehmann 2003), or communities (Newell & Leathwick 2005), and to assess the representativeness of vegetation communities protected in the conservation estate on the grounds of climate (Walker et al. 2003a, 2003b).

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Appendices

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Appendix 2.	Equipment required to establish and measure permanent plots
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Appendix 1. Glossary

Basal area (BA)	The cross-sectional area of a tree stem at breast height (e.g. 1.35 m along the stem), which may be calculated using a diameter measurement. The term may be used to describe the area occupied by an individual tree or species, as well as the area occupied by all trees in a stand (often expressed as m^2/ha).
Canopy cover	The percentage of ground covered by a vertical projection over the plot area of all vascular and non-vascular live or dead material (leaves, trunks and branches) >1.35 m above the ground.
Clinometer	An instrument for measuring slopes.
Density	A value describing the number of individuals of a species on a unit/area basis.
Diameter at breast height (DBH)	A term used in this document to describe a tree diameter measurement taken 1.35 m along the stem from the ground.
Diameter tape	A specially graduated tape measure used to convert a circumference measurement into a diameter measurement, so that diameter may be determined directly when the tape is placed around a tree stem.
Dymo-tape writer	An instrument used to emboss letters and numbers onto aluminium tape, to make replacement tree tags. Use of a Dymo-tape writer is by far the easiest and most efficient method of making replacement tags, though they may also be made using blank aluminium tags and alpha-numeric punches.
Epicormic shoots	Straight, unbranched stems originating from buds under the bark on the tree trunk, rather than from terminal or axillary buds (also called coppice or sucker shoots).
Epiphyte	A non-parasitic plant that grows on another plant. See section 5 for specific details regarding epiphytes for Recce and stem diameter protocols.
Extrusive	Relating to or denoting rock that has been extruded at the Earth's surface as lava or other volcanic deposits.
Flora	All the plant species present within a particular area or region.
Frequency	A term that describes the distribution of a species through an area. Frequency is determined by calculating the percentage of plots or subplots in a sample on which a species occurs.
Global Positioning System (GPS)	A navigation system that provides satellite signals that are processed in a GPS receiver to compute its location.
Hectare	10,000 square metres (approximately 2.471 acres).

Hip-chain	A piece of equipment used to measure distance, consisting of a distance counter and spool of cotton. The device operates by measuring the length of string drawn from the spool.
Intrusive	Relating to or formed by the intrusion of rock.
Metadata	Often defined as ‘data about data’. Metadata includes all important information about a data set that may potentially have a bearing on its use.
Non-vascular plant	A general term for those plants without a vascular system for transporting water and nutrients (i.e. xylem and phloem). Although lacking such tissues, some non-vascular plants possess other tissues specialised for the internal transport of water.
Permanent plot	A plot that is established with the intention that it will be remeasured in future. Permanent plots are marked in the field so that they can be relocated.
Permolat	A painted aluminium strip, often brightly coloured, used to mark transects and plot locations in the field and to mark understorey subplots on permanent plots. Plastic markers (robust and suitably sized) may be used if Permolat cannot be obtained.
Plot	In a general sense, any area of land of any shape (e.g. circle, square, rectangle) or size, which may be used for any purpose (e.g. sampling). In this manual, ‘plot’ is mainly used in the context of instructions for measuring permanent 20 × 20 m plots.
Quadrat	A specific ecological sampling term that usually refers to a square (or rectangular) sampling plot of a predetermined area or size.
Recce description	A site and vegetation description, similar to those undertaken on ecological relevés or phytosociological descriptions (see Mueller-Dombois & Ellenberg 1974).
Taxa	Plural of ‘taxon’.
Taxon	Any unit of any rank within a taxonomic classification (e.g. genus, species, family).
Tier	As used in this document, a horizontal layer of vegetation bounded at fixed heights, for which cover of each species present is recorded on the Recce vegetation description.
Vascular plant	A term used to describe any plant with a vascular transport system for water and nutrients.

Appendix 2. Equipment required to establish and measure permanent plots

Plot measurement equipment:

- Permanent plot field manual
- Plant identification texts and a species list from other studies in the area
- Lightweight plant press or hard-covered book for temporarily pressing unknown plants
- Hip-chain
- Lightweight metal detector to relocate plot pegs
- Two 50 m tapes or four 20 m tapes, to establish the plot boundary
- Six 20 m tapes to subdivide the plot into 16 subplots
- Laminated copies of the plot layout
- Laminated copy of the Canopy Cover Scale
- Global Positioning System (GPS) receiver
- Topographical maps and aerial photographs
- Geological Survey map
- Clipboards
- Sighting compasses (two)
- Altimeter
- Clinometer or equivalent instrument (e.g. abney level or hypsometer)
- Binoculars, for viewing canopy foliage to identify cryptic small-leaved species, and for examining browse in the canopy
- Bum-bags or toolbelts, for carrying equipment around the plot
- Hammers, for nailing tree tags and plot markers
- Tree-tag dispenser (e.g. loop of wire or shoelace)
- Diameter tapes (e.g. two 2 m and one 5 m)
- Dymo tape-writer (or equivalent instrument); a Dymo tape-writer is the easiest and most efficient way to create replacement tree tags where necessary during plot remeasurement, but blank tags and alphanumeric punches can also be used to make replacement tree tags on surveys where relatively few are needed (usually only surveys with short intervals between measurements)
- Steel measuring tapes (8 m), hypsometer or extendable height pole, which are needed when the optional tree fern height protocol is followed, but can also be used to help calibrate height estimates made on the Recce description with measured heights
- Understorey subplot string (49 cm, nylon cord); tie a loop at one end to secure over the understorey peg and tie a knot 49 cm along the cord, allowing extra cord past the knot for holding
- Steel measuring tapes (e.g. 2 m)

Consumable items

Adequate supplies of the following consumable items should be available and the field kit restocked each day as necessary:

- Pens, pencils, erasers, etc.
- Batteries for GPS, metal detector and other electronic equipment
- Chalk (for use in dense plots to mark saplings once they are counted)
- Waterproof plant labels and waterproof marker
- Plastic bags for transporting large plant specimens
- Plastic bags for storing and transporting plot sheets
- Hip-chain cotton and flagging tape
- Permolat or equivalent markers to mark the route to the plot
- Aluminium corner pegs (e.g. 7 mm diameter, 45 cm long, pre-bent at the top)
- Permolat (or equivalent) markers for corner pegs, labelled ‘A’, ‘D’, ‘M’, and ‘P’, with holes near the top and bottom to secure them to the corner pegs
- Permolat (or equivalent) corner tree markers, marked ‘A’, ‘D’, ‘M’, ‘P’
- Aluminium understorey pegs (e.g. 5 mm diameter, 30 cm long, pre-bent at the top)
- Permolat strips (or equivalent markers; labelled 1–24, with holes near the top and bottom to secure them to the understorey subplot pegs)
- Nails (e.g. 40 mm galvanised flathead), for tagging trees
- Nails (e.g. 75 mm galvanised flathead), for tagging tree ferns
- Aluminium tree tags (sequentially numbered); the number of tree tags required per plot varies depending on the vegetation, but a good rule of thumb is to carry 200 tags for each plot that you plan to measure each day
- Metal tape for Dymo tape-writer, for plot remeasurement only

Field sheets required per plot

Two sets of field sheets (one on normal paper and one on waterproof paper), with each set containing:

- two Recce description sheets
- eight stem diameter/sapling sheets
- four understorey subplot sheets

When remeasuring existing plots, the following are also required:

- pre-printed stem diameter plot sheets (on waterproof paper)
- photocopies of all plot sheets from previous measurements
- a species list from any previous measurement of the plot

Other items required at the field base

- Species lists and reports from previous vegetation surveys in the area
- Access and/or collection permit from the Department of Conservation and/or other agencies/landowners
- Plant storage and identification equipment – includes plant press, newsprint, blotters, nursery tags, plant identification texts, hand lenses, large plastic bags
- Envelopes and boxes to temporarily store completed plot sheets
- Spare 50 m and 20 m measuring tapes
- Spare hammer(s)

Appendix 3a. Recce plot sheet: site description

PERMANENT PLOT RECONNAISSANCE (RECCE) PLOT SHEET

National Vegetation Survey Databank (http://nvs.landcareresearch.co.nz/) Page 1 of 2

PLOT IDENTIFIER: 11 - 2
DAY/MONTH/YEAR: 7 March 2007
SURVEY: Mt. Fyffe
TOPO. MAP NO. & NAME: Topo 50 BT27 Kaikoura
REGION: Kaikoura
GPS REFERENCE: GPS Make & Model: Garmin 64S
CATCHMENT: Hapuku River
Easting: 1652112
SUB-CATCHMENT: unnamed
Northing: 5319823
MEASURED BY: Roger Carran
GPS FIX: Single [✓ Averaged] 2D / [✓ 3D] Datum: NZGD49 [✓ NZGD2000]
RECORDED BY: Alex Fergus
GPS ACCURACY: 100% [✓ Y] / N: ± 4 m
PERMANENT PLOT: [✓ Y] / N
GPS LOCATION: [✓ CORNER P] / other: NA

PLOT LAYOUT	Bearing	Tape length
A–D	224°	18.5m
D–M	130°	18.5m
M–P	45°	20.0m
P–A	315°	20.2m

ALTITUDE (m) 760 m
PHYSIOGRAPHY Ridge, [✓ Face], Gully, Terrace
ASPECT (1–360°) 130°
SLOPE (°) 30°
PARENT MATERIAL Greywacke ~~Mapped~~ / [✓ Observed]
DRAINAGE: [✓ Good], Moderate, Poor
CULTURAL [✓ None], Burnt, Logged, Cleared, Mined, Grazed, Tracked
TREATMENT: N A

MESOSCALE TOPOGRAPHIC & TERRAIN SHAPE INDEX (°, record +/–)

	MTI	TSI
N	+32	+18
NE	+16	-6
E	+6	-16
SE	+21	-27
S	+27	-12
SW	+20	+3
W	+36	+22
NW	+40	+32

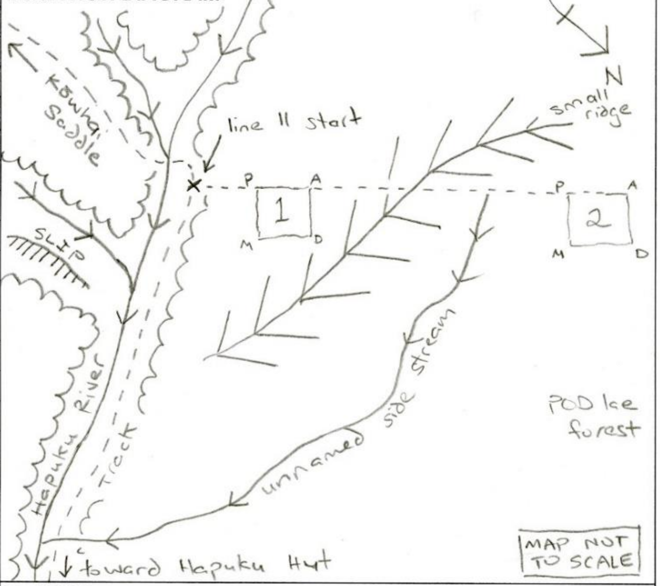
SURFACE CHARACTERISTICS:
Bedrock % 0%
Broken rock % 10%
Size of broken rock ~~<30cm~~ / [✓ >30cm]
~~Alluvial~~, [✓ Colluvial], ~~Moraine~~, ~~Volcanic~~

GROUND COVER %:
Vegetation 85%
Non-vascular 15%
Litter 90%
Bare Ground 1%
Rock 1%
AVERAGE TOP HEIGHT (m) 17 m
CANOPY COVER (%) 45%

APPROACH: From Hapuku Hut (E1653720 N5319765) follow track 1,7 km toward kōwhai saddle. Line start is marked on the track. Follow a bearing of 315° from plot 1 corner A (E1652185 N5319654) for 200 m to plot 2. The line start and line are marked with red on white permolat.

Corner M was not found so it was replaced.

LOCATION DIAGRAM



VEGETATION DESCRIPTION & NOTES:
PODlae dominates the canopy. There is no subcanopy. The browse tier and understorey are dominated by dense POLves, with occasional CARser and FUCexc saplings. Sparse non-vascular cover.

FAUNA (e.g., mammal, bird, reptile, invertebrate):
pīwakawaka, korimako, kakaruwai, pig-sign, possum-fur, cast red deer antlers.

BROWSE:

Species	Severity	Herbivore	Species	Severity	Herbivore
VERONIC	L [✓ M] H	possum		L M H	
GRI lit	L [✓ M] H	red deer		L M H	
ASP gra	L M [✓ H]	red deer		L M H	
VER fra	[✓ L] M H	red deer		L M H	
	L M H			L M H	
	L M H			L M H	
	L M H			L M H	
	L M H			L M H	

Appendix 3b. Recce plot sheet: vegetation description

Page 2 of 2

PLOT IDENTIFIER: H171 MEASURED BY: Brian Rance

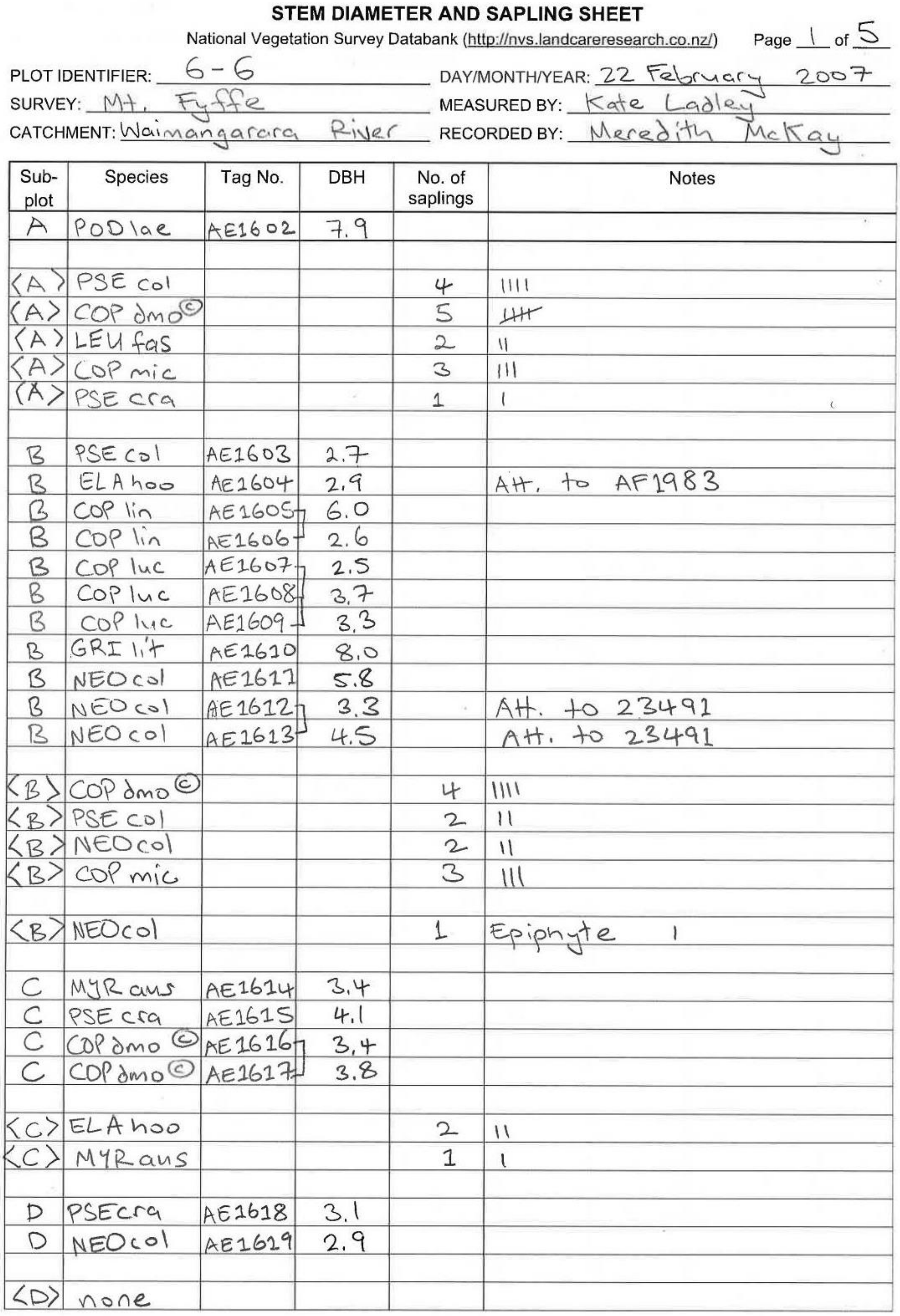
DAY/MONTH/YEAR: 03 December 2013 RECORDED BY: Alex Fergus

Cover-classes: 1= <1%, 2=1–5%, 3=6–25%, 4=26–50%, 5=51–75%, 6=76–100%.

For a 20×20-m plot area: 1% = 2×2-m (i.e. 4 m^2); 5% = 4×5-m (i.e. 20 m^2).

	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5	Tier 6
	>25 m	12–25 m	5–12 m	2–5 m	0.3–2 m	<0.3 m
Overall Cover		2	3	4	5	4
		METumb 2	✓ 2	✓ 3	✓ 2	✓ 1
Tier 7			FUScli 2	✓ 3	✓ 2	✓ 1
Epiphytes			HALbif 2	✓ 3	✓ 3	✓ 3
ARCtra 1				LEPint 3	✓ 4	✓ 3
HYMarm 1				LEPsco 2	✓ 1	✓ 1
HYMlya 1				PSE lin 1	✓ 1	—
PSE lin 1				DRA lon 1	✓ 2	✓ 1
RAUsim 1				WEIrac 1	✓ 2	✓ 1
DRA lon 1				COP foe 1	✓ 1	✓ 1
HYMmul 1				DRAmen 1	✓ 2	✓ 2
GRI lit 1				LEPjun 1	✓ 1	—
METumb 1				RUBcis 2	—	—
NOThet 1				(c)	GAH pro 3	✓ 2
HYMfla 1					MYR div 2	✓ 1
HYMrar 1					COP col 1	✓ 1
EAR muc 1					RAU sim 1	✓ 1
						ASTner 1
						AND emp 1
						GRI lit 1
						TME ton 1
						LIB mic 1
						GAS cun 1
						LUZ por 1
					(dead)	WAIste P
					(c)	THELYM 1
						APObif 1
						HYM mul 1
						HYM arm 1
						HYM lya 1
				(leaning	out)	ARCtra P

Appendix 4. Stem diameter and sapling sheet



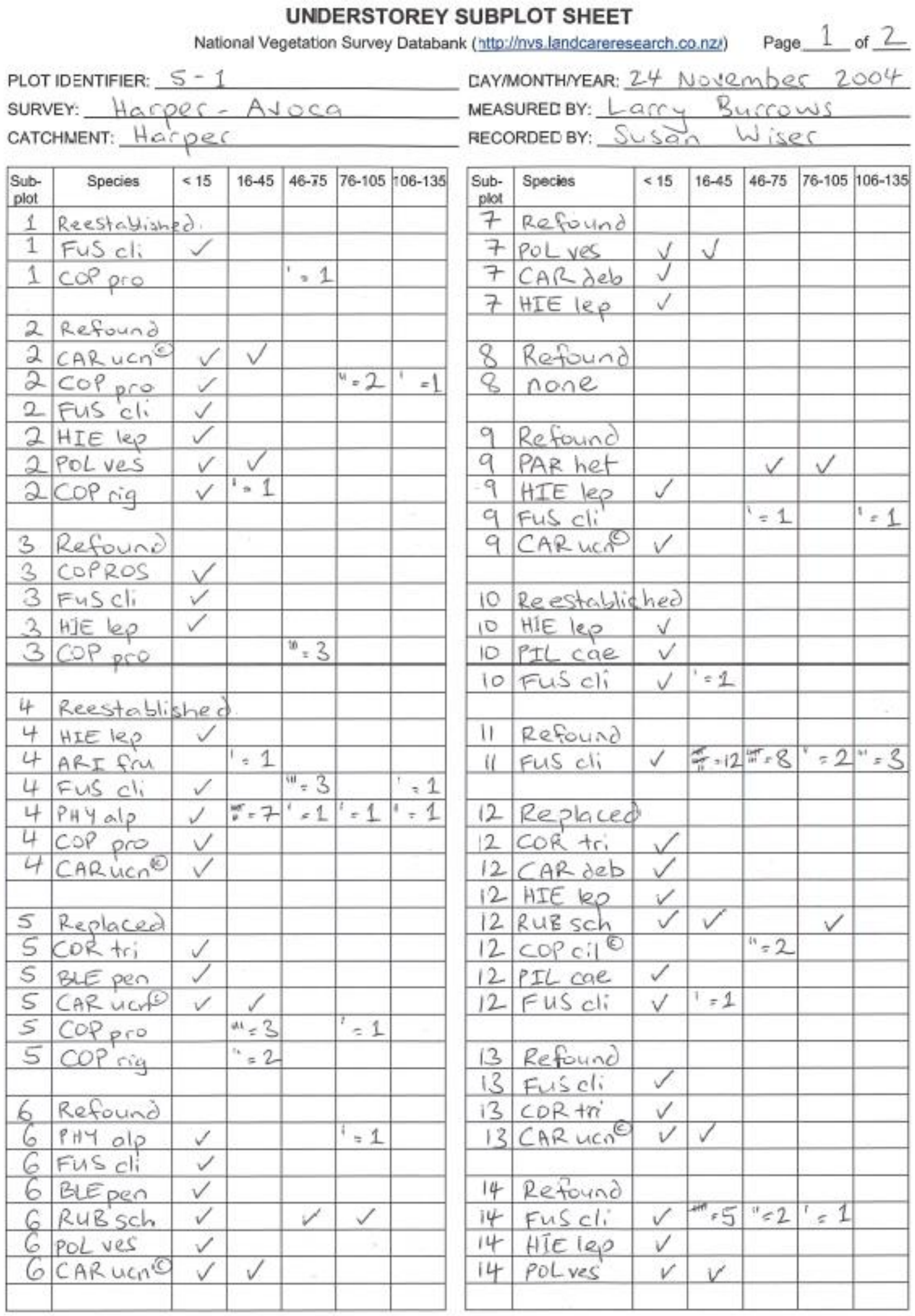
STEM DIAMETER AND SAPLING SHEET

National Vegetation Survey Databank (http://nvs.landcareresearch.co.nz/) Page 1 of 5

PLOT IDENTIFIER: 6 - 6
DAY/MONTH/YEAR: 22 February 2007
SURVEY: Mt. Fyffe
MEASURED BY: Kate Ladley
CATCHMENT: Waimangarara River
RECORDED BY: Meredith McKay

Sub-plot	Species	Tag No.	DBH	No. of saplings	Notes
A	POD lae	AE1602	7.9		
<A>	PSE col			4	||||
<A>	COP dmo©			5	卌
<A>	LEU fas			2	||
<A>	COP mic			3	|||
<A>	PSE cra			1	|
B	PSE col	AE1603	2.7		
B	ELA hoo	AE1604	2.9		Att. to AF1983
B	COP lin	AE1605	6.0		
B	COP lin	AE1606	2.6		
B	COP luc	AE1607	2.5		
B	COP luc	AE1608	3.7		
B	COP luc	AE1609	3.3		
B	GRI lit	AE1610	8.0		
B	NEO col	AE1611	5.8		
B	NEO col	AE1612	3.3		Att. to 23491
B	NEO col	AE1613	4.5		Att. to 23491
<B>	COP dmo©			4	||||
<B>	PSE col			2	||
<B>	NEO col			2	||
<B>	COP mic			3	|||
<B>	NEO col			1	Epiphyte |
C	MYR aus	AE1614	3.4		
C	PSE cra	AE1615	4.1		
C	COP dmo©	AE1616	3.4		
C	COP dmo©	AE1617	3.8		
<C>	ELA hoo			2	||
<C>	MYR aus			1	|
D	PSE cra	AE1618	3.1		
D	NEO col	AE1629	2.9		
<D>	none				

Appendix 5. Understorey subplot sheet



UNDERSTOREY SUBPLOT SHEET

National Vegetation Survey Databank (http://nvs.landcareresearch.co.nz/) Page 1 of 2

PLOT IDENTIFIER: S - 1
DAY/MONTH/YEAR: 24 November 2004
SURVEY: Harper - Avoca
MEASURED BY: Larry Burrows
CATCHMENT: Harper
RECORDED BY: Susan Wiser

Sub-plot	Species	< 15	16-45	46-75	76-105	106-135
1	Reestablished.					
1	FUS cli	✓				
1	COP pro			' = 1		
2	Refound					
2	CAR ucn©	✓	✓			
2	COP pro	✓			'' = 2	' = 1
2	FUS cli	✓				
2	HIE lep	✓				
2	POL ves	✓	✓			
2	COP rig	✓	' = 1			
3	Refound					
3	COPROS	✓				
3	FUS cli	✓				
3	HIE lep	✓				
3	COP pro			''' = 3		
4	Reestablished.					
4	HIE lep	✓				
4	ARI fru		' = 1			
4	FUS cli	✓		''' = 3		' = 1
4	PHY alp	✓	𝍸'' = 7	' = 1	' = 1	' = 1
4	COP pro	✓				
4	CAR ucn©	✓				
5	Replaced					
5	COR tri	✓				
5	BLE pen	✓				
5	CAR ucn©	✓	✓			
5	COP pro		''' = 3		' = 1	
5	COP rig		'' = 2			
6	Refound					
6	PHY alp	✓			' = 1	
6	FUS cli	✓				
6	BLE pen	✓				
6	RUB sch	✓		✓	✓	
6	POL ves	✓				
6	CAR ucn©	✓	✓			

Sub-plot	Species	< 15	16-45	46-75	76-105	106-135
7	Refound					
7	POL ves	✓	✓			
7	CAR deb	✓				
7	HIE lep	✓				
8	Refound					
8	none					
9	Refound					
9	PAR het			✓	✓	
9	HIE lep	✓				
9	FUS cli			' = 1		' = 1
9	CAR ucn©	✓				
10	Reestablished					
10	HIE lep	✓				
10	PIL cae	✓				
10	FUS cli	✓	' = 1			
11	Refound					
11	FUS cli	✓	𝍸𝍸'' = 12	𝍸''' = 8	'' = 2	''' = 3
12	Replaced					
12	COR tri	✓				
12	CAR deb	✓				
12	HIE lep	✓				
12	RUB sch	✓	✓		✓	
12	COP cil©			'' = 2		
12	PIL cae	✓				
12	FUS cli	✓	' = 1			
13	Refound					
13	FUS cli	✓				
13	COR tri	✓				
13	CAR ucn©	✓	✓			
14	Refound					
14	FUS cli	✓	𝍸 = 5	'' = 2	' = 1	
14	HIE lep	✓				
14	POL ves	✓	✓			

Appendix 6. Non-standard species codes for the New Zealand vascular flora

Use this list (current July 2021) to check unintuitive NVS codes (see section 5.2 for details). The taxon that holds the intuitive NVS code has been included in the table below for reference. These have not been included if the taxon name is no longer the preferred name. A full list of species codes used in the NVS Databank can be obtained from the NVS website (http://nvs.landcareresearch.co.nz/).

Taxon name	NVS code	Taxon with intuitive NVS code
Abrotanella rostrata	ABRrst	NA
Abrotanella rosulata	ABRrsl	NA
Aciphylla montana	ACImot	*Aciphylla monroi*
Aciphylla simplex	ACIsmp	*Aciphylla similis*
Aciphylla traversii	ACItrv	*Aciphylla traillii*
Agrostis personata	AGRpes	NA
Anisotome aromatica var. *incisa*	ANIinc	NA
Asplenium flabellifolium	ASPflb	*Asplenium flaccidum*
Astelia graminea	ASTgrm	*Astelia grandis*
Brachyscome montana	BRAmnt	*Brachyglottis monroi*
Brachyglottis species	BRACHG	*Brachyscome* species
Cardamine corymbosa	CARcoy	*Carex coriacea*
Carmichaelia corrugata	CARcog	*Carex coriacea*
Carmichaelia appressa	CRMapp	*Carex appressa*
Carex carsei	CRXcar	*Carmichaelia carmichaeliae*
Carex divisa	CARdvs	*Carex divulsa*
Carex flacca	CARflc	*Carex flaviformis*
Carex flagellifera	CARfgl	*Carex flaviformis*
Carpobrotus glaucescens	CARglc	*Carmichaelia glabrescens*
Cardamine lacustris	CARlct	*Carex lachenalii*
Carmichaelia kirkii	CRMkir	*Carex kirkii*
Carex muricata	CARmrc	*Carmichaelia muritai*
Carex petriei	CARptr	*Carmichaelia petriei*
Cardamine subcarnosa	CARsbc	*Carex subdola*
Carex traversii	CARtrv	*Carex trachycarpa*
Carmichaelia uniflora	CRMuni	NA
Cardamine unicaulis	CARunl	NA
Celmisia cordatifolia	CELcrd	*Celmisia coriacea*
Celmisia graminifolia	CELgrm	*Celmisia gracilenta*
Celmisia lindsayi	CELlnd	*Celmisia xlinearis*
Celmisia macmahonii	CELmcm	*Celmisia mackaui*
Celmisia macmahonii var. *macmahonii*	CELvmc	*Celmisia macmahonii*

Taxon name	**NVS code**	**Taxon with intuitive NVS code**
Celmisia spedenii	CELspd	*Celmisia spectabilis*
Cenchrus purpurascens	CENpup	*Cenchrus purpureus*
Chenopodium trigonon	CHEtrg	*Chenopodium triandrum*
Chionochloa crassiuscula subsp.	CHIscr	*Chionochloa conspicua* subsp. *conspicua*
Chionochloa flavicans	CHIflv	*Chionochloa flavescens*
Clematis marmoraria	CLEmmr	*Clematis marata*
Coprosma distantia	COPdst	*Coprinus disseminatus*
Coprosma dumosa	COPdmo	NA
Coprosma macrocarpa subsp. *macrocarpa*	COPmcm	*Coprosma macrocarpa* subsp. *minor*
Coprosma petiolata	COPptl	*Coprosma petriei*
Coprosma pseudociliata	COPpsc	*Coprosma pseudocuneata*
Coprosma tenuicaulis	COPtec	NA
Coprosma tenuifolia	COPtef	NA
Corunastylis pumila	CORpml	*Cordyline pumilio*
Corokia macrocarpa	CORmcc	*Corybas macranthus*
Craspedia uniflora var. *maritima*	CRAvmr	NA
Cyperaceae	CYPSPP	*Cyperus eragrostis*
Deschampsia species	DESCHM	*Deschampsia chapmanii*
Dracophyllum prostratum	DRAprs	*Dracophyllum pronum*
Echinochloa species	ECHLOA	*Echinopogon* species
Epilobium brunnescens	EPIbrn	*Epilobium brunnescens* subsp. *brunnescens*
Epilobium brunnescens subsp. *brunnescens*	EPIbru	*Epilobium billardiereanum* subsp.
Euchiton delicatus	EUCdlc	*Eucalyptus delegatensis*
Genista monspessulana	GENmns	*Gentianella montana*
Hakea salicifolia	HAKslc	NA
Hectorella species	HECTOL	NA
Juncus acutiflorus	JUNact	*Juncus acuminatus*
Juncus acutus	JUNacs	*Juncus acuminatus*
Juncus gerardii	JUNgrd	*Jungermannia* species
Leptinella intermedia	LPTint	*Lepidothamnus intermedius*
Leptostigma setulosum	LEPstl	*Lepidozia setigera*
Linaria maroccana	LINmac	NA
Linum trigynum	LINtrg	*Lindsaea trichomanoides*
Machaerina articulata	MACatc	*Machaerina arthrophylla*
Malus sylvestris	MLSsyl	*Malva sylvestris*
Melilotus officinalis	MLLoff	*Melissa officinalis*
Microsorum scandens	MICscn	*Microseris scapigera*
Microsorum species	MCROSO	*Microseris* species
Myrsine aquilonia	MYRaql	*Myriophyllum aquaticum*
Nephrolepis species	NEPHRL	*Nephroma* species
Ourisia macrocarpa	OURmcc	NA

Taxon name	NVS code	Taxon with intuitive NVS code
Ourisia macrophylla	OURmap	NA
Ourisia macrophylla subsp. *macrophylla*	OURmsp	NA
Pachycladon latisiliquum	PACltq	*Pachyschistochila latiloba*
Persicaria maculosa	PERmcl	NA
Pittosporum crassifolium	PITcrf	*Pittosporum crassicaule*
Plantago lanigera	PLAlng	*Plantago lanceolata*
Plantago unibracteata	PLAunb	NA
Poa anceps subsp. *anceps*	POAsan	*Poa acicularifolia* subsp. *acicularifolia*
Pseudognaphalium species	PSEUDG	*Pseudopanax* species
Pseudopanax colensoi	NEOcol	*Pseudowintera colorata*
Pseudotsuga species	PSEUDT	*Pseudopanax* species
Pseudowintera species	PSEUDW	*Pseudopanax* species
Ranunculus grahamii	RANgrh	*Ranunculus gracilipes*
Ranunculus maculatus	RANmcl	*Ranunculus macropus*
Raoulia subsericea	RAOsbs	*Raoulia subulata*
Rumex acetosa	RUMact	*Rumex acetosella*
Schoenus nitens	SCHnte	NA
Stellaria graminea	STEgrm	*Stellaria gracilenta*
Stenostachys gracilis	STEgrc	*Stellaria gracilenta*
Trifolium striatum	TRIstt	*Trichomanes strictum*
Triglochin palustre	TRIpls	*Triglochin palustris*
Triglochin species	TRIglc	*Trifolium glomeratum*
Triglochin striata	TRIsta	*Trichomanes strictum*
Veronica catarractae	VERcaa	*Veronica catenata*
Veronica colostylis	VERclo	*Veronica colensoi*
Veronica decumbens	VERdcm	*Veronica decora*
Veronica hookeri	VERhok	*Veronica hookeriana*
Veronica macrantha	VERmcr	*Veronica macrocarpa*
Veronica macrocarpa var. *macrocarpa*	VERmvc	*Veronica macrantha* var. *macrantha*
Veronica notialis	VERnol	NA
Veronica stenophylla var. *stenophylla*	VERssv	*Veronica stricta* var. *stricta*
Veronica strictissima	VERsts	*Veronica stricta*
Veronica subfulvida	VERsbf	*Veronica subalpina*
Veronica tetrasticha	VERttr	*Veronica tetragona*
Veronica vernicosa	VERvrn	*Veronica verna*

Appendix 7. Canopy cover scale

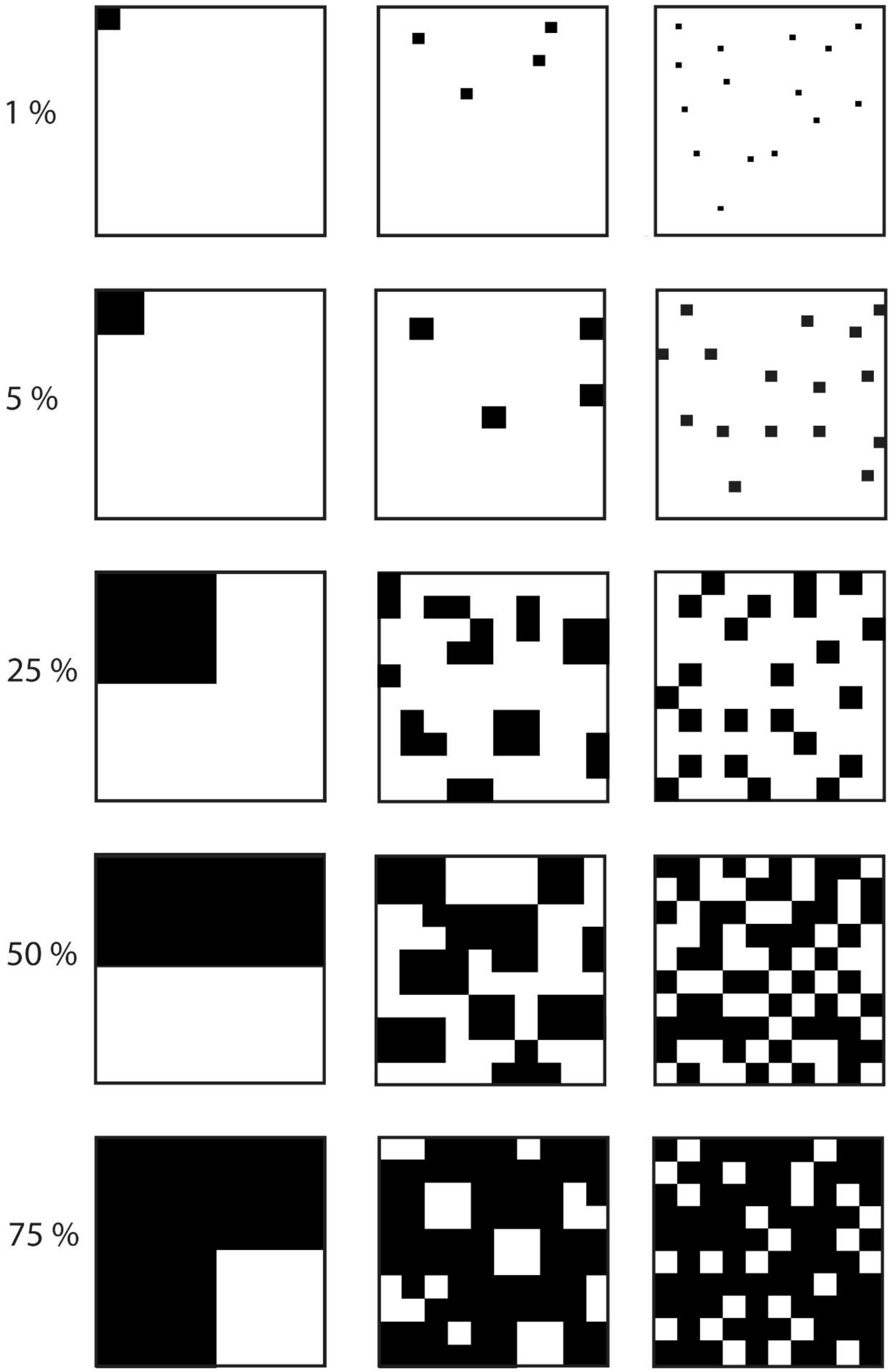
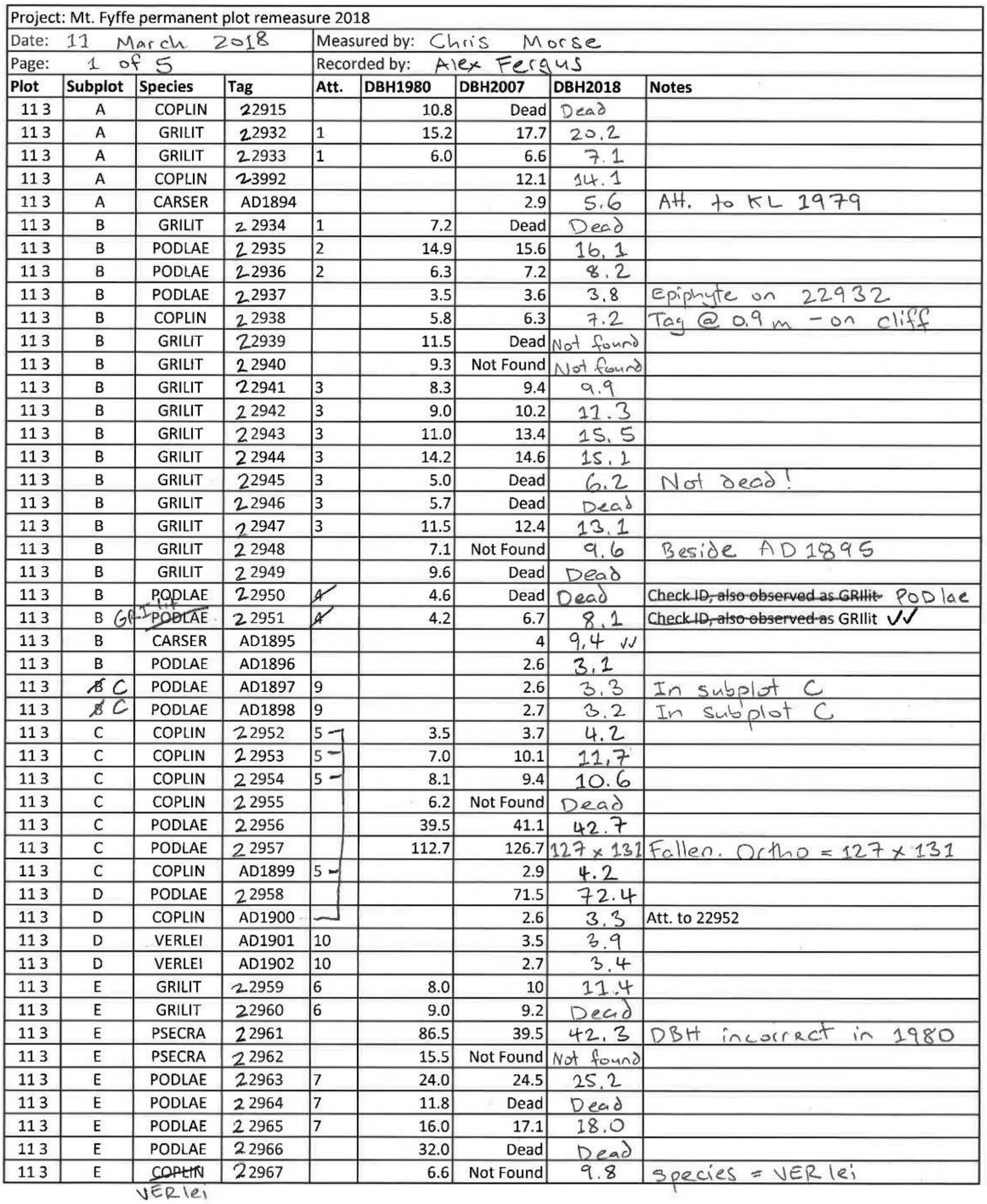


Figure A7. Divisions of the standard cover abundance scale (showing the equivalent area of each 20 × 20 m plot represented by each division). Use this scale when assigning cover classes for the Recce vegetation description.

Appendix 8. Pre-printed stem diameter plot sheet

Formatted datasets for creating pre-printed plot sheets for stem diameter remeasurement such as the example below can be downloaded directly from the NVS website (https://nvs.landcareresearch.co.nz/Data/Search). When creating pre-printed stem diameter sheets, subplot data should be included whenever possible, as it can assist with the relocation of previously tagged stems. Dead trees should be retained because there may be errors in the historical data. Include as many measurements of the plots as possible.



Project: Mt. Fyffe permanent plot remeasure 2018
Date: 11 March 2018 Measured by: Chris Morse
Page: 1 of 5 Recorded by: Alex Fergus

Plot	Subplot	Species	Tag	Att.	DBH1980	DBH2007	DBH2018	Notes
113	A	COPLIN	22915		10.8	Dead	Dead	
113	A	GRILIT	22932	1	15.2	17.7	20.2	
113	A	GRILIT	22933	1	6.0	6.6	7.1	
113	A	COPLIN	23992			12.1	14.1	
113	A	CARSER	AD1894			2.9	5.6	Att. to KL 1979
113	B	GRILIT	22934	1	7.2	Dead	Dead	
113	B	PODLAE	22935	2	14.9	15.6	16.1	
113	B	PODLAE	22936	2	6.3	7.2	8.2	
113	B	PODLAE	22937		3.5	3.6	3.8	Epiphyte on 22932
113	B	COPLIN	22938		5.8	6.3	7.2	Tag @ 0.9 m - on cliff
113	B	GRILIT	22939		11.5	Dead	Not found	
113	B	GRILIT	22940		9.3	Not Found	Not found	
113	B	GRILIT	22941	3	8.3	9.4	9.9	
113	B	GRILIT	22942	3	9.0	10.2	11.3	
113	B	GRILIT	22943	3	11.0	13.4	15.5	
113	B	GRILIT	22944	3	14.2	14.6	15.1	
113	B	GRILIT	22945	3	5.0	Dead	6.2	Not dead!
113	B	GRILIT	22946	3	5.7	Dead	Dead	
113	B	GRILIT	22947	3	11.5	12.4	13.1	
113	B	GRILIT	22948		7.1	Not Found	9.6	Beside AD1895
113	B	GRILIT	22949		9.6	Dead	Dead	
113	B	PODLAE	22950	~~4~~ ✓	4.6	Dead	Dead	~~Check ID, also observed as GRIlit~~ PODlae
113	B	GRIlit ~~PODLAE~~	22951	~~4~~ ✓	4.2	6.7	8.1	~~Check ID, also observed as~~ GRIlit ✓✓
113	B	CARSER	AD1895			4	9.4 ✓✓	
113	B	PODLAE	AD1896			2.6	3.1	
113	~~B~~ C	PODLAE	AD1897	9		2.6	3.3	In subplot C
113	~~B~~ C	PODLAE	AD1898	9		2.7	3.2	In subplot C
113	C	COPLIN	22952	5	3.5	3.7	4.2	
113	C	COPLIN	22953	5	7.0	10.1	11.7	
113	C	COPLIN	22954	5	8.1	9.4	10.6	
113	C	COPLIN	22955		6.2	Not Found	Dead	
113	C	PODLAE	22956		39.5	41.1	42.7	
113	C	PODLAE	22957		112.7	126.7	127 x 131	Fallen. Ortho = 127 x 131
113	C	COPLIN	AD1899	5		2.9	4.2	
113	D	PODLAE	22958			71.5	72.4	
113	D	COPLIN	AD1900			2.6	3.3	Att. to 22952
113	D	VERLEI	AD1901	10		3.5	3.9	
113	D	VERLEI	AD1902	10		2.7	3.4	
113	E	GRILIT	22959	6	8.0	10	11.4	
113	E	GRILIT	22960	6	9.0	9.2	Dead	
113	E	PSECRA	22961		86.5	39.5	42.3	DBH incorrect in 1980
113	E	PSECRA	22962		15.5	Not Found	Not found	
113	E	PODLAE	22963	7	24.0	24.5	25.2	
113	E	PODLAE	22964	7	11.8	Dead	Dead	
113	E	PODLAE	22965	7	16.0	17.1	18.0	
113	E	PODLAE	22966		32.0	Dead	Dead	
113	E	~~COPLIN~~ VERlei	22967		6.6	Not Found	9.8	species = VERlei

Appendix 9. Quality control checklist for permanent plots

PLOT IDENTIFIER: MEASURED BY:
SURVEY: DAY/MONTH/YEAR:

All field sheets	
Are the unique plot identifier, date and full names of staff recorded on every sheet?	Y / N
Are the sheets for each type of plot data (e.g. Recce, stem diameter, understorey subplot) separately cross-referenced (e.g. 'Page 1 of 5')?	Y / N
Have the tag names of collected plant specimens been marked with a '©' and recorded consistently across all field sheets?	Y / N
Recce data	
Are all data fields complete and legible?	Y / N
Has a GPS grid reference been recorded (or saved in the GPS receiver), and the plot location marked on a topographical map?	Y / N
Is the location information complete, with all information needed to relocate the plot? For example, is there an arrow marking north? Is the direction of flow marked for rivers or streams? Are significant landscape features marked (e.g. gully, ridge, bluff, road)? Are GPS coordinates given for significant landscape features? Do approach notes include all bearings and distances needed to easily relocate the plot?	Y / N
Is the back page of the Recce complete?	Y / N
Have all species been recorded in appropriate height tiers and assigned a cover class?	Y / N
Have *all* species recorded on the understorey subplot and stem diameter sheets been recorded on the Recce vegetation description?	Y / N
Have browse and fauna records been completed?	Y / N
Stem diameter data	
Have stem diameter data been recorded for all 16 subplots? (If there were no stems present in a subplot, has 'none' been recorded?)	Y / N
Have all previously tagged trees been relocated or searched for?	Y / N
Are all tag numbers recorded in full?	Y / N
Are all notes clear and easy to follow?	Y / N
Have any DBH values that vary considerably from previous measure been double-checked?	Y / N
Sapling data	
Have sapling data been recorded for all 16 subplots? (If there were no stems present in a subplot, has 'none' been recorded?)	Y / N
Are sapling tallies clear, legible and recorded in a consistent manner?	Y / N
Understorey subplot data	
Are all fields completed and legible?	Y / N
Have understorey data been recorded for all 24 understorey subplots? (If there were no species present in a subplot, has 'none' been recorded?)	Y / N
Do all species records from the 24 seedling plots have a count or presence recorded?	Y / N