Introduction to vegetation monitoring

Version 1.0

This specification was prepared by Alan Rose in 2012.

Contents

Department of Conservation
Te Papa Atawhai

What are vegetation inventory and monitoring?

These methods have been specifically developed for plant communities or vegetation types (e.g. kauri forest, mānuka shrubland, tall-tussock grassland). Inventory is a stocktake of vegetation composition, structure, and condition at one point in time, without any intended remeasurement. Monitoring involves repeated measurements, usually of the same sample units, to assess changes in composition, structure and condition over time (vegetation dynamics) which also permits investigation of the processes that influence that change. Well-designed monitoring programmes can establish whether biodiversity objectives are being met, detect changes and trigger appropriate management responses, help diagnose the causes of change, and assess the success of management actions which will contribute to their improvement (Hill et al. 2005).

This introduction provides comparative tables and decision trees which are tools to support decisions about which inventory or monitoring method (or combination of methods) is best suited to your objectives. These methods are used to collect numeric and/or demographic population data for each plant species and can provide information on:

- Community composition, structure, and biomass
- Spatial distributions of communities and species which can be linked to other interpretative information (e.g. soil fertility, animal pest abundances)
- Community and species condition in relation to abiotic or biotic threats
- Ecosystem processes, inferred from the above data (e.g. changes in recruitment following pest control)

Several of these methods are designed for comprehensive studies of community patterns and vegetation dynamics, where they must be capable of assessing complex assemblages of different species and life forms distributed over several height tiers. Other, simpler methods are designed for targeted studies that measure a subset of plant species or attributes as indicators of relative vegetation condition. The relationship between indicators and community condition should be quantified. Successful indicators simplify information about complex phenomena, and are a cost-effective alternative to assessing many individual species and processes (Lee et al. 2005). Examples of indicators are possum browse assessments on selected forest canopy species to indicate possum impacts, and tussock height tier information to indicate deer impacts.

It is important to note that for most inventory and monitoring studies, interpretation is improved by collecting covariate data on abiotic and biotic factors considered likely to affect the vegetation—these are termed 'optional attributes' in the Toolbox (e.g. altitude, aspect, slope, drainage, animal pest densities, burning history).

Why inventory and monitor vegetation?

DOC has clear international and national obligations to inventory and monitor vegetation. Although studies often are locally focused, it is important to note they can contribute to DOC's requirements to assess the status and trend of vegetation communities at higher levels, i.e. regionally, nationally, or internationally (Lee et al. 2005). Standardised methods ensure maximum comparability between studies.

Five types of biodiversity inventory and monitoring are recognised, each focused on a particular purpose, although they may overlap to some degree (Lee et al. 2005):

- Management inventory/monitoring, aimed at assessing the need for, or effectiveness of, management intervention
- General habitat inventory to comprehensively define a resource, with no implied remeasurement timing
- Status and trend monitoring, where regular remeasurements are intended
- Surveillance monitoring, where the problem is well understood and the threat immediate
- Research monitoring, where long-term monitoring results are used to address fundamental ecological questions

Vegetation inventory and monitoring are undertaken at a wide range of scales depending on the stated objectives. General habitat inventory and research monitoring may contribute to fundamental ecological knowledge of vegetation patterns and processes. Examples include the effects of site factors such as altitude and drainage on vegetation composition; successional pathways following disturbance (e.g. earthquakes, landslides, and flooding); and recovery following natural pest and disease outbreaks. Such background knowledge may be critical for interpreting the outcomes of management-focused studies (e.g. the impacts of weeds and pests) through partitioning out natural variation from changes induced through management.

Management-focused studies may also contribute to fundamental knowledge. At the local level, most vegetation monitoring is management-focused, aimed at assessing the need for, or effectiveness of, some kind of intervention. Within this, the most common approach is outcome monitoring, i.e. to assess the effects of management on specified outcomes for communities, species or sites. Outcome monitoring frequently centres on the impacts of introduced herbivores. Vegetation composition, structure, and condition are used as indicators of wider ecosystem condition. For example: (1) an aerial canopy survey determines that un-controlled possum populations are causing excessive canopy dieback, (2) the effectiveness of subsequent possum control is assessed by monitoring canopy dieback, canopy cover, and seedling regeneration on permanent sample sites before and after control, and (3) changes in canopy condition and regeneration of southern rātā are used as indicators of forest condition for kākā.

About inventory & monitoring methods

This section overviews some common inventory and methods and their applications. It is not a comprehensive treatment of vegetation analysis and interpretation. Relevant text books and published papers as well as the sections on statistical concepts and sampling approaches in 'A guideline to monitoring populations' (docdm-870579) should be consulted for more information. Use the comparative tables and decision trees as tools to guide you to the most suitable and cost-effective method(s) for addressing the specific questions you have formulated.

As indicated by these tools, not all methods are suitable for both inventory and monitoring; nor are they appropriate for all vegetation types and study objectives. Choose carefully and know your inventory and monitoring objectives well before using the tools. As far as possible, general objectives should be broken down into a series of specific objectives; these then govern the study design and the type of data collected. Key questions in selecting the most appropriate inventory method include:

- What is your objective?
- What scale are you working at?
- Is the target vegetation woody or non-woody?
- Are you monitoring the impacts of possums or terrestrial herbivores?
- Are you assessing the forest canopy, understorey, or both?
- Are you monitoring all/most species or selected indicator species (e.g. palatable species)?
- Are you monitoring condition indices?
- Are you monitoring changes in population size/abundance in a plant community?
- Do you need quantitative, semi-quantitative, or qualitative data?
- What parameters are essential to measure?
- What resources are available?
- What is the distribution of the species of interest?

Inventory methods

Inventory methods are primarily designed for documentation of vegetation patterns at one point in time; sometimes complete inventories are required for more information on design and sampling. Common inventory questions include:

- What species and communities are present and how are they spatially distributed over the landscape?
- What are the main environmental/site factors associated with changes in species composition?
- How does the condition of selected indicator species vary over the landscape?

The inventory methods that will be included in this module in time include**:**

- RECCE plots—semi-quantitative surveys of virtually all vegetation types
- Wraight plots—semi-quantitative grassland surveys
- Aerial canopy surveys—semi-quantitative surveys of forest canopy condition
- Photopoints and photoplots—qualitative and semi-quantitative documentation of conspicuous vegetation features.
- Rapid impact assessment—rapid qualitative or semi-qualitative one-off assessments of a defined study or management area. Assessment may include an inventory of the plant species present, description of vegetation patterns and composition, and other relevant information on the health and state of the site (e.g. signs of pest animals).

Main applications of these methods

The main applications of these methods are to document the species and communities present, describe how they are distributed, and determine what condition they are in. Note, however, that not all methods are capable of addressing all these applications.

Vegetation patterns identified from inventories can be examined spatially or in relation to variation in other abiotic or biotic data such as environmental/site variables (like soil fertility), habitat assessments, and animal pest densities. Spatial analyses show how the vegetation is distributed across the landscape and have become increasingly powerful with the advent of geographic information systems (GIS) because they allow 'layers' of information to be spatially depicted. Examples of spatial analyses include: mapping vegetation types or species distributions; comparing the mean composition of communities by catchment or map unit; and comparing the condition of an indicator species in different catchments. Analysing relationships between vegetation and environmental/site factors using multivariate techniques such as classification and ordination provides insight into the factors driving vegetation patterns. Examples include: comparing mean altitude, rainfall, and soil pH for different communities; determining the main environmental/habitat factors correlated with gradients in individual species abundances and total vegetation composition; and comparing the condition of indicator species in areas with different vegetation, soils and herbivore densities.

Interpretation of inventories is always limited to some extent because they are measurements at one point in time. In lieu of earlier data for comparison (unlike monitoring studies which involve repeated measurements over time) this information is not useful for interpreting change in vegetation patterns. Statistically significant correlations between vegetation composition and spatial or environmental/site factors can be used to suggest or hypothesise the causes for the documented vegetation patterns. However, measurements at one point in time may not identify factors that are the proximate causes of the patterns.

Examples of common study designs

Some examples of common study designs using measurements at one point in time include:

- Sampling one or several areas to define the main vegetation communities and assess the effects of environmental factors on composition and structure (Wraight 1963; Wardle et al. 1971; Reif & Allen 1988)
- Sampling one or several areas to define the distribution, abundance, and condition of indicator species (Rose et al. 1992)
- Synchronous comparisons of the vegetation in areas with different herbivore management histories (Veblen & Stewart 1980; Allen et al. 1984; Rose et al. 1998)

Monitoring methods

Monitoring methods are designed primarily to detect changes in vegetation over time, often at selected sites and based on the remeasurement of sample units (e.g. plots, transects or individual plants). The main aims are to determine whether vegetation composition, structure and condition are changing over time or in response to a management intervention. Examples of monitoring questions include:

- Have the densities of understorey herbs, seedlings and saplings increased after 10 years of intensive deer control?
- Has 5 years of goat control resulted in recovery of palatable shrubs and herbs compared with untreated areas?
- Have regeneration of southern rātā increased and dieback and mortality decreased 10 years after intensive possum control?
- Has snow tussock condition declined more rapidly in areas with high thar density compared with areas with lower density over 10 years?
- Has the density of mountain beech seedlings increased 5 years after extensive canopy collapse caused by heavy snowfall?
- Are tussocks and native herbs recovering and weeds declining 10 years after fire?

The monitoring methods in this module are outlined in comparative tables and decision trees. These tables and decision trees focus on assessing herbivore impacts, which is the main aim of DOC vegetation monitoring.

The monitoring methods that will be covered in this module in time, and their main applications are:

- Permanent 20 × 20 m forest plots—quantitative monitoring of woody vegetation
- Scott height frequency—semi-quantitative monitoring of non-woody vegetation < 2 m tall
- Wraight plots—semi-quantitative monitoring of non-woody vegetation < 1 m tall
- RECCE plots—semi-quantitative monitoring of most vegetation types
- Foliar browse index (ground)—semi-quantitative monitoring of forest canopy condition
- Photopoints and photoplots—qualitative and semi-quantitative monitoring of conspicuous, broad-scale vegetation change
- Foliar browse index (aerial)—semi-quantitative assessment of possum impacts on canopy tree species
- Foliar browse index (mistletoe)—semi-quantitative assessment of possum impacts on large-leaved mistletoe species
- Thar impact plots—quantitative assessment of alpine/subalpine tussocks and shrubs
- Mistletoe population plots—counts and size-class distributions of large-leaved mistletoe populations
- Goat 5 × 5 m plots—quantitative and semi-quantitative assessments of forest understorey condition to goat impacts
- Aerial canopy survey—semi-quantitative large-scale assessment of forest dieback
- Seedling ratio index—quantitative assessment of forest understorey condition from ungulate impacts

- Deer browse rapid assessment—quantitative and semi-quantitative assessment of grassland and herbfield condition from ungulate impacts
- Rātā view—semi-quantitative assessment of possum impacts on northern and southern rātā

Not all methods are appropriate for all vegetation types

While some methods are designed for comprehensive monitoring of all species present (e.g. permanent 20 × 20 m forest plots, Scott height frequency transects, Wraight plots), others are targeting a limited number of indicator species and attributes (e.g. foliar browse index (ground), aerial canopy survey, mistletoe population plots).

Temporal changes can be examined using a wide range of statistical methods, ranging from non-parametric statistics to analysis of variance and multivariate methods such as ordination. The aim of monitoring may be simply to describe the temporal trends and assess whether they are significant. More complex aims include examining the variation in temporal trends in vegetation populations in relation to spatial/environmental/habitat factors or under different treatments, such as animal pest control and non-treatment sites.

The use of permanently marked locations (e.g. plots) allows for the advantages of repeated sampling at that point, increasing the ability to determine temporal trends in measures derived from the data. Interpretative ability is further improved when the monitoring programme includes pre- and post-treatment measurements in treated as well as non-treated (control) areas. A well-designed monitoring programme will help separate out the effects of natural disturbance from management-induced effects on vegetation. For example, an increase in understorey diversity may reflect a reduction in deer numbers, crown thinning after herbivory by native insects, or both.

Objectives and questions determine your design

The study design used for monitoring depends on the objectives and questions to be addressed. These may range from very specific (are broadleaf saplings increasing more rapidly after deer control than in an area without control?) to more general (where are thar threatening the composition of alpine grasslands?). Some examples of common study designs include:

- Pre- and post-treatment measurements within an area to determine if there has been a change in composition/structure (Rose & Platt 1987; Stewart et al. 1987; Wiser et al. 1998; Mark & Dickinson 2003; Husheer & Frampton 2005)
- Pre- and post-treatment measurements in treated and untreated areas to determine if there are differences in vegetation trends (e.g. Urlich & Brady 2005)
- Comparison of temporal trends in areas with different management histories, such as using available historical data, conducting remeasurement(s), and inferring the causes of different trends (Rose et al. 1995; Jensen et al. 1997; Duncan et al. 2001)
- Paired comparisons of temporal trends inside and outside herbivore-proof exclosures (Rose & Frampton 2007)

Types of data collected

The methods prescribed in this module are capable of assessing vegetation composition, structure, condition, and biomass using a range of numeric and demographic population measures. Each measure has advantages and disadvantages and within one method several measures are often used in combination (for good discussions of the merits and applications of different measures see Mueller-Dombois & Ellenberg 1974; and Elzinga et al. 1998). Population measures can be divided into three types: qualitative, semi-quantitative, or quantitative. Exact definitions of these terms vary, but they reflect (respectively) an increasing degree of precision in assessing how much of a species or attribute is actually present (Mueller-Dombois & Ellenberg 1974; Elzinga et al. 1998; Hill et al. 2005). Qualitative measurements assess whether a species or attribute is present or absent, they may describe how much is present (e.g. 'many' plants per hectare) but do not directly measure how many. In contrast, quantitative measurements involve accurate and precise measurement of the amount present (e.g. 10 plants per hectare). Between these extremes, semi-quantitative measurements are made when the amount is either visually estimated, such as categories of cover abundances (e.g. < 1%, 1–5%, 6–25%, 26–50%, 51–75%, 76–100%), or when a variable is measured accurately but the value obtained does not necessarily reflect the precise amount (e.g. 10–20 plants per hectare).

Numeric measures include:

- Presence/absence—the presence or absence of a species or attribute in a sample unit or sub-unit. This is the most basic, qualitative measure which can be obtained from most of the methods in the module. Presence/absence can be converted to frequency by calculating the proportion of sample units/sub-units occupied.
- Frequency—the proportion (%) of sample units or sub-units occupied. Frequency is a quantitative measure that is easily and accurately obtained for virtually all growth forms. However, values are affected by the size of sample unit and the spatial distribution of plants. It is good for detecting temporal change, but comparison between species is difficult or impossible. Frequency is poorly related to cover or biomass unless the sample units or sub-units are very small (approaching a point of zero size).
- Cover—a quantitative measure of the proportion (%) of the ground surface covered by the vertical projection of the plant. Cover is applicable to virtually all growth forms and is a good measure of biomass and hence dominance. However, cover is time-consuming to measure precisely—for this reason it is often estimated visually, when it becomes less-precise and semi-quantitative.
- Density—the number of individual plants or plant units per unit area. Density is a highly quantitative and precise measure, but is only applicable where individual plants or plant units (e.g. stems, tillers, clonal units) are distinguishable.
- Census—the total number of plants in an area or sample unit. Similar to density but absolutely requires that all individuals are detected, which is difficult for large sample areas or sample units.
- Biomass—mass per unit area (e.g. approximated from tree basal area and height, tussock diameter and height, or frequency in small sub-plots in contiguous height tiers). Biomass is a good measure of the relative dominance of different species, but can be difficult, destructive, or time-consuming to measure precisely.

Demographic measures include survival, mortality, productivity, and sex ratio. Most demographic measures relate to change over time and are therefore applicable to robust, quantitative monitoring rather than inventory. As for density, individuals must be clearly distinguishable.

Issues to consider before undertaking a study

Clear objectives

A fundamental requirement for successful vegetation assessment is that it should be driven by clearly formulated objectives/questions aimed at providing the knowledge required for effective management. The objectives drive the study at all levels, including such factors as sampling design, sampling method(s), and number and type of sample units.

Appropriate study design and method

Use the 'Standard inventory and monitoring project plan' (docdm-146272) to plan your study and to seek approval before proceeding. Once your objectives have been formulated, selecting the appropriate study design and method(s) are key steps in determining whether the study is capable of addressing the objectives. Refer to 'A guideline for monitoring populations' (docdm-870579) for more information on design and sampling.

Long-term commitment

Detecting change in vegetation can be a slow process. Even for well-designed and efficiently targeted studies it can take a long time for trends to emerge, highlighting the value of long-term investment and commitment to established studies and data sets. History has also shown that many data sets will prove invaluable for addressing future questions that were not apparent or urgent at the time the study was initiated—hence the temptation to establish 'quick and dirty' data sets should be strongly resisted.

Inheriting and adapting an existing study

Investigators frequently inherit an ongoing study or need to adapt an existing study for different or additional objectives. Common issues include:

- Will the existing study design adequately address the new objectives or will it limit statistical inference and ecological interpretation?
- The perceived 'ideal' plot, method, or study design may need to be traded off for a less perfect but existing plot/method/design which is adequate but also has the benefit of long-term data that will greatly aid analysis and interpretation of trends.
- Data continuity and comparability must be maintained by ensuring that any changes to the field methods and measurements are documented, and are added to the existing methods.

- Deciding whether a study should be continued or whether the remeasurement interval can be extended in the face of changing objectives or diminishing resources.
- Uncertain quality of historic data, such as plant species identification, counts, or measurements. Of these the most common issue is uncertain species identification in earlier data, usually because of recent taxonomic advances (e.g. splitting of former taxa) or dubious identification. Most credible studies will have adequately documented methods for counting and measuring plants—if they are not well documented, the value of continuing or adapting the study needs to be questioned.
- Finding the sample units in the field. Finding plots or other sample units has been greatly simplified by the use of GPS units over the last 20 years or so. However, even these have limits for exact re-location of specific points such as plot corners or photoplot centres, which need to be conspicuous and permanently marked. It is surprising how easily most old plots can be found using maps, grid coordinates, aerial photographs, photopoints, and location notes and sketches. This highlights the value of permanently marked, exactly re-locatable plots.
- Poorly documented study design and objectives may restrict the usefulness for later studies. Such factors do not necessarily mean the study is of little value, as long as the data are accurate. The question is whether the data can be legitimately used to address the current objectives.

Value of existing data

When initiating a study, it is important to determine whether there are any existing data that can be used; for example, the strong legacy of sample plots established by former agencies. Foremost among these are the permanent plots established by Protection Forestry Division of the New Zealand Forest Service (NZFS) (which also had a primary aim of assessing introduced herbivore impacts). The NZFS data include over 16 000 permanent forest plots, 3000 permanent grassland plots, and 300 exclosures established between 1947 and 1985 (Lee et al. 2005). Virtually all of these data are archived and accessible in Landcare Research's National Vegetation Survey (NVS) databank.[1] Other contributing agencies include the former Department of Scientific and Industrial Research (DSIR) Botany Division, Department of Lands and Survey, Ministry of Works, and catchment boards, as well as Landcare Research, universities, private consultants, regional and district councils, and DOC itself. NVS Lite is a free software program to enter and submit RECCE and permanent plot data into NVS.[2]

Over the last 30 years or so, many New Zealand vegetation studies have used existing long-term data from NVS or other sources for a wide variety of objectives. For example, NVS annual reports between 2002 and 2008 cite over 60 scientific papers using NVS data. Some examples of studies using long-term data include:

- Herbivore impacts (Allen et al. 1984; Rose & Platt 1987; Stewart et al. 1987; Rogers 1991; Bellingham, Wiser et al. 1999; Bellingham & Allan 2003; Coomes et al. 2003; Mark & Dickinson 2003; Husheer & Frampton 2005)

[1] http://nvs.landcareresearch.co.nz/html/NVSdatabank.aspx
[2] Free download available at http://nvs.landcareresearch.co.nz/html/NVSLite.aspx

- Dynamics of weed and pest invasions (Treskonova 1991; Rose et al. 1995; Wiser et al. 1998; Allen & Lee 2006)
- Changes in species composition and dominance (Scott et al. 1988; Jensen et al. 1997; Allen et al. 2002; Rose et al. 2004; Peltzer et al. 2005; Brown et al. 2006)
- Changes in species diversity (Bellingham, Stewart et al. 1999; Duncan et al. 2001)
- Patterns in vegetation distribution and composition (Reif & Allen 1988, Leathwick 2002; Lloyd et al. 2003; Dymond & Shepherd 2004)
- Vegetation ecology and management (Wardle, J. 1984; Wardle, P. 1991)

Value of 'covariate data'

Interpretation of inventory and monitoring studies is considerably enhanced by collection of interpretative (covariate) data on abiotic and biotic factors considered likely to affect the vegetation—these are termed 'optional attributes' in the Inventory and Monitoring Toolbox. Examples include ground cover, altitude, slope, aspect, drainage, soil type, animal pest densities, and burning history.

Permanent or temporary plots?

Permanent plots permit the option of repeatedly monitoring individual plants or discrete patches to assess population attributes (like recruitment, mortality, reproductive state and life stage) to help interpret trends in population abundance. For monitoring, the choice between permanent and temporary plots involves a trade-off between the precision and power of permanent plots to detect change against their higher establishment costs. It is recommended that even if temporary plots or sample sites are used for monitoring they should be re-locatable (e.g. at a minimum by using a good GPS unit), this allows options such as re-visiting plots to collect further information, correct possible errors, or convert them to more intensive plots. Likewise, inventory objectives and requirements can change over time and permanent or re-locatable plots/sample sites provide similar advantages—notably, they allow initial inventory plots to be remeasured as part of a future monitoring study.

Decision trees

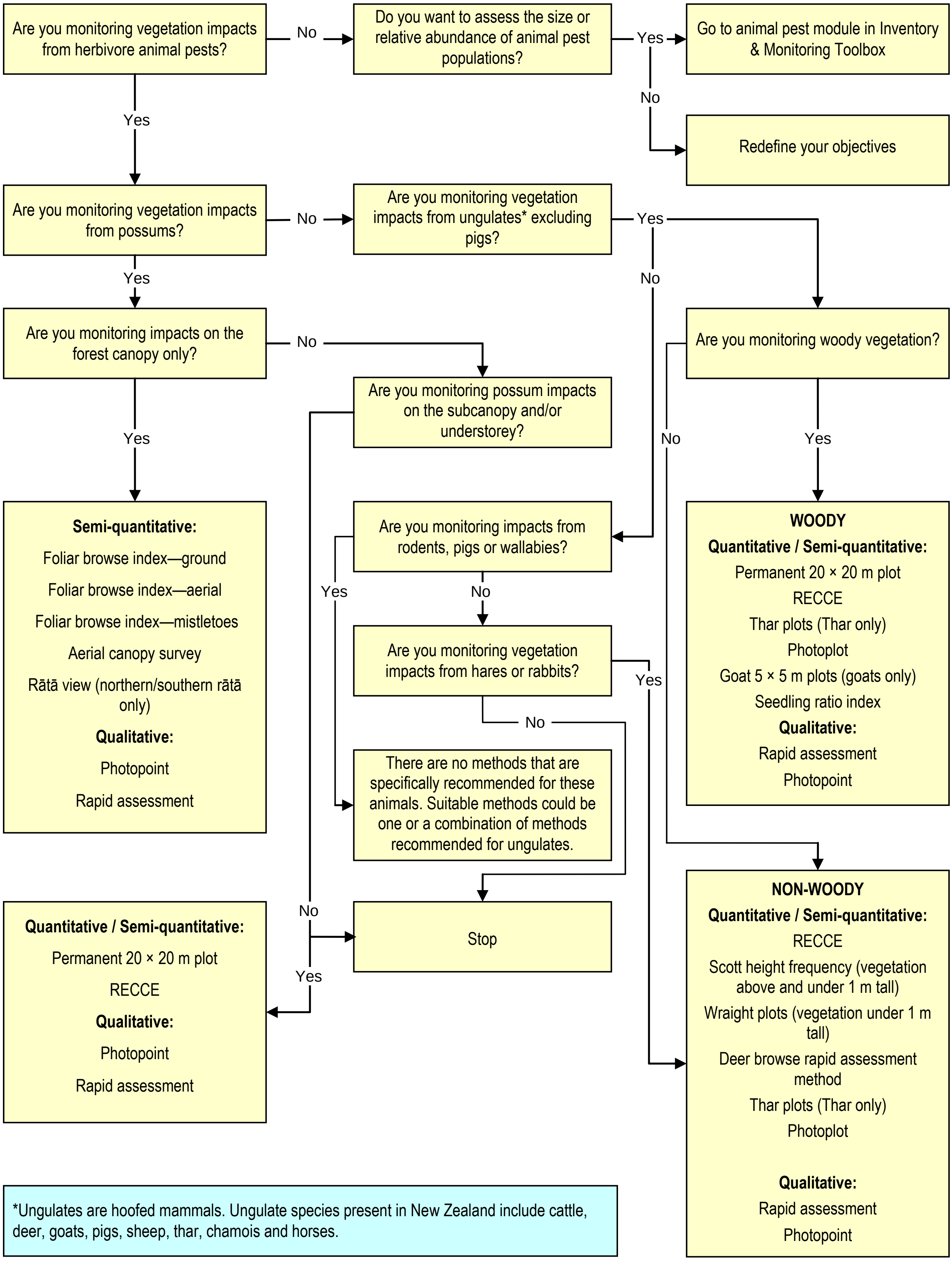
The decision trees are tools to help you choose the most appropriate methods for your study. Use them in conjunction with the comparative tables. Read the full description for each method once you have made your selection.

The decision trees can be used either independently or together to choose appropriate methods.

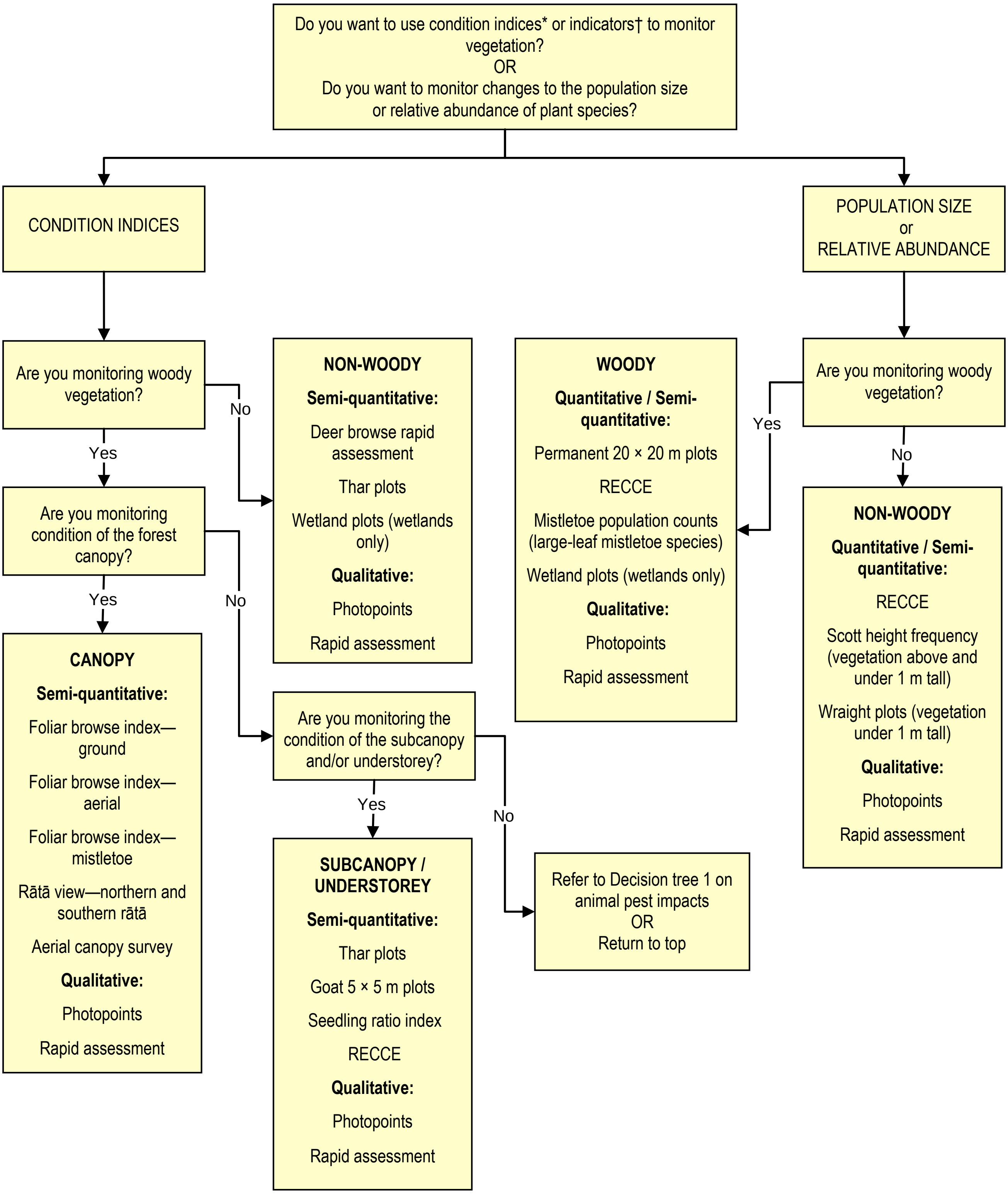
Use Decision tree 1 when your primary study objective is to monitor the *impacts of herbivore animal pests* on vegetation.

Use Decision tree 2 when your primary objectives are to *inventory or monitor vegetation communities* in general.

Decision tree 1: Monitoring impacts from herbivore animal pests



Decision tree 2: General vegetation monitoring



* Vegetation condition indices are indirect measures of the health of a vegetation community, site or habitat. They have an assumed or known relationship to condition (e.g. % ungulate browse on seedlings = index of browse pressure).

† Indicators are indirect measures of species that are difficult to count and measure in their entirety (e.g. instead of measuring every individual of every plant species within a forest it is more sensible to monitor selected indicator plant species).

Comparative tables of methods

The comparative tables(s) are tools to help you choose the most appropriate methods for your study. Use them in conjunction with the decision trees. Read the full description for each method once you have made your selection.

There are four comparative tables below; use any combination of tables to help you. Methods have been divided into:

- Inventory or monitoring (Tables 1 & 2)
- Working in woody or non-woody vegetation (Tables 3 & 4)

All methods are principally for terrestrial vegetation.

Table 1. Choosing an *inventory* method for complete counts and indices of relative abundance, or for condition indices of vegetation in New Zealand. **Method precision** (relative to objectives): ✓✓✓ Good; ✓✓ Medium; ✓ Poor; ✗ Not Recommended; **–** Not Applicable. **Resources:** L = Low; M = Medium; H = High. Methods that have been blacked out are under development.

	Inventory objectives*	Resources		
Method	Suitability for inventory	Equipment costs	Personnel costs	Skills required
Complete counts or indices of relative abundance				
Permanent 20 × 20 m forest plots	✓	H	H	M
RECCE plots	✓✓✓	M	M	M
Photoplots	[redacted]			
Scott height frequency	✗	L	M	M
Wraight plots	✓✓	L	M	M
Mistletoe population plots	[redacted]			
Thar plots (species counts, cover abundance)				
Goat 5 × 5 m plots (species counts)				
Rapid deer assessment (species counts)				
Variable area plots	–	–	–	–
Cruciform plots	–	–	–	–
Condition indices				

	Inventory objectives*	Resources		
Method	Suitability for inventory	Equipment costs	Personnel costs	Skills required
Semi-quantitative				
Foliar browse index (ground and mistletoe)	[redacted]	[redacted]	[redacted]	[redacted]
Foliar browse index (aerial)	[redacted]	[redacted]	[redacted]	[redacted]
Goat 5 × 5 m plots	[redacted]	[redacted]	[redacted]	[redacted]
Thar plots (browse & condition indices)	[redacted]	[redacted]	[redacted]	[redacted]
Aerial canopy survey	✓	H	M	M
Seedling ratio index	[redacted]	[redacted]	[redacted]	[redacted]
Deer browse rapid assessment method	[redacted]	[redacted]	[redacted]	[redacted]
Rātā view (ground)	[redacted]	[redacted]	[redacted]	[redacted]
Rātā view (aerial)	[redacted]	[redacted]	[redacted]	[redacted]
Qualitative				
Rapid impact assessment	[redacted]	[redacted]	[redacted]	[redacted]
Photopoints	[redacted]	[redacted]	[redacted]	[redacted]

* Inventory is a one-off survey or assessment with no intention to re-measure. If inventory of a site is repeated in the future this can be considered monitoring. Typical inventory objectives include: What species are present at a site and how are they distributed over a landscape? What are the species habitat relationships? What is the wildlife value/significance of an area (SSWI, etc)? Is this a baseline survey? Interpretation of results must be based on the understanding that these are single surveys.

Table 2. Choosing a *monitoring* method for complete counts and indices of relative abundance, or for condition indices of vegetation in New Zealand. **Method precision** (relative to objectives): ✓✓✓ Good; ✓✓ Medium; ✓ Poor; ✗ Not Recommended; **–** Not Applicable. **Resources:** L = Low; M = Medium; H = High. Methods that have been blacked out are under development.

	Monitoring objectives†			Resources		
Method	Surveillance[1]	Status & trend[2]	Management[3]	Equipment costs	Personnel costs	Skills required
Complete counts or indices of relative abundance						
Permanent 20 × 20 m forest plots	✓	✓✓✓	✓✓✓	H	H	M
RECCE plots	✓✓	✓✓	✓✓	M	M	M
Photoplots	[redacted]					
Scott height frequency	✗	✓✓✓	✓✓✓	L	M	M
Wraight plots	✗	✓✓✓	✓✓	L	M	M
Mistletoe population plots	[redacted]					
Thar plots (species counts, cover abundance)						
Goat 5 × 5 m plots (species counts, cover abundance)						
Rapid deer assessment (species counts)						
Variable area plots	–	–	–	–	–	–
Cruciform plots	–	–	–	–	–	–
Condition indices						
Semi-quantitative	[redacted]					
Foliar browse index (ground and mistletoe)						
Foliar browse index (aerial)						
Goat 5 × 5 m plots (palatable seedling ratios)						
Thar plots (browse & condition indices)						
Aerial canopy survey	✓	✓✓	✓✓	H	M	M
Seedling ratio index	[redacted]					

	Monitoring objectives[†]			Resources		
Method	Surveillance[1]	Status & trend[2]	Management[3]	Equipment costs	Personnel costs	Skills required
Deer browse rapid assessment method	[redacted]					
Rātā view (ground)						
Rātā view (aerial)						
Qualitative						
Rapid impact assessment						
Photopoints						

† Monitoring assesses change or trend over time and requires re-measurement of parameters at some pre-determined frequency. Typical monitoring objectives include:

1 What species have moved into an area? Have range extensions occurred for a species of interest (e.g. monitoring for biosecurity risk—illegal introductions and cage bird releases)?
2 What is the population abundance or density of a species or community? Is this stable over time? What are the population trends? Does this relate to habitat use?
3 Do population estimates of density and abundance change as a result of management action? Over what time-scale does this occur? Has a species translocation succeeded? Has management been effective? Has species composition altered as a result of management? What are the visitor impacts?

Table 3. Choosing an *inventory* method for woody and non-woody vegetation in New Zealand. **Method precision** (relative to objectives): ✓✓✓ Good; ✓✓ Medium; ✓ Poor; ✗ Not Recommended; **–** Not Applicable. **Resources:** L = Low; M = Medium; H = High. Methods that have been blacked out are under development.

	Inventory objectives*	Resources		
Method	Suitability for inventory	Equipment costs	Personnel costs	Skills required
Woody vegetation				
Canopy				
Foliar browse index (ground and mistletoe)	[redacted]			
Foliar browse index (aerial)	[redacted]			
RECCE plots	✓✓✓	M	M	M
Aerial canopy survey	✓	H	M	M
Rātā view (ground)	[redacted]			
Rātā view (aerial)	[redacted]			
Photopoints	[redacted]			
Rapid impact assessment	[redacted]			
Variable area plots	–	–	–	–
Understorey/Subcanopy				
Permanent 20 × 20 m forest plots	✗	L	H	M
RECCE plots	✓✓✓	L	M	M
Goat 5 × 5 m plots	[redacted]			
Thar plots	[redacted]			
Seedling ratio index	[redacted]			
Mistletoe population plots	[redacted]			
Photopoints	[redacted]			
Rapid impact assessment	[redacted]			
Non-woody vegetation				
RECCE plots	✓✓✓	M	M	M
Scott height frequency	✗	L	M	M
Wraight plots	✓✓	L	M	M

	Inventory objectives*	Resources		
Method	Suitability for inventory	Equipment costs	Personnel costs	Skills required
Thar plots (shrub counts & heights)	[redacted]	[redacted]	[redacted]	[redacted]
Seedling ratio index	[redacted]	[redacted]	[redacted]	[redacted]
Photoplots	[redacted]	[redacted]	[redacted]	[redacted]
Rapid impact assessment	[redacted]	[redacted]	[redacted]	[redacted]
Photopoints	[redacted]	[redacted]	[redacted]	[redacted]
Deer browse rapid assessment method (species counts)	[redacted]	[redacted]	[redacted]	[redacted]
Cruciform plots	–	–	–	–

* Inventory is a one-off survey or assessment with no intention to re-measure. If inventory of a site is repeated in the future this can be considered monitoring. Typical inventory objectives include: What species are present at a site and how are they distributed over a landscape? What are the species habitat relationships? What is the wildlife value/significance of an area (SSWI, etc)? Is this a baseline survey? Interpretation of results must be based on the understanding that these are single surveys.

Table 4. Choosing a *monitoring* method for woody and non-woody vegetation in New Zealand. **Method precision** (relative to objectives): ✓✓✓ Good; ✓✓ Medium; ✓ Poor; ✗ Not Recommended; **–** Not Applicable. **Resources:** L = Low; M = Medium; H = High. Methods that have been blacked out are under development.

	Monitoring objectives[†]			Resources		
Method	Surveillance[1]	Status & trend[2]	Management[3]	Equipment costs	Personnel costs	Skills required
Woody vegetation						
Canopy						
Foliar browse index (ground and mistletoe)	[redacted]					
Foliar browse index (aerial)						
RECCE plots	✓✓	✓✓	✓✓	M	M	M
Aerial canopy survey	✓	✓✓	✓✓	H	M	M
Rātā view (ground)	[redacted]					
Rātā view (aerial)						
Photopoints						
Rapid impact assessment						
Variable area plots	–	–	–	–	–	–
Understorey/Subcanopy						
Permanent 20 × 20 m forest plots	✓	✓✓✓	✓✓✓	H	H	M
RECCE plots	✓✓	✓✓	✓✓	M	M	M
Goat 5 × 5 m plots	[redacted]					
Thar plots						
Seedling ratio index						
Mistletoe population plots						
Photopoints						
Rapid impact assessment						
Non-woody vegetation						
RECCE plots	✓✓	✓✓	✓✓	M	M	M
Scott height frequency	✗	✓✓✓	✓✓✓	L	M	M

Method	Monitoring objectives[†]			Resources		
	Surveillance[1]	Status & trend[2]	Management[3]	Equipment costs	Personnel costs	Skills required
Wraight plots	✗	✓✓✓	✓✓	L	M	M
Thar plots (shrub counts & heights)	[redacted]					
Seedling ratio index	[redacted]					
Photoplots	[redacted]					
Rapid impact assessment	[redacted]					
Photopoints	[redacted]					
Deer browse rapid assessment method (species counts)	[redacted]					
Cruciform plots	–	–	–	–	–	–

[†] Monitoring assesses change or trend over time and requires re-measurement of parameters at some pre-determined frequency. Typical monitoring objectives include:

[1] What species have moved into an area? Have range extensions occurred for a species of interest (e.g. monitoring for biosecurity risk—illegal introductions and cage bird releases)?

[2] What is the population abundance or density of a species or community? Is this stable over time? What are the population trends? Does this relate to habitat use?

[3] Do population estimates of density and abundance change as a result of management action? Over what time-scale does this occur? Has a species translocation succeeded? Has management been effective? Has species composition altered as a result of management? What are the visitor impacts?

References and further reading

Allen, R.B.; Lee, W.G. 2006 (Eds): Biological invasions in New Zealand. Springer, Berlin.

Allen, R.B.; Payton, I.J.; Knowlton, J.E. 1984: Effects of ungulates on structure and species composition in the Urewera forests as shown by exclosures. *New Zealand Journal of Ecology 7*: 119–130.

Allen, R.B.; Rogers, G.M.; Stewart, G.H. 2002: Maintenance of key tree species. *Science for Conservation 190*. Department of Conservation, Wellington.

Bellingham, P.J.; Allan, C.N. 2003: Forest regeneration and the influences of white-tailed deer (*Odocoileus virginianus*) in cool temperate New Zealand rain forests. *Forest Ecology and Management 175*: 71–86.

Bellingham, P.J.; Stewart, G.H.; Allen, R.B. 1999: Tree species richness and turnover throughout New Zealand forests. *Journal of Vegetation Science 10*: 825–832

Bellingham, P.J.; Wiser, S.K.; Hall, G.M.H.; Alley, J.C.; Allen, R.B.; Suisted, P.A. 1999: Impacts of possum browsing on the long-term maintenance of forest biodiversity. *Science for Conservation 103*. Department of Conservation, Wellington.

Brown, C.S.; Mark, A.F.; Kershaw, G.P.; Dickinson, K.J.M. 2006: Secondary succession 24 years after disturbance of a New Zealand high-alpine cushionfield. *Arctic, Antarctic, and Alpine Research 38*: 325–334.

Coomes, D.A.; Allen, R.B.; Forsyth, D.M.; Lee, W.G. 2003: Factors preventing the recovery of New Zealand forests following the control of invasive deer. *Conservation Biology 17*: 450–459.

Duncan, R.P.; Webster, R.J.; Jensen, C.A. 2001: Declining plant species richness in the tussock grasslands of Canterbury and Otago, South Island, New Zealand. *New Zealand Journal of Ecology 25*: 35–47.

Dymond, J.R.; Shepherd, J.D. 2004: The spatial pattern of indigenous forest and its composition in the Wellington region, New Zealand, from EMT+ satellite imagery. *Remote Sensing of Environment 90*: 116–125.

Elzinga, C.L.; Salzer, D.W.; Willoughby, J.W. 1998: Measuring and monitoring plant populations. U.S. Department of the Interior, Bureau of Land Management, National Applied Resource Sciences Center, Denver. Download free of charge at: http://www.blm.gov/nstc/library/pdf/MeasAndMon.pdf

Hill, D.; Fasham, M.; Tucker, G.; Shrewry, M.; Shaw, P. 2005: Handbook of biodiversity methods: survey, evaluation and monitoring. Cambridge University Press, Cambridge.

Hunter, G.R.; Scott, D. 1997: Changes in tussock grasslands, South Island high country, 1973–93. *Science for Conservation 63*. Department of Conservation, Wellington.

Husheer, S.W.; Frampton, C.M. 2005: Fallow deer impacts on Wakatipu beech forest. *New Zealand Journal of Ecology 29*: 83–94.

Jensen, C.A.; Webster, R.J.; Carter, D.; Treskonova, M. 1997: Succession in tussock grasslands: implications for conservation management. *Science for Conservation 61*. Department of Conservation, Wellington.

Leathwick, J.R. 2002: Incorporating the effects of inter-specific competition when modelling species distributions at landscape levels. *Biodiversity and Conservation 11*: 2177–2187.

Lee, W.G.; McGlone, M.; Wright, E. (Comp.) 2005: Biodiversity Inventory and monitoring: a review of national and international systems and a proposed framework for future biodiversity monitoring by the Department of Conservation. Landcare Research Contract Report LC0405/122 (unpublished).

Lloyd, K.M.; Wilson, J.B.; Lee, W.G. 2003: Correlates of geographic range size in New Zealand *Chionochloa* (Poaceae) species. *Journal of Biogeography 30*: 1751–1761.

Mark, A.F.; Dickinson, K.J.M. 2003: Temporal responses over 30 years to the removal of grazing from a mid-altitude snow tussock grassland reserve, Lammerlaw Ecological Region, New Zealand. *New Zealand Journal of Botany 41*: 655–668.

Mueller-Dombois, D.; Ellenberg, H. 1974: Aims and methods of vegetation ecology. John Wiley & Sons, New York. 547 p.

Peltzer, D.A.; Allen, R.B.; Rogers, G.M. 2005: Dieback and recruitment of the forest dominants *Nothofagus fusca* and *Libocedrus bidwillii*, central North Island, New Zealand. *Science for Conservation 255*. Department of Conservation, Wellington.

Reif, A.; Allen, R.B. 1988: Plant communities of the steepland conifer-broadleaved hardwood forests of central Westland, South Island, New Zealand. *Phytocoenologia 16*: 145–224.

Rogers, G.M. 1991: Kaimanawa feral horses and their environmental impacts. *New Zealand Journal of Ecology 15*: 49–64.

Rose, A.B.; Basher, L.R.; Wiser, S.K.; Platt, K.H.; Lynn, I.H. 1998: Factors predisposing short-tussock grasslands to *Hieracium* invasion in Marlborough, New Zealand. *New Zealand Journal of Ecology 22*: 121–140.

Rose, A.B.; Frampton, C.M. 2007: Rapid short tussock grassland decline with and without grazing, Marlborough, New Zealand. *New Zealand Journal of Ecology 31*: 232–244.

Rose, A.B.; Pekelharing, C.J.; Platt, K.H. 1992: Magnitude of canopy dieback and implications for conservation of southern rata-kamahi (*Metrosideros umbellate – Weinmannia racemosa*) forests, central Westland, New Zealand. *New Zealand Journal of Ecology 16*: 23–32.

Rose, A.B.; Platt, K.H. 1987: Recovery of northern Fiordland alpine grasslands after reduction in the deer population. *New Zealand Journal of Ecology 10*: 23–33.

Rose, A.B.; Platt, K.H.; Frampton, C.M. 1995: Vegetation change over 25 years in a New Zealand short tussock grassland: effects of sheep grazing and exotic invasions. *New Zealand Journal of Ecology 19*: 163–174.

Rose, A.B.; Suisted, P.A.; Frampton, C.M. 2004: Recovery, invasion, and decline over 37 years in a Marlborough short-tussock grassland, New Zealand. *New Zealand Journal of Botany 42*: 77–87.

Scott, D.; Dick, R.D.; Hunter, G.G. 1988: Changes in the tussock grasslands in the central Waimakariri River basin, Canterbury, New Zealand, 1947–1981. *New Zealand Journal of Botany 26*: 197–222.

Smale, M.C.; Rose, A.B.; Frampton, C.M.; Owen, H.J. 1995: The efficacy of possum control in reducing forest dieback in the Otira and Deception catchments, central Westland. *Science for Conservation 13*. Department of Conservation, Wellington.

Stewart, G.H.; Wardle, J.A.; Burrows, L.E. 1987: Forest understorey changes after reduction in deer numbers, Northern Fiordland, New Zealand. *New Zealand Journal of Ecology 10*: 35–42.

Treskonova, M. 1991: Changes in the structure of tall-tussock grasslands and infestation by species of *Hieracium* in the Mackenzie Country, New Zealand. *New Zealand Journal of Ecology 15*: 65–78.

Urlich, S.C.; Brady, P.J. 2005: Benefits of aerial 1080 possum control to tree fuchsia in the Tararua Range, Wellington. *New Zealand Journal of Ecology 29*: 299–309.

Veblen, T.T.; Stewart, G.H. 1980: Comparison of forest structure and regeneration on Bench and Stewart Islands, New Zealand. *New Zealand Journal of Ecology 3*: 50–68.

Wardle, J.; Hayward, J.; Herbert, J. 1971. Forests and scrublands of northern Fiordland. *New Zealand Journal of Forestry Science 1*: 80–115.

Wardle, J.A. 1984: The New Zealand beeches: Ecology, utilisation and management. New Zealand Forest Service, Wellington.

Wardle, P. 1991: Vegetation of New Zealand. Cambridge University Press, Cambridge.

Wiser, S.K.; Allen, R.B.; Clinton, P.W.; Platt, K.H. 1998: Community structure and forest invasion by an exotic herb over 23 years. *Ecology 79*: 2071–2081.

Wraight, M.J. 1963: The alpine and upper montane grasslands of the Wairau River catchment, Marlborough. *New Zealand Journal of Botany 1*: 351–376.

Appendix A

The following Department of Conservation documents are referred to in this method:

docdm-870579	A guideline for monitoring populations
docdm-146272	Standard inventory and monitoring project plan