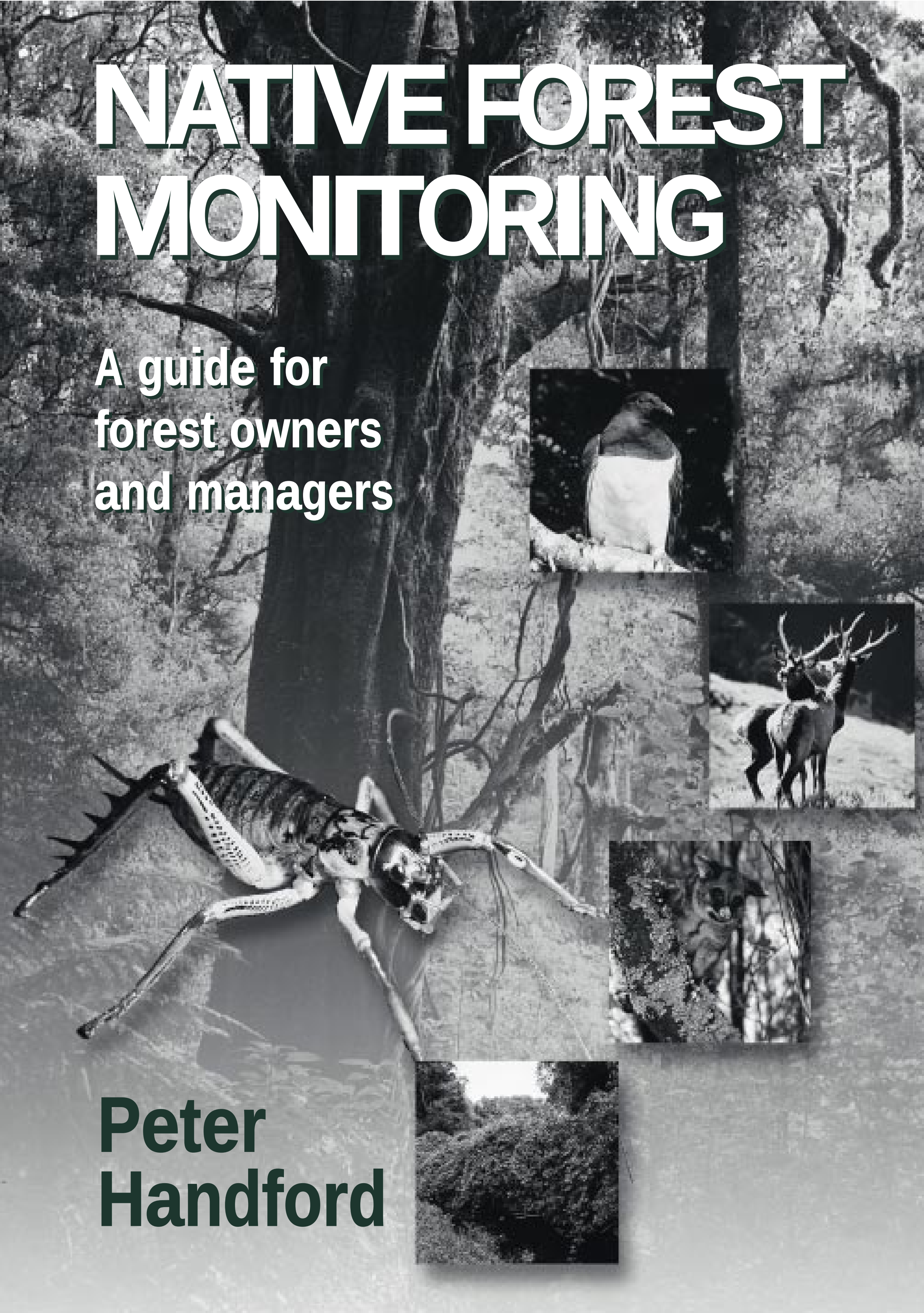
NATIVE FOREST MONITORING

A guide for forest owners and managers



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INTRODUCTION

Native forests and monitoring are important

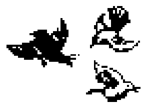
Native forests are important to all New Zealanders in different ways. They are extremely important reservoirs of plant and animal biodiversity. Many species of native birds have become extinct in the past 200 years because of pressures from forest clearance and the introduction of new predators. Native forests also provide other values such as the maintenance of high water quality, the protection of soils from erosion and a high-quality visual landscape, which is important to recreation, tourism and leisure.

Native forests are continually changing. They are exposed to threats such as browsing and predation by introduced animals, human development and changes in climate.

Whether you are managing native forests, have a native forest area on your farm, are in a community group that looks after a forest area or are interested in native forests for other reasons, monitoring the condition of the forest is important. Without monitoring, native forests can become degraded and remedial action may be too late to be of use. Monitoring also provides ways of checking if the current management systems are working – is the possum control worthwhile? – is goat hunting keeping numbers down?

This publication aims to provide information so forest owners, managers, community groups and individuals can effectively monitor New Zealand's native forests.

HOW THIS PUBLICATION WORKS



The publication is split into four parts:

1. **Monitoring Outline**: *everyone should read this*!
   This gives a brief summary of the important considerations in native forest monitoring.
2. **Monitoring Toolbox**: *read this when you are ready to do some fieldwork.*
   This provides specific instructions on monitoring methods.
3. **Understanding Native Forest Monitoring**: *use this when you are planning monitoring, or dealing with results.*
   This gives more detailed explanations of the important aspects of native forest monitoring, including design, sampling, fieldwork, analysis and data storage.
4. **Forest Ecosystem Indicators and Monitoring**: *use this to identify what to measure and how.*
   This is a listing of possible native forest indicators and ways to measure them. Use this to design your monitoring programme, to help you identify what you should measure and how you should measure it. Seek out more detail on the measurement methods once you have found them in this part, either from the Monitoring Toolbox or references listed.

The publication is structured so you use it at a level that suits you. If you have a small area of forest and want to begin monitoring, read the Monitoring Outline, then select a method from the Monitoring Toolbox to try. Refer to the other parts of the publication if you strike problems. If you are involved in managing a variety of areas of forest and need to design a robust monitoring programme, you will need to use the entire publication.

If you are unsure about your monitoring – seek advice. Staff from organizations such as the Department of Conservation, regional councils and universities may be able to assist you. Commercial organizations such as ecological consultants, Landcare Research Ltd, and others can also provide assistance.

1. MONITORING OUTLINE

What is monitoring?

Monitoring is the assessment of change in specific characteristics, over time or between areas. We are dealing with native forest ecosystems. Therefore, we are interested in changes in characteristics such as canopy condition, the abundance of plant species in the understorey, the abundance of bird species or the abundance of particular pests.

What are indicators?

Indicators are specific characteristics of a forest ecosystem that can be assessed to give indications of its condition.

Forest ecosystems are complex so there are many indicators. Figure 1 and Table 1 identify some of these.

Why monitor native forest ecosystems? (*see* also 'Why do you want to monitor?' p.86)

Monitoring to identify changes over time or between areas is important because native forests are exposed to a wide range of threats, including introduced plant and animal pests and human development.

We need to identify if management programmes such as animal or weed control are required to stop forests being further degraded. Monitoring can also help us learn the benefits of any management, and how we can come up with better management. Reasons for monitoring can be summarised as:

- Generalist surveillance monitoring: To check if there are any immediate threats to the forest, requiring intervention.
- Specialist surveillance monitoring: To check on a specific forest indicator or group of indicators. You may want to set a baseline and then understand how things are changing.
- Conservation outcome monitoring: To see the impacts of your operations (for example, animal control) on forest condition.
- Operational monitoring: To check the effectiveness of your operations, for example, did you really kill 90 percent of the possums.

What to monitor? (*see* also 'Design monitoring …', p.88)

Many different indicators can be examined to assess aspects of forest condition (*see* Figure 1 and Table 1).

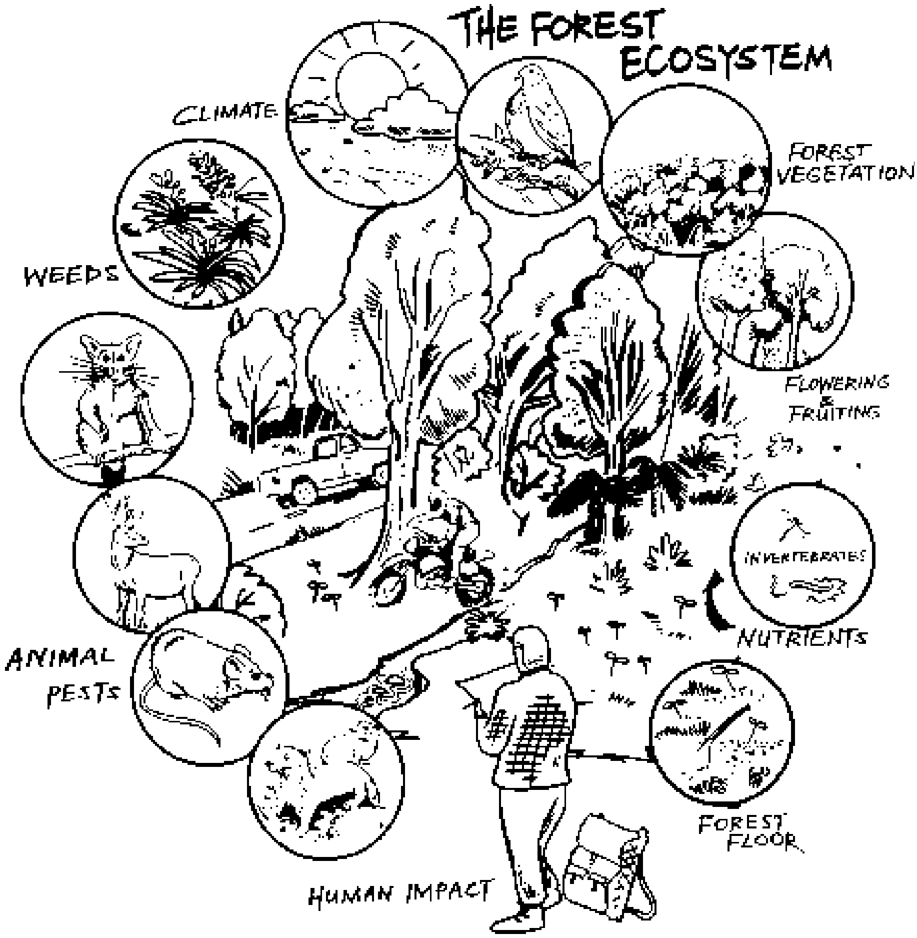
What you measure will depend on your objectives and questions. Once these are determined, you can select relevant indicators to measure.

Examples of monitoring questions are: "What impact will reducing possum numbers have on species that possums eat in the forest canopy?" and "Where is the weed-climbing asparagus distributed through the forest area, and is it spreading?"

If you are uncertain what you should be monitoring, talk to experts, and do some quick generalist surveillance monitoring first. This will help identify any issues you need to look at.

Monitoring is a complex subject described here in a simplified form. Always seek advice if you are unsure – this can save you wasted effort and money.

FIGURE 1: The forest ecosystem involves interactions between many different components. Different parts of the ecosystem, and interactions between them, can be used as indicators of ecosystem condition.



When to monitor (*see* also 'Design monitoring …', p.88)

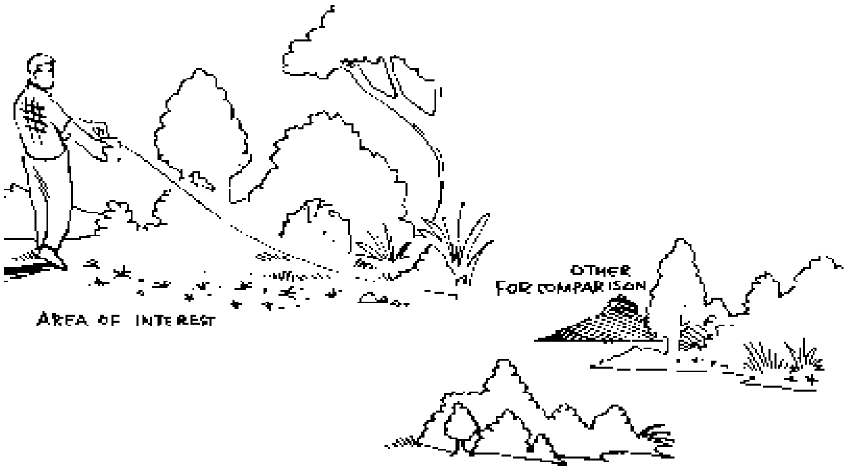
If you want to examine the results of a management programme or some other operation, such as determining the number of possums after a poison operation, or if there is greater foliage density in the canopy or more seedlings, it is important to monitor before and after the programme.

Many things to be measured will change naturally during the year. For example, birds will be more active in spring, plant species will fruit at certain times of the year, rodent numbers will be higher in summer than winter. Changes also occur depending on the weather and time of day, particularly when monitoring animals. If it is likely these sorts of natural changes will occur, try to be consistent about when you undertake monitoring, bearing in mind:

- Time of year – season.
- Time of day.
- Weather conditions.

Where to monitor

As well as monitoring the area of forest you are interested in, it is important to monitor other areas for comparison at the same time.



Monitoring other areas as well as the area of interest will show you:

- How the area of interest differs from other areas
- How changes in the area of interest compare with changes in other areas. You will need to do this if you want to look at changes in relation to some management operation. For example, you may wish to look at improvements in the abundance of mahoe seedlings in the understorey in response to a goat-control programme. You would need to also look at changes in other areas where goats were not controlled. If mahoe seedlings increase in the area where goats were controlled but not in the other areas, you can show that goat control has had a positive benefit. If you only measure the area where goats were controlled, you won't know if seedlings would have increased naturally without the control programme.

If you need to show conclusive changes scientifically, the way you design your monitoring to compare different areas is important. You are likely to need advice on how to set up your monitoring to compare different areas.

Precision (*see* also 'What is precision?', p.96)

When measuring forest indicators, it is not usually possible to measure every tree canopy, count every bird, or every understorey seedling in the forest. Instead, we have to select a small number of them from the whole forest, measure them and use these measurements to estimate the situation for the whole forest.

TABLE 1: Forest Ecosystem Indicators		
CHARACTERISTIC OF INTEREST	**INDICATOR** *See Part 4 for explanation of indicators*	**RELEVANT METHODS IN MONITORING TOOLBOX** *See Part 4 for other methods*
Vegetation Condition	Canopy cover and condition	Forest general surveillance checklist Ground photography to monitor forest canopycover Foliar browse index
	Understorey plant abundance	20m x 20m permanent vegetation plots Quick plot method for vegetation assessment
	Vertical and horizontal vegetation structure	Recce – for vegetation description Point/cylinder intercept assessment of forest structure
	Species composition and diversity	Recce – for vegetation description 20m x 20m permanent vegetation plots Quick plot method for vegetation assessment
	Abundance of indicator species	Quick plot method for vegetation assessment Recce – for vegetation description 20m x 20m permanent vegetation plots Epicormic shoot counts
	Distribution of key/uncommon species	*See Part 4 for possible methods*
	Fruiting and flowering of key species	Fruiting and flowering observation record Ground plot monitoring of seed and fruit-fall
	Plant species population structure	Quick plot method for vegetation assessment 20m x 20m permanent vegetation plots
	Plant species mortality	*See Part 4 for possible methods*
	Litterfall	*See Part 4 for possible methods*
Weeds	Distribution of weeds	Weed map monitoring
	Abundance of weeds	Quick plot method for vegetation assessment 20m x 20m permanent vegetation plots
	Population structure of weeds	Quick plot method for vegetation assessment 20m x 20m permanent vegetation plots
	Mortality of weeds	*See Part 4 for possible methods*
Ground Cover/ Disturbance	Ground cover	Point intercept assessment of forest ground cover
Birds	Distribution of bird species	*See Part 4 for possible methods*
	Abundance of bird species	Forest bird slow walk transect
	Species composition and diversity	Forest bird slow walk transect
	Bird species population structure	*See Part 4 for possible methods*
Invertebrates	Abundance and species composition/ diversity (may be separate)	*See Part 4 for possible methods*
Large Vertebrate Pests – deer, goats, pigs	Distribution of particular species	*See Part 4 for possible methods*
	Abundance of particular species	*See Part 4 for possible methods*
	Population structure of particular species	*See Part 4 for possible methods*
Possums	Distribution	*See Part 4 for possible methods*
	Abundance	Possum percentage trap catch
	Population structure	*See Part 4 for possible methods*
Rodents	Distribution of particular species	*See Part 4 for possible methods*
	Abundance of particular species	Tracking tunnels for rodents and stoats Rodent 'gnaw stick' bait interference
	Population structure of particular species	*See Part 4 for possible methods*
Stoats	Abundance	Tracking tunnels for rodents and stoats
Cats	Abundance	*See Part 4 for possible methods*
Drainage	Drainage condition (height of water table, surface water)	*See Part 4 for possible methods*
Climate	Records of important climate measures (monthly max and min temp, salt laden storms, wind storms, monthly rainfall)	*See Part 4 for possible methods*

How reliable these estimates are as a measure of the true situation for the whole forest is the *precision of the estimate*. Precision can vary from:

- Low precision – an educated guess. For example, results suggest there may be between 500 and 900 tawa stems per hectare in the forest.
- Good precision – 95 percent confidence. For example, there are 450-550 tawa stems per hectare in the forest.
- Extreme precision – 100 percent confidence, the whole population has been assessed. For example, there are a total of 5022 stems in the 10-hectare forest, or 502 per hectare.

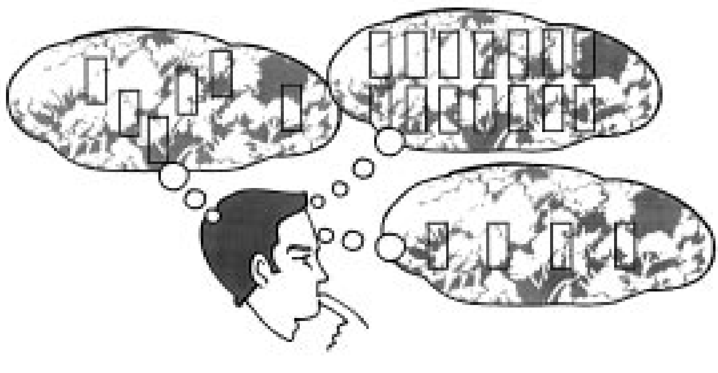
Monitoring should be designed so the level of precision is adequate to answer your monitoring questions. Low precision may be good enough to pick up big changes over long periods. Good precision will be necessary when looking at small changes over shorter periods. Extreme precision is seldom practical or necessary.

Sampling (*see* also 'Sampling', p.95)

Monitoring forests almost always involves picking a selection or 'sample' from the forest to measure and draw conclusions about the whole forest. The size of this sample and the way it is selected are extremely important in determining precision.

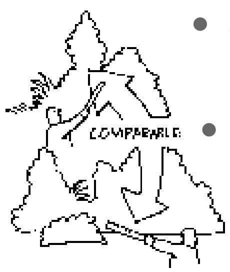
It is important to decide how you will sample – expert advice may be useful. Information on sampling is also provided in 'Sampling', p.95.

FIGURE 2: The way you select samples is very important. Seek advice if you are unsure.

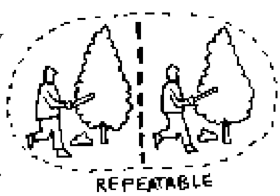


Fieldwork – taking measurements in the forest (*see* also 'General notes …', p.102)

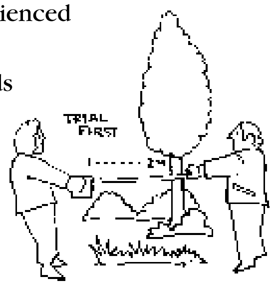
The care with which fieldwork is planned and carried out will determine if the information collected is useful and reliable, or virtually worthless. When planning and undertaking fieldwork, always make sure fieldwork has the following features:

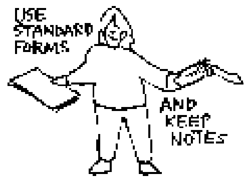


- *Repeatable:* Always record enough information about how the measurement was taken so others can easily re-measure in future.
- *Comparable:* Measurement should be undertaken in a standard and consistent way so it is comparable with other similar studies.



- *Relocatable:* In most cases measurements will be repeated at fixed points. Make sure the locations are well marked and recorded so they can easily be relocated.
- *Knowledge and skills:* Ensure people doing the measurements have enough knowledge and skills. Ways of improving knowledge and skills include reference books, or training from experts and other experienced people.
- *Works in practice:* Do a quick trial of your measurement methods before the main monitoring. Ask questions if you are not sure, and make sure things are working before you do too much.
- *Standard forms:* Use standard field forms where possible. These should stop you forgetting to record important information.
- *Notes on measurements:* Record anything different or unusual about a particular site or measurement. This may be useful when the data is being analysed, or the site is re-measured.





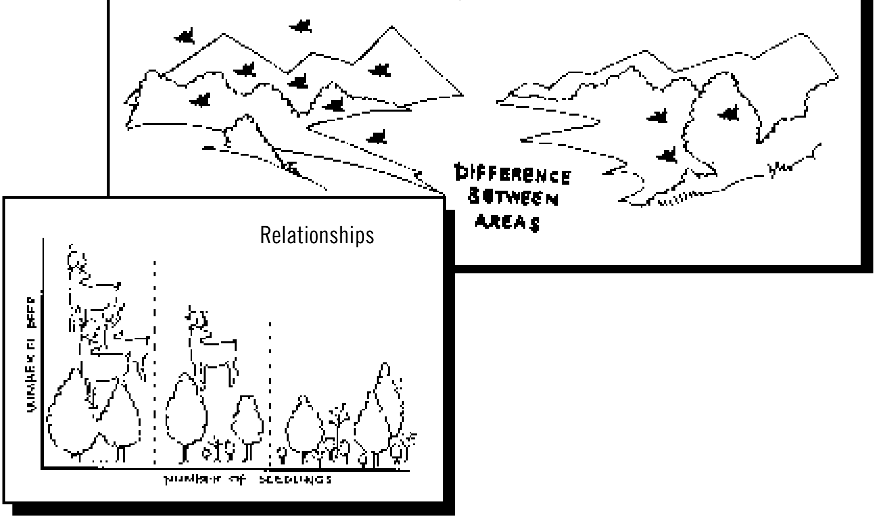
Data analysis and presentation (*see* also 'Analysis of data', p.104)

Analysis can examine:

- Change over time.
- Difference between areas.
- Relationships between different indicators.

Analysis needs to be carefully planned and linked to good sampling and other aspects of monitoring design. Always keep analysis simple and use graphs wherever possible. They help give you a feel if there are differences, changes or relationships. Seek advice to make sure your analysis is scientifically valid.

FIGURE 3: Analysis can include examining differences between areas, and relationships between indicators



Data storage (*see* also 'Records, …', p.108)

The data that your monitoring collects will be important in future to allow comparisons and to track changes. It must:

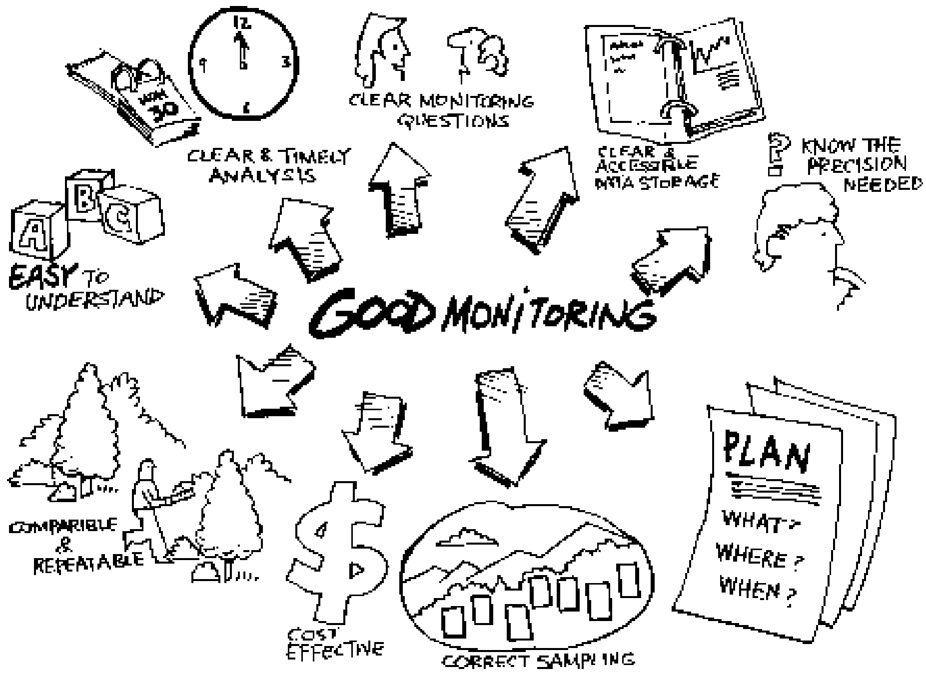
- *Contain all relevant information:* Store the data and information on where and how it was collected. Make sure there is enough information so people can re-measure to get comparable new data. Keeping the data and background information together in a ring binder folder is a good idea.
- *Be accessible:* Make sure other people know the data exists and can get hold of a copy of it. It may be valuable to other people doing similar monitoring who wish to compare results.
- *Be secure:* Make sure the data is safe from damage or loss. Keep at least two copies stored in different locations.

A good monitoring system

Good monitoring has the following elements:

- Clear reasons for monitoring and specific monitoring questions.
- Knowing how precise your results need to be to answer your questions.
- A plan of what, where, and when to monitor to answer these questions.
- Well-planned sampling and measurement methods to give the level of precision you need.
- Is cost-effective and affordable.
- Comparable and repeatable fieldwork.
- Is easy to understand – both monitoring methods and analysis.
- Clear and timely analysis.
- Safe and accessible data storage.

FIGURE 4: Features of good monitoring



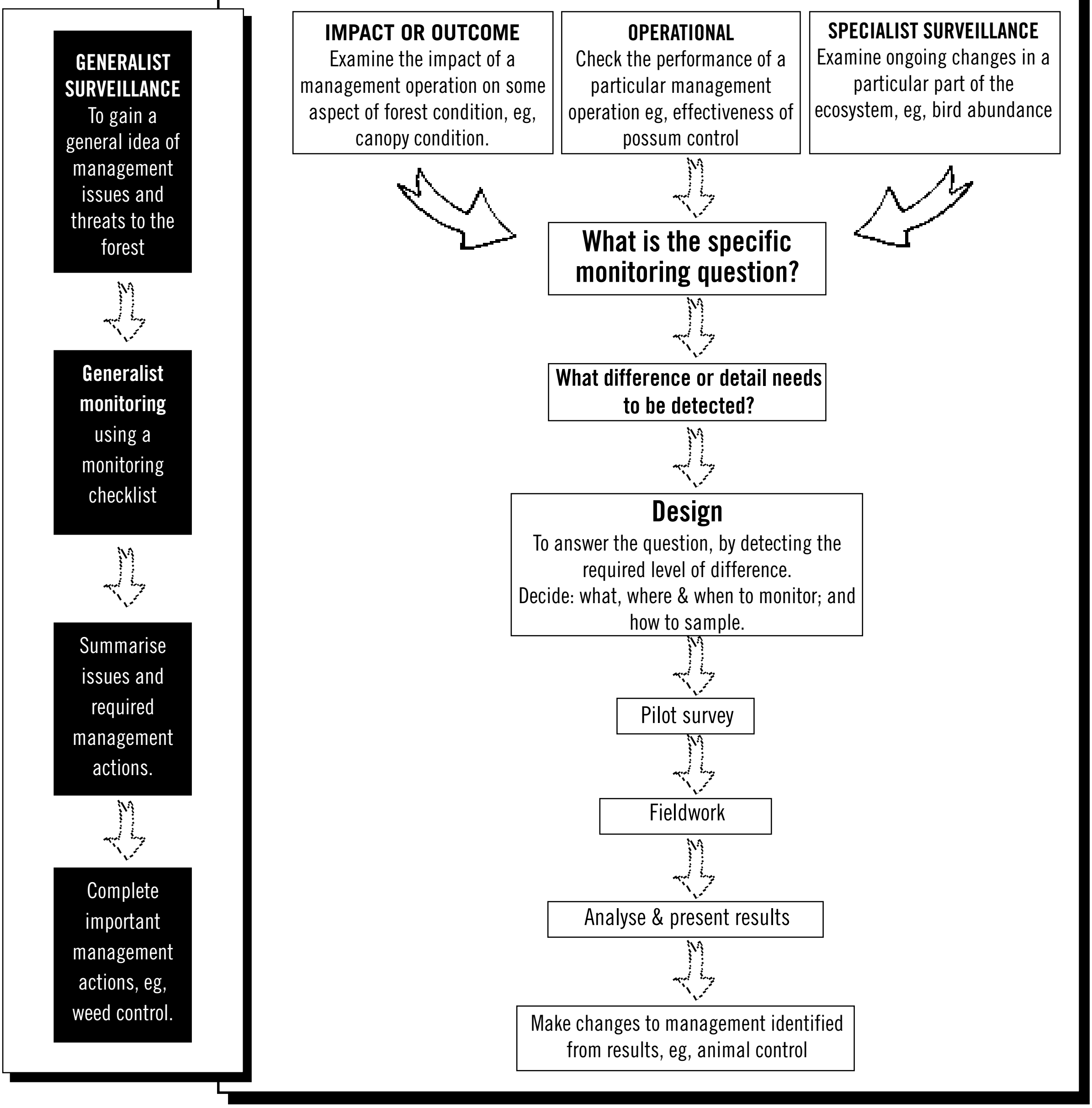
Indicators and measurement methods (*see* also Part 4)

Table 1 (page 12) provides a summary of some common indicators for managers of native forests. It also lists monitoring methods provided in the Monitoring Toolbox which could be used to measure some of these indicators.

This is only an introductory list and it may not provide the best approach. Many methods are listed in Part 4.

The steps in a good monitoring system are set out in the following flow chart.

FIGURE 5:
DECIDE WHY YOU WANT TO MONITOR



2. MONITORING TOOLBOX

Use this part when you are ready to start some fieldwork.

It contains a series of monitoring instructions and field forms but these are only a few of the monitoring methods that you could use.

Part 4 contains a more complete list of useful forest ecosystem indicators and ways to measure them.

Quick reference list to monitoring methods listed in protocol

Monitoring Plan
General Surveillance Checklist for Forest Ecosystems
Ground Photography to Monitor Forest Canopy Cover
Quick Plot Method for Vegetation Assessment
20m x 20m Permanent Vegetation Plots
RECCE – For Vegetation Description
Foliar Browse Index for Possum-Related Damage
Epicormic Shoot Counts
Cylinder Intercept Assessment of Forest Structure
Point Intercept – For Forest Ground Cover Assessment
Flowering and Fruiting Observation Record
Ground Plot Monitoring of Seed and Fruit-Fall
Forest Bird Slow Walk Transects
Weed Map Monitoring
Possum Percentage Trap Catch
Tracking Tunnels for Rodents and Stoats
Rodent 'Gnaw Block' Bait Interference

RECORDING AND MEASUREMENT STANDARDS FOR USE WITH THE TOOLBOX

Many of the instructions in this toolbox require recording of similar background information such as location, or plant species. The list below provides some general standards for recording this information. Additional specific definitions are provided in the individual instructions.

Location name

This is the name of the specific area where the monitoring is being undertaken. It must be a widely used location name. Ideally it should be location that is published on a topographical map. For example Kaitawa Reserve, Wainui Stream, etc.

Grid reference

The six figure grid reference from an NZMS 260, 1:50,000 topographical map. This gives a grid reference estimated to the nearest 100m. The grid reference is preceded by the map sheet number. Instructions for giving grid references are provided on New Zealand 1:50,000 topographical maps. For example the grid reference for Mt Mathews on sheet R27 is given as R27 785819.

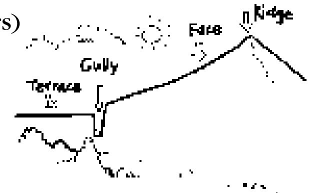
Fieldworker names

Record the names of people who undertook the monitoring that is being recorded. Where more than one person is involved, identify the individual that was recording information, and the individuals undertaking measurements.

Landscape unit

Where there is reference to 'Landscape', or 'Landscape unit', the position where the monitoring is being undertaken should be recorded in one of the following four classes:

- Ridge (including spurs)
- Face
- Gully
- Terrace



Altitude

Height above sea level in metres. This can be estimated off a 1:50,000 topographical map, or measured using an altimeter.

Aspect

The predominant direction that the area faces. Measured by pointing a compass in that direction and recording the magnetic bearing.

Drainage

Recorded in one of the following categories:

- *Poor:* swampy sites where water stands for long periods.
- *Medium:* runoff may be slow, with water accumulating in hollows for a day or two after rain.
- *Good:* water runs off site rapidly.

Diameter at breast height (DBH)

Tree diameter is measured in centimetres to one decimal place, e.g. 23.6cm, at 1.35m above ground level on the uphill side of the stem. This height is chosen as it is used in 20x20 m permanent vegetation plots (Allen 1993). Diameter is measured using a diameter tape which allows diameter to be read directly from a tape wrapped around the stem.

Plant names

The standard for plant names is to record the shortened scientific (latin) name using a six letter code, in capital letters. This code is made up of the first three letters of the Genus (first word in the scientific name) and first three letters of the species, (second word in the scientific name). For example *Elaeocarpus dentatus* (hinau) is recorded ELADEN, *Dacrycarpus dacrydioides* (kahikatea) is recorded as DACDAC. If you do not know the scientific name, record a well accepted common name, during fieldwork, and replace this with the six letter code later.

Sources of measurement equipment & materials

- Length measurement tapes and diameter tapes can be obtained from survey or forestry supply companies. These companies include… Geosystems Ltd (phone 03 343 2333), Trig Surveying Instrument Co, phone 04 473 7935
- Aluminium rod for making stakes can be obtained from metal suppliers such as Mico Metals in your area.

MONITORING PLAN

Purpose

The Monitoring Plan provides a structure to help you ensure that important aspects of design are considered and recorded.

Introduction

This form allows you to work through the important components of designing your monitoring programme, to make sure you consider all the important points and come up with an effective monitoring design.

Recording the reasons for monitoring (your objective and monitoring questions) and the way the monitoring project will be implemented is essential. It will ensure monitoring is done in a consistent way. It will allow the project, once under way, to be checked against what was planned. It will allow people repeating the monitoring in future to re-measure in a consistent way, using the same indicators and measurement methods.

Completing the monitoring plan form

Work through each section of the monitoring form as set out below. Refer to later sections of this publication and ask experts about completing this form.

- *Why do you want to monitor?* The reasons for monitoring and your specific monitoring questions need to be defined (*see* 'Why do you want to monitor', p.86 and 'What is the monitoring question?' p.87).
- *What level of precision is required?* Identify what broad level of precision is necessary to answer your questions. For example, do you need to pick up small changes over a year or two, or are you only interested in major changes over several years, *see* 'What sort of difference … ?' and 'Design monitoring …', p.88.
- *Indicators and Measurement:* Select the most appropriate indicator or indicators, relevant to your questions. Also identify the measurement methods you will use to match the precision you require, and your skills and resources. Identify the specific measurement instructions you will use. See 'What will you measure', p.89, 'Selected measurement methods' p.89 and 'Using marked or unmarked measurements' p.92.
- *Design:* Decide how you will design your monitoring to answer your questions. How will you design it to compare differences between areas or, if relevant, change after a management operation. See 'Design monitoring …', p.88.
- *Fieldwork:* Develop a plan for efficiently carrying out the fieldwork (*see* 'General notes on undertaking fieldwork', p.102). This will include considering points such as: When will it be undertaken? What people and equipment are needed? Are there any particular training requirements?
- *Data analysis and storage:* Identify how you will analyse the data that is collected. This may include specifying what will be calculated, such as calculating mean tracking frequency for different areas from tracking tunnels, or percentage vegetation cover from digital analysis of photographs. Identify how data will be stored. For example, where will the hardcopy field sheets be stored? Will a computer data file be created? See 'Analysis of data', p.104 and 'Records …' p.108.

Records

The Monitoring Plan form should be stored with the data collected under this plan. It may form the cover sheet on a series of data sheets.

MONITORING PLAN

Forest areas involved: Kaitawa Scenic Reserve

Plan prepared by: James Hannah **Date:** 14.11.99

Why do you want to monitor?

Broad objectives (general surveillance, specialist surveillance, conservation outcome, operational monitoring)
Examine the conservation outcome of Goat Control

Monitoring questions
What impact has reducing the numbers of goats had on species in the under storey that goats eat.

Precision required
Need to pick up moderate changes occuring over a 3–5 year period

Indicators and measurement

Indicators
Understorey abundance, species composition and diversity, abundance of indicator species.

Measurement methods
Assessment of understorey density, composition and epicormic shoots

Measurement protocol Quickplot, Epicormic Shoot Counts

Design

How will change be examined? (BACI (before after control impact), treatment and non treatment areas, etc)
Areas in the same catchment and forest type where no control has been undertaken will also be measured.

Marked or unmarked plots?
Marked

Sample size: Attached calculations show 35 Quickplots will be required in the reserve area and a similar number in the areas with no goat control.

Sample selection (systematic, random, stratification, etc — explain field layout)
Transects will be run out on a bearing of 160° (magnetic) from the road. Transect starts randomly located. Quickplots at 75m spacing along transects.

Field trial of design
Will be trialed on 10.12.99. One transect will be established.

Fieldwork

Fieldwork
Will require measurement in accordance with Quickplot and Epicormic Shoot Count methods.

Timing
17.1.00 — 31.3.00

Resources
One team of two people, measurement tapes etc. See method checklists.

Particular requirements
None

Analysis and data storage

Proposed analysis: Comparison of changes in density and composition of browse preferred species over time, and between the area with goat control and without goat control. Advice is being obtained on statistical tests.

Proposed storage of records
Daily storage in paper file.

Blank copies of these forms can be obtained at www.fronz.net.nz or under SMF project 5073 at www.smf.govt.nz

GENERAL SURVEILLANCE CHECKLIST FOR FOREST ECOSYSTEMS

Purpose

To identify any immediate threats or issues about the general forest condition that may require management input.

Summary

Indicators
- Canopy cover
- Understorey abundance
- Ground cover
- Bird relative abundance
- Abundance of weeds
- Abundance of large vertebrate pests
- Abundance of possums

Skills
- General knowledge of the assessment of forest values and threats
- Ability to identify main native plant and weed species
- Ability to identify conspicuous sign of animal pests

Time

0.5-1 hour per sheet

Sampling
- Needs to be determined when planning monitoring
- One checklist completed for one similar area of forest ecosystem
- In small reserves, one sheet per reserve may be adequate
- In larger forest areas, use sheets for different areas

Equipment and people
- 1-2 fieldworkers
- Map
- Aerial photograph
- Pencils
- Surveillance checklist
- Clipboard
- Camera and film (to photograph important features or issues)
- Plastic bags and labels, to collect any important plant specimens

Strengths
- Simple to undertake without special skills or equipment
- Provides a good initial identification of key threats and issues
- Examines a wide range of indicators at one time

Weaknesses
- Relies on visual assessments so precise changes cannot be examined
- Subjective assessments – may vary between observers

Introduction

This method is broadly based and intended to provide an indication of the current important management issues for a forest area. It may identify where more monitoring and management input are required. It can be used to examine big differences between areas or over time, but it should not be used for more detailed studies.

Its main use is as part of a regular inspection of a forest area by field staff.

Sampling

One checklist (*see* page 23 and 24) is completed for a particular, similar area of forest. For a small reserve, one checklist would be completed for the whole reserve. For larger areas, or where there are distinctly different parts of a forest area, several checklists may be completed.

Each checklist should relate to an area that can be walked through and visually assessed by one person, for example, a small catchment area, or a defined area of an important vegetation type.

Method

Define the forest and area that the checklist is for.

- This may be a whole forest area, or one part, such as a small stream catchment, a defined area along a forest edge, etc. It is important to define where you walked in assessing the area, for example, did you follow an existing track, or walk systematically through the whole area.
- Fill out the header information.
- Walk through the whole area being assessed; referring to the checklist as you go to make sure all the important indicators are noted.
- Tick the appropriate description for each indicator that is closest to the state of the area assessed.
- If you are not sure about the assessment of a particular aspect of forest condition, record this in the notes.
- Add any additional notes about key points or important work that needs to be done. For example, is there a break in a fence that needs fixing?

Records

File the completed checklists and any associated notes and maps.

Analysis and presentation

Because of the relatively crude nature of the data collected, involved analysis is not warranted. Some approaches to using the information are as follows:

- Compare the estimates (1-4 on the checklist) for each indicator between different areas, and different assessment periods to identify any big differences. Individual indicators should be compared rather than an overall combined rating.
- Identification of high-risk combinations. If certain combinations of indicators are identified, this should 'ring alarm bells' and result in a more thorough examination of the area. Important combinations may include:
  - ~ Poor canopy condition and high possum populations.
  - ~ Poor canopy condition, poor understorey condition and high goat or deer populations.
  - ~ Poor canopy condition and high weed populations.
- Identify and note follow-up of management needs.

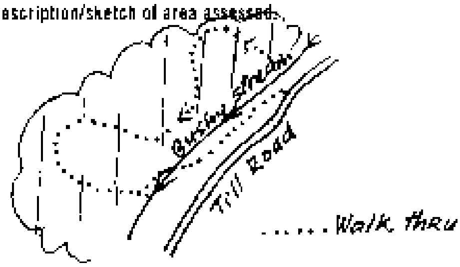
Frequency of re-measurement

The frequency of re-assessment will depend factors such as:

- The importance of the area – does it have particular significance in terms of rare species or communities?
- Issues and actions raised at the last assessment – if there are important actions to follow up on, re-assessment may be sooner.
- Is the area under threat, for example, close to an urban area or road, meaning introduction of new threats is likely?

A generalist monitoring checksheet is suitable for a regular annual or two-yearly field check of an area.

FOREST GENERAL SURVEILLANCE CHECKLIST

Location name Bushy Hill Reserve	**Grid reference:** R26555984 **Date:** 27·3·00
Fieldworker names: David Jones, William Burns	**Weather:** Overcast
Landscape unit: Face	**Altitude:** 130m
Aspect: 260°	**Drainage:** Good
Description/sketch of area assessed: 	**Special species or communities:** *(rare, threatened, unusual distribution etc)* None identified. **Forest canopy composition:** *Underline dominant species.* Kohekohe, mahoe, tawa

Indicator	Rating	Estimate *(Tick appropriate level)*	Notes *Species etc*
Birds	1	☐ Very few birds and only 1-2 species.	tui, kereru, blackbird, grey warbler
	2	☑ Occasional birds and 2-4 species	
	3	☐ Common birds, and 5-10 species	
	4	☐ Abundant birds, and >10 species.	
Canopy condition	1	☐ Very sparse foliage, many large holes, dieback > 20% of tree crowns.	
	2	☐ Foliage sparse in some areas, canopy holes common. Some dieback.	
	3	☑ Foliage mostly dense, only occasional sparse areas, canopy holes rare, very occasional dieback	
	4	☐ Abundant dense foliage over whole canopy, no canopy holes or dieback	
Understorey	1	☐ No browse palatable species 45cm-1.35m. Understorey bare	
	2	☐ Very few browse palatable species 45cm-1.35m. Scattered seedlings of less palatable species	
	3	☑ Moderate browse palatable species 45cm-1.35m. Other species relatively abundant.	
	4	☐ Abundant browse palatable species and other species present	
Ground cover	1	☐ Bare soil, rock/gravel > 20% of forest floor. Ground vegetation (ferns, moss, seedlings etc < 45cm tall) absent or very uncommon. Leaf litter on remainder of forest floor.	Some steep rocky areas.
	2	☑ Scattered bare soil and rock. Ground vegetation (ferns, moss, seedlings etc < 45cm tall) < 20%. Leaf litter on remainder of forest floor	
	3	☐ Bare soil, rock absent or very uncommon. Ground vegetation (ferns, moss, seedlings etc < 45cm tall) 20%-50%. Leaf litter on remainder of forest floor	
	4	☐ No bare soil, rock, or eroding soil. Ground vegetation (ferns, moss, seedlings etc < 45cm tall) abundant, 50%-100%. Leaf litter on remainder of forest floor	
Vine Weeds	1	☐ Very common, > 50% canopy cover	none in main reserve, but present on margins.
	2	☐ Common, 10%-50% canopy cover.	
	3	☐ Occasional, up to 10% canopy cover	
	4	☑ None present.	
Shrub / Tree Weeds	1	☐ Very common, > 50% understorey or canopy cover	Holly present in some areas.
	2	☐ Common, 10%-50% understorey or canopy cover.	
	3	☑ Occasional, up to 10% understorey or canopy cover	
	4	☐ None present.	

Page 1 of 2

Blank copies of these forms can be obtained at www.fronz.net.nz or under SMF project 5073 at www.smf.govt.nz

Indicator	Rating	Estimate (Tick appropriate level)	Notes Species etc
Ground cover weeds	1	☐ Very common, covers > 50% ground area.	Tradescantia present in some areas. Appears to be spreading.
	2	☐ Common. 10%–50% ground area.	
	3	☑ Occasional, up to 10% ground area.	
	4	☐ None present.	
Possums	1	☐ Abundant fresh sign (droppings, pad runs, bark scratching and biting)	
	2	☐ Common fresh sign but sometimes scattered	
	3	☑ Sign uncommon, often quite old.	
	4	☐ No sign.	
Deer	1	☐ Abundant fresh sign (droppings, major tracks and hoof prints). Occasional deer may be disturbed	
	2	☐ Common fresh sign but sometimes scattered Sightings of deer uncommon	
	3	☐ Sign uncommon. Sign is often old	
	4	☑ No sign.	
Goats	1	☐ Abundant fresh sign (droppings, major tracks and hoof prints, bedding areas) Goats commonly heard, seen, or smelt.	Some goats heard outside the reserve.
	2	☐ Common fresh sign but sometimes scattered Occasional goats heard, seen, or smelt	
	3	☑ Sign uncommon. Sign is often old	
	4	☐ No sign	
Pigs	1	☐ Abundant fresh sign (rooting, droppings and hoof prints) Pigs commonly seen, or heard nearby.	
	2	☐ Common fresh sign but sometimes scattered.	
	3	☐ Sign uncommon. Sign is often old.	
	4	☑ No sign.	
Stock	1	☐ Abundant fresh sign (droppings, major tracks and hoof prints) Stock heard or seen throughout area	
	2	☐ Common fresh sign but sometimes scattered Occasional stock heard or seen, generally confined to scattered areas on edge.	
	3	☐ Sign uncommon. Sign is often old. Only near edges.	
	4	☑ No sign	
Fencing	1	☐ No fencing	Whole boundary not checked. Looks O.K.
	2	☐ Some fencing, for example one side, or fence poorly maintained with large breaks.	
	3	☑ Most of boundary fenced, includes all areas where stock access likely. Some small recent breaks	
	4	☐ Secure, intact fencing around whole area	
Human Visitors	1	☐ Widespread trampling, and other damage throughout area	Some dumping of rubbish from road.
	2	☐ Common trampling and damage but limited to certain areas.	
	3	☑ Occasional localised minor damage.	
	4	☐ No damage.	

Management needs/actions	By whom	By when
Examine feasibility of removing holly.	O.J	30·4·00
Trial control on areas of tradescantia.	W.B.	30·11·00
Contact neighbour about goats.	O.J.	30·4·00

Page 2 of 2

GROUND PHOTOGRAPHY TO MONITOR FOREST CANOPY COVER

Purpose

To determine levels of foliage cover and canopy condition using photographs taken from the ground.

Summary

Indicators
- Canopy cover and condition

Skills
- Basic understanding of photography
- Ability to identify key canopy species

Time
- 0.5 hr per photopoint to establish, less to re-photograph

Sampling
- Needs to be determined when planning
- For careful repeat monitoring of individual trees, 10-20 trees may be sufficient

Equipment and people
- 1 fieldworker
- Topographical map
- Pencil and eraser
- Instruction sheet
- Photopoint record sheet
- Clipboard
- Camera (preferably with a fixed focal length lens)
- Film
- Tripod and cable release – essential for telephoto and low-light photographs.
- UV filter
- Polarising filter (optional but can improve monitoring result)
- Aluminium stakes, permolat (venetian blind), and nails for marking photopoints

Strengths
- Can be done with standard camera equipment
- Photographs are available for future re-examination
- Can provide good precision, particularly if computer image analysis used

Weaknesses
- Care required to get good quality photographs for comparison

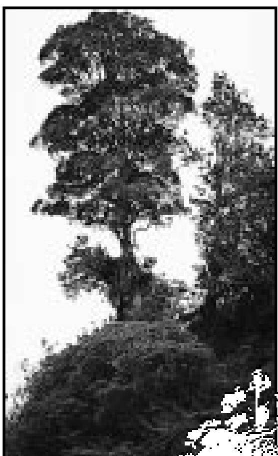


PHOTO: ROBIN BLAKE

Introduction

Three general types of canopy photographs are identified that are useful for monitoring.

Uplooking

These are photographs taken looking vertically upwards into the forest canopy from the forest floor.

Side view single tree/emergent

Photographs showing the entire crown of a single tree that is usually emergent above the forest canopy, for example, northern rata. These photographs are taken from the side.

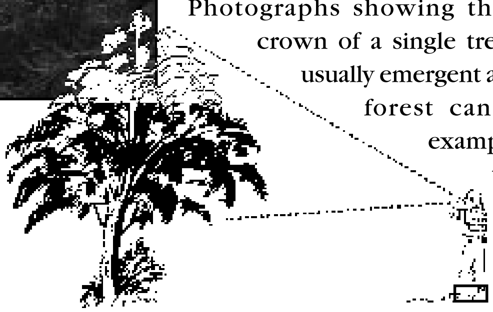


PHOTO: ROBIN BLAKE

Panorama

Photograph of an area of forest canopy viewed from the outside from some vantage point. For example, a forest covered face across a narrow valley from an access road.

Sampling

When photographing the canopies of a sample of trees through an area, trees should be located in some random or systematic way, to avoid bias. This may involve identifying trees along some pre-defined transect, such as is set out in the instruction for epicormic shoot counts. Also, refer to 'Sampling', p.95.

Sometimes photographs may be selected subjectively to monitor particular sites of interest. When monitoring large emergent species such as northern rata, it may be possible to photograph all the visible trees in an area.

When selecting sites as photopoints, make sure the view from the photopoint will not be obscured by vegetation growth over the monitoring period.

Uplooking

- Each photograph, which forms an individual sample point, is taken looking vertically upward into the crown of an individual tree. If the impact of possum browse is being assessed, canopy species are chosen that are likely to be browsed by possums. Trees photographed must have at least part of their canopy clearly visible against the sky when viewed from directly underneath.

Side view – emergent

- Side-view photographs of individual tree crowns form the sample points. The easiest analysis is achieved where crowns can be photographed silhouetted against the sky so, where possible, choose trees that can be photographed in this way. Trees can also be photographed against a bush background, but extra care must be taken with the photography (*see* table on p.29).

Panorama

- Each section of the forest canopy photographed from the outside vantage point forms a sample point. Availability of vantage points allowing a view of the canopy will limit the number of available sample points.

Method

Establishing a photopoint and photoframe

- *Photopoint:* a specific, referenced and relocatable site where a camera is set up and photographs taken.
- *Photoframe:* the exact direction, focus and variables of photographs taken from the photopoint. Many photoframes can be established at a photopoint.

Guidelines for the establishment of photopoints and photoframes are provided by Elwood (1997).

Photography

Specific guidelines for canopy photography are set out in the table on page 29.

Timing

Photographs should be taken at the same time of year to allow realistic comparison. For this reason, it is important to record details of date and time on photopoint sheets.

Leaf growth generally occurs from spring until mid summer each year. Photography during this period should be avoided if possible, because small changes in the timing of leaf growth, and of photography during this period may affect the results. Repeat photographs should be taken at a similar time of day and under similar light conditions to minimise variation.

Records

Maps, aerial photographs and other location information.

Standard photopoint record sheets. *See* page 30.

Analysis and presentation

The photographs obtained with this method may be used in several ways depending on the objectives of the study.

FIGURE 6: Example photo and digital image analysis of area in circle.

PHOTO: ROBIN BLAKE

Computer image analysis
Photographs are analysed using computer image analysis software to identify vegetation cover. With high quality side-view and panorama photos, the amount of dieback present can also be determined. A fixed area within the photograph is analysed.

Changes occurring between repeat photographs from the same photopoints can be tested for statistical significance.

Manual analysis
A measure of canopy cover can be obtained by placing a standard dot grid over the photograph, and then counting the number of dots falling on vegetation or open space. This measure is tedious and will have a lower level of precision than that obtained by computer image analysis.

Subjective presentation
Sometimes photographs are only required to provide a visual demonstration of the change that has occurred. Wherever possible, this should be combined with one of the above measures to provide more objective results.

Frequency of re-measurement
The frequency will depend on growth rate of the species and area photographed, and how easy it is to re-photograph the photopoints. In some cases, annual photography may be possible, otherwise re-measurement every two to three years will be acceptable. As discussed above, photographs should be taken at the same time of year and similar time of day.

FOREST CANOPY COVER PHOTOGRAPHY REQUIREMENTS				
Photo	**Image characteristics**		**Suitable photographic technique**	
	Avoid	*Achieve*	*Conditions*	*Equipment*
Upward Looking	• Sun on canopy • Overexposure 'washing out' fine leaves around canopy holes and gaps	• Sharp focus • Crisp exposure out to fine leaves • Photo of the identical area of tree crown if taking repeat photos. This can be achieved by taking the previous image into the field, and putting a permanent peg in the ground showing position and orientation of the camera • The area of interest centred in the photo	• Overcast or shaded by topography – no sun on tree canopy • Sufficiently still conditions that sharp image can be obtained	• Good quality camera with a lens of focal length in the 28-55mm range. The same focal length should be used for repeat photographs • Colour print film with a speed of 200-400 ASA • Polarising filter useful, but not essential • Tripod • Minimum resolution of 1,200,000 pixels if using digital photography
Side View Emergent	• Areas of light and shade on the crown • Over or underexposure • Small, distant images • Trees against a bush background. These images can still be analysed but are more difficult and less reliable	• Sharp focus over the whole tree crown • Crisp exposure out to fine leaves • The tree silhouetted against sky, if possible • Even light over the whole part of the tree being photographed • Photograph from an identical location if taking repeat photos. This can be achieved by taking the previous image into the field, and putting a permanent peg in the ground showing position and orientation of the camera	• Full sun shining directly on to the side of the tree being photographed • Where trees are photographed in silhouette, overcast sky or shading by topography can be suitable • Sufficiently still con-ditions that sharp image can be obtained	• Good quality camera with a lens of suitable focal length to allow a large image of the tree. The lens required will depend how far the photopoint is from the tree. Use the same focal length for repeat photographs • Colour print film with a speed of around 200 ASA • A polarising filter is strongly advised • Tripod – particularly if a longer focal length lens, or slow shutter speed is used • Minimum resolution of 1,200,000 pixels if using digital photography
Panorama	• Areas of light and shade on the canopy • Over or underexposure • Low intensity light	• Sharp focus over the whole picture • Crisp exposure out to fine leaves • Even, bright, light over the whole photograph • Photograph from an identical location if taking repeat photos. This can be achieved by taking the previous image into the field, and putting a permanent peg in the ground showing position and orientation of the camera	• Full sun shining directly onto the area being photographed • Sufficiently still conditions that sharp image can be obtained	• Good quality camera with a lens of suitable focal length to allow a large image of the area photographed. The lens required will depend how far the photo point is from the area, and how large an area is being photographed. The same focal length should be used for repeat photographs. Colour print film with a speed of around 200 ASA. A polarising filter is strongly advised • Tripod – particularly if a longer focal length lens, or slow shutter speed is used • Minimum resolution of 1,200,000 pixels if using digital photography

PHOTOPOINT SHEET

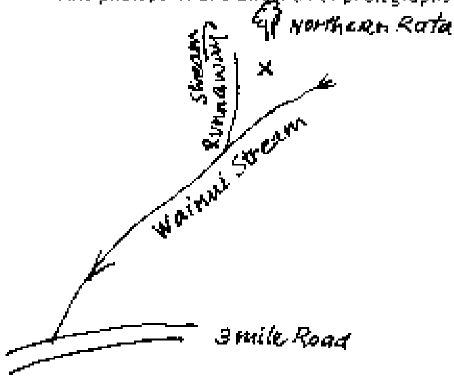
Photopoint location

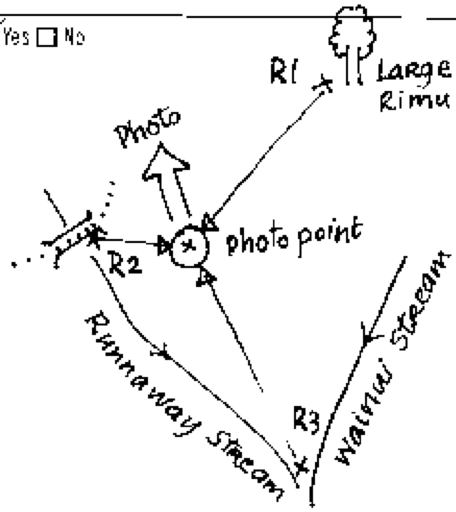
Location name: Angle Gully	**Photosite number:** 21
Landscape unit: Terrace	**Grid reference:** R 27 723 926
Date established: 17.5.00	**Fieldworker names:** David Sims

Peg placed at site: ☑ Yes ☐ No **Photo of setup taken:** ☑ Yes ☐ No

Sketch of location and reference points

Indicate photopoint and direction of photographs taken.





Reference point 1:	Reference point 2:	Reference point 3:
Object: Large Rimu tree	**Object:** Foot Bridge	**Object:** Fork in Stream
Distance to photopoint: 25 m.	**Distance to photopoint:** 10 m	**Distance to photopoint:** 30 m
Bearing to photopoint: 40°	**Bearing to photopoint:** 288°	**Bearing to photopoint:** 130°

Photoframe data

Photo No	Photo Description	Date	Time	Weather (sunny etc)	Film Brand	Film ASA	Frame no	Focal length	Shutter speed	Aperture
1	Northern Rata	17.5.00	1340	overcast	Fuji	200	7	50mm	1/125	f8

Blank copies of these forms can be obtained at www.fronz.net.nz or under SMF project 5073 at www.smf.govt.nz

QUICK PLOT METHOD FOR VEGETATION ASSESSMENT

Purpose
To assess the abundance of various plant species in the forest understorey.

Summary

Indicators
- Understorey abundance
- Species composition/diversity
- Abundance of 'indicator' species
- Population structure

Skills
- Good knowledge of native and introduced plant species

Time
- 0.5 hr per plot

Sampling
- Depends on feature such as variability and precision required
- Needs to be determined when planning monitoring

Equipment and people
- 2 fieldworkers
- Topographical map
- Pencil and eraser
- Instruction sheet
- Quick plot field form
- Camera and film (to photograph important features or issues)
- Plastic bags and labels (to collect plant specimens for identification)
- 20m measuring tape.
- Hip chain or long (50-100m) tape, for locating plots.
- 2m pole, marked at 0.5m intervals, with additional marks at 0.15m from one end (the bottom) and 0.45m and 1.35m from the same end.
- A diameter tape
- Compass
- Plant identification references (if necessary)
- Aluminium stakes and permolat (venetian blind)
- Numbered tree tags

Strengths
- Relatively quick to measure compared to other plot methods
- Provides precise stem count data
- Provides information for use in the study of a several different vegetation indicators

Weaknesses
- Can be difficult to assess less common species
- Considerable number of plots can be required to get good data

Introduction
These plots are relatively quick and easy to establish.They are most effective at obtaining data on the understorey, but also collect data on larger canopy trees. Measurement methods and height tier distinctions have been designed to be compatible with the well established 20mx20m plot protocol (Allen 1993).This allows broad comparison of results with data from any existing long-term 20mx20m plots.

The cylinder intercept method of examining forest structure (*see* 'Cylinder intercept assessment …', p.49), and the point intercept method for ground cover (*see* 'Point intercept … ', p.53) can be easily combined with the standard quick plot.

Sampling

Plot location and layout

Each plot forms a sample point. Plots will normally be located in a systematic or systematic random way using transects running through the forest area.

Transects should run in the same direction as an environmental gradient. In many cases, the main gradient will be in altitude, in which case, transects should run up or down the slope. Individual plots on a transect should all be run out on the same bearing, at right angles to the transect bearing (*see* Figure 7). This should ensure that most plots are run out along the contour to minimise the effect of slope.

The transect and plot bearing should be selected before starting fieldwork to remove any chance of bias.

Plot size

Plot size must be kept the same for each block (*see* 'Breaking areas into blocks …', p.97) that is sampled. At the start of a survey, different plot size can be set for the tree, sapling, tree fern and ground fern tiers. But these plot sizes must be maintained in all plots in the sample.

The standard plot length is 20m, though this can be increased if necessary, providing this change is well documented and is applied to all plots in the sample.

When choosing plot size for the various tiers follow the following process:

- Walk through and examine the general density in the forest area you will be monitoring.
- Choose one of the plot sizes listed in Figure 6 for each tier, so that on average, about 20 individual plants will be counted in that tier. If the understorey is very sparse, this may mean using the maximum plot size (4m wide) even though fewer than 20 individuals are included.
- It is suggested that you quickly lay out 4-5 plots in the area to check if the plot sizes you have selected are right. If you get many more than 20 stems in a tier (say, more than 30), try a smaller plot size for that tier to get closer to 20 stems. If you get many fewer than 20 stems (say, fewer than 12), try a larger plot size to get closer to 20 stems.

FIGURE 6: Diagram with six different plot sizes and required layout.

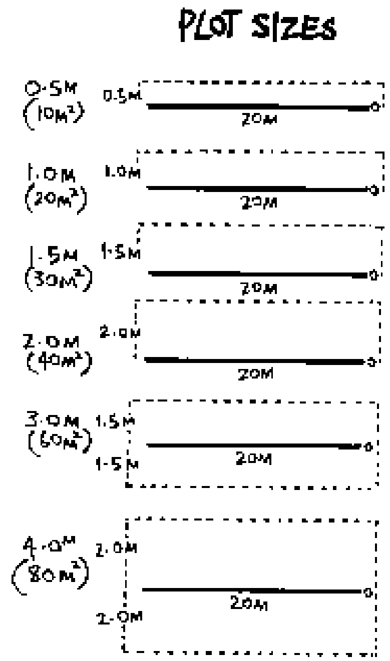
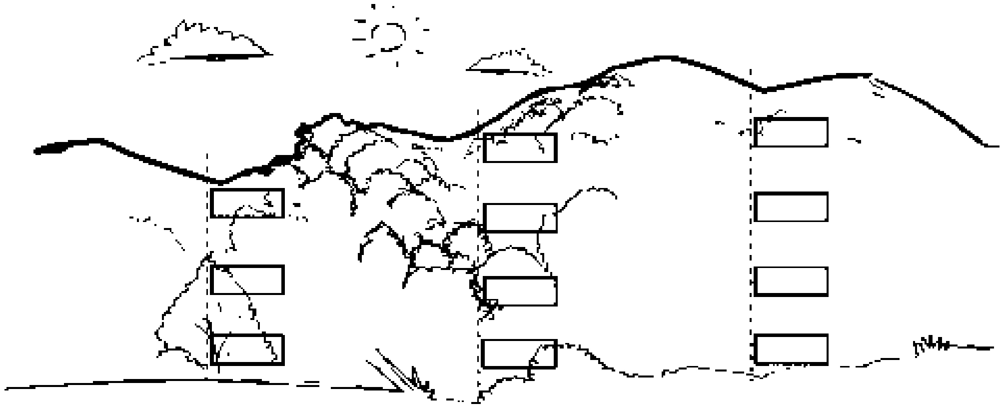


FIGURE 7: Individual plots can be run out at right angles, at set intervals along a transect.



As a rough guide, consider the following:

A good tree cover of moderate-sized trees, but a sparse understorey with very few seedlings or ferns	A 4m-wide plot for all tiers will probably be appropriate
A good tree cover of moderate-sized trees, and seedlings and saplings are common enough that you are brushing past one every 3-4m	A 4m-wide plot for trees and tree ferns, and a 2m-wide plot size for all other tiers
A good tree cover of moderate sized trees. Saplings are common enough that you are brushing past one every 3-4m. Seedlings and ground ferns are extremely abundant, and you are almost constantly brushing past them	A 4m-wide plot for trees and tree ferns, a 2m-wide plot size for saplings, and a 0.5m-wide plot for seedlings and ground ferns

Plots of 2m or less in width are searched only on one side of the tape. On sloping ground, always search on the uphill side of the tape. On flat ground, search on the right-hand side of the tape, as you face from the start toward 20m. Always record the side (left or right facing from the start) that was searched.

Method

- Run a 20m tape along the bearing selected (at right angles to the survey transect).
- As you run the tape out, put aluminium pegs with venetian blind markers (*see* Figure 8) in the ground at 0, 5m, 10m, 15m and 20m and put the tape through these markers (*see* Figure 8) to hold it in place. Wind the tape around the last marker to hold it tight.
- Take care during plot layout and measurement not to step on or damage seedlings because this can affect your future measurements.
- Use a 2m pole marked in 0.5m intervals, with additional marks 0.15 m, 0.45 m and 1.35m from one end, to assess the plot width, and measure height tiers (*see* Figure 9).

FIGURE 8: Tape is run through pegs to hold it in position.

PHOTO: PETER HANDFORD

- It is important to assess the plot by moving consistently along the plot from the start (0m), recording all stems in each tier as you go.This prevents confusion over what part of the plot has already been assessed.
- In most cases, plots will be permanently marked so they can be re-measured. If this is the case, attach a numbered aluminium tree tag to each tree stem, at 1.35m above ground on the uphill side. Leave the nail head 1-2cm out from the stem to allow for growth.
- For each tier, record, on the plot sheet on page 39:
  - ~ The width of the transect. This is the width of plot assessed in that tier (either the chosen width or full 4m).
  - ~ The species of each stem. This can be recorded as a shortened scientific name using a six letter code. This code is made up of the first three letters of the Genus (first word in the scientific name) and first three letters of the species, (second word in the scientific name). Information on using plant names is provided in Measurement Standards.
  - ~ Number of stems. The count of stems for that species in the tier. This applies to sapling, seedling, tree fern and ground fern tiers. Trees are recorded individually with their diameter.
  - ~ DBH (diameter at breast height – 1.35m) of tree stems in the plot.
- Record all vine species present in a 4m-wide transect in broad abundance classes of:
  - ~ Occasional – a small number, 1-5 vines in the plot.
  - ~ Common – vines common, with possibly 5-20 along the plot, but they do not affect your movement in the plot area.
  - ~ Abundant – vines throughout the plot area and restricting your movement over parts of the plot.
- Record all woody epiphyte species present in the tree plot.

Definitions

Tree

- Greater than or equal to 3cm in diameter at breast height (1.35m).
- Any stem forking below breast height (1.35m) is a separate tree stem. However, it is bracketed on the data sheet to link it to its companion stems.

FIGURE 9: A 2m pole is used to measure the boundary of the plot for each tier, as well as the height of seedling tiers.

PHOTO: PETER HANDFORD

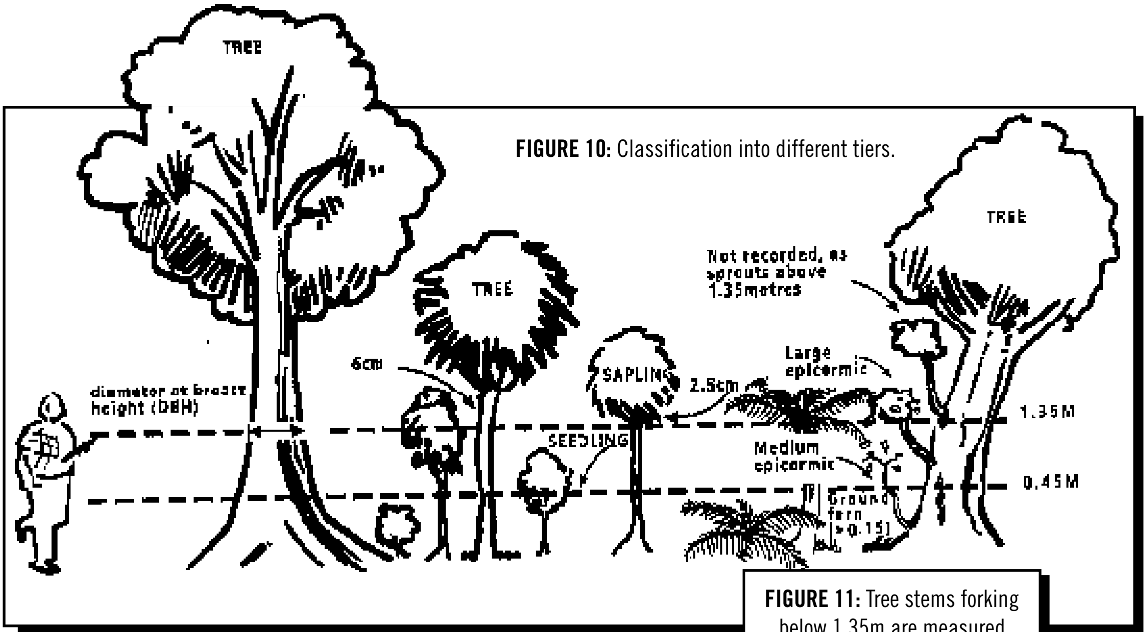
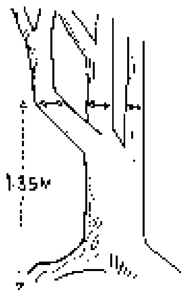


FIGURE 10: Classification into different tiers.

FIGURE 11: Tree stems forking below 1.35m are measured separately.



Sapling

- Greater than 1.35m in height but less than 3cm in DBH.
- Any stem forking below breast height (1.35m) is a separate stem. However, it is bracketed on the data sheet to link it to its companion stems.

Seedlings

- Greater than 0.45m, but less than 1.35m in height.
- Count groups of stems from the same plant that fork visibly above ground level as one stem.

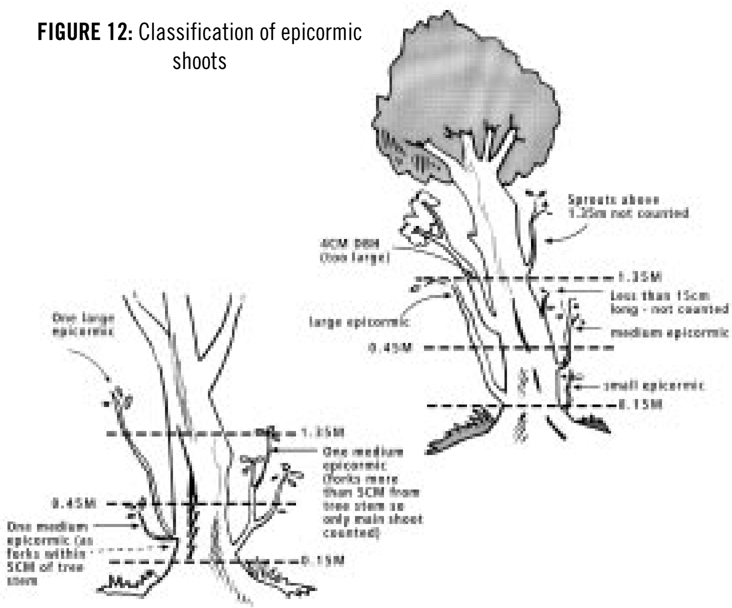
Small-medium epicormic

- Shoot from a tree stem that is within the plot.
- Must sprout from below 1.35m on the tree stem.
- Must be longer than 0.15m from the tree stem to the tip of the shoot.
- Height from ground to top of shoot must be less than 1.35m.

Large epicormic

- Shoot from a tree stem that is within the plot.

FIGURE 12: Classification of epicormic shoots



- Must sprout from below 1.35m on the tree stem.
- Must be longer than 0.15m from the tree stem to the tip of the shoot.
- Height from ground to top of shoot must be greater than 1.35m.
- Diameter of shoot at 1.35m from ground must be less than 3cm.

Tree ferns
- Have a distinct trunk.
- Must be tree fern species.
- If less than 1.35m in height, record as a ground fern.

Vines
- Greater than 0.45m in height.

Ground ferns
- Greater than 0.15m (15cm) in height.
- Must be fern species that form a single 'plant', and not spreading species on rhizomes.

Woody epicormics

Woody plants that are rooted in tree or tree fern stems above ground level.
- *Height:* Measured vertically from ground level, immediately adjacent on the uphill side of the stem.
- *DBH (Diameter at breast height):* Measured at 1.35m height, on the uphill side of stem. This 1.35 m convention is the same as that used in the established 20x20m plot method. Where stems have fallen over and are lying horizontally, DBH is measured 1.35m along the stem from the base.
- *Diameter of multiple stems:* Where trees in the plot have multiple stems, forking below 1.35 m, they are treated as separate stems, and their diameter is measured separately (*see* Figure 11). The stems are shown as linked on the field form.

Records

These should include:
- Objectives and monitoring plan.
- Details on the monitoring method, any changes, etc.
- Field data sheets.
- Location information, including maps of survey lines, transect locations, etc.
- Any general notes on the monitoring.

Analysis and presentation

A wide range of analysis of plant abundance, composition, population structure can be undertaken (*see* 'Species composition and diversity', p.124, 'Abundance of indicator species', p.127 and '– Population structure', p.136).

Frequency of re-measurement

This will depend on the monitoring question and the growth rate of the vegetation being monitored, and any other change likely to be occurring. Re-measurement after two to three years may be appropriate to examine changes in the understorey.

Example

A manager is undertaking monitoring of the forest understorey in a reserve area where there is a good forest canopy cover, and moderately common seedlings and saplings. They undertake trial measurement of a small number of plots and decide that they will use a 4m wide plot for tree stems, and tree ferns, and a 2m wide plot for all other tiers. They measure 10 plots. They then calculate the mean number of plants in each tier from the 10 plots (*see* 'Datapoints and means … ', p.104). The results for some of the major species in the tree, sapling, and seedling tiers are presented below.

Species		**Trees**			**Saplings**			**Seedlings**		
Scientific code	*Common name*	*Measured in a 4m wide plot (80m^2)*			*Measured in a 4m wide plot (80m^2)*			*Measured in a 2m wide plot (40m^2)*		
		no	*No/m^2 **	*No/ha ***	*no*	*No/m^2 **	*No/ha ***	*no*	*No/m^2 **	*No/ha ****
DYSSPE	kohekohe	3	0.0375	375	12	0.15	1500	4	0.1	1000
HEDARB	pigeonwood	1	0.0125	125	8	0.1	1000	6	0.15	1500
MELRAM	mahoe	2	0.025	250	2	0.025	250	7	0.175	1750

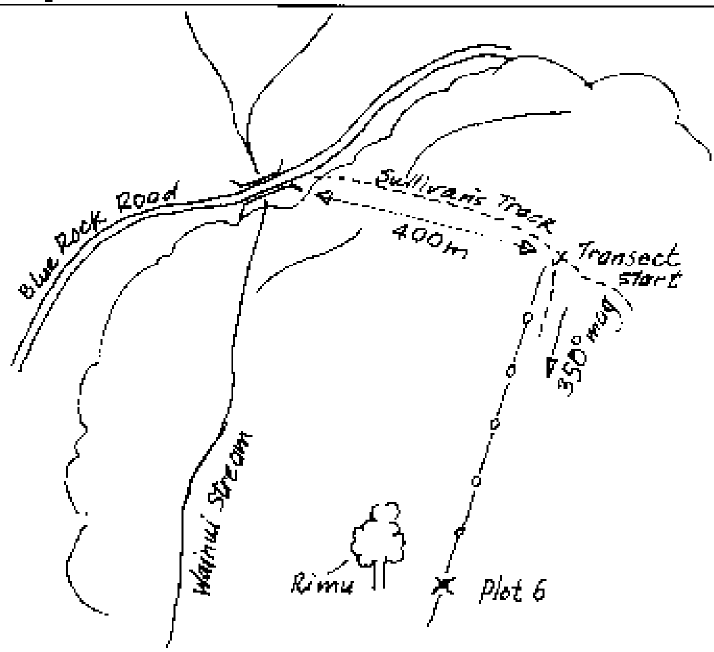
* no / 80, i.e number of stems divided by the plot area
** no X 10,000, i.e one hectare = 10,000m^2.
*** no / 40, i.e number of stems divided by the plot area.

QUICK PLOT

Location

Date: 18·11·99	**Plot no:** 6
Recorded by: John Hansen	**Measured by:** Duncan Jones
Location name: Blue Gully Reserve	**Grid reference:** R27 535 942

Location diagram/notes:



Approach: From the road walk up Sullivans Track for 400m to transect start. Transect runs on bearing of 350° magnetic. Plots are at 100m intervals along the transect. Plot 6 is 600m from the transect start and just above the large Rimu tree

Notes: Canopy is open in some areas around the plot.

Understorey quite dense compared to nearby areas

Site

Landscape: Face	**Aspect:** 160°	**Altitude:** 180m	**Drainage:** Good

Page 1 of 2

QUICK PLOT

Transect Widths (m)		
Trees	4	
Tree ferns	4	
Saplings	4	
Ground ferns	2	
Seedlings	2	

Note: If any widths are 2m or less, which side of the centre line (facing from start) was measured? Left/Right

Tree Stems and Epicormic Shoots

Species	Stem 1 Tag	Stem 1 DBH	Stem 2 Tag	Stem 2 DBH	Stem 3 Tag	Stem 3 DBH	Stem 4 Tag	Stem 4 DBH	Stem 5 Tag	Stem 5 DBH	Small-Med Epicormic (<1.35m)	Large Epicormic (>1.35m <3cm DBH)
MELRAM	1254	32·7*	1255	4·7*	1256	34·5					3	4
HEDARB	1257	23·2	—								—	3
BEITAW	1258	36·9									—	—

*note ⌒ = stems joined below 1·35m

Understorey

Species	Saplings (>1.35m <5cm DBH)	Seedlings (>0.45m <1.35m)	Tree Ferns (>1.35m) Distinct trunk	Ground Ferns (>45cm <1.35m distinct crowns, not layered)	Vines Occasional (O) Common (C) Abundant (A)
CYADEA			4		
ASPBUL				5	
CYASMI			7	7	
PSEAXI	5	1			
DICSQU			2	1	
ELADEN	1	2			
KNIEVC	3	8			
POLVES				3	
CARSER	2	2			
RIPSCA					O

Epiphytes – list all species present within the tree plot boundary.

COPGRA, WEIRAC, ASPBUL

Page 2 of 2

Blank copies of these forms can be obtained at www.fronz.net.nz or under SMF project 5073 at www.smf.govt.nz

20M X 20M PERMANENT VEGETATION PLOTS

Purpose

To monitor detailed changes in abundance, population structure and composition of forest vegetation. This is an overview only – see Allen 1993 for the full method.

Summary

Indicators
- Canopy condition (indirectly)
- Understorey abundance
- Species composition and diversity
- Abundance of indicator species
- Population structure

Skills
- Good plant identification knowledge

Time
- 3-6 hours per plot

Sampling
- Depends on features such as variability
- Needs to be determined when planning monitoring

Equipment and people
- 2 fieldworkers
- Map
- Aerial photograph
- Pencils
- Stem diameter sheet
- Understorey subplot sheet
- Clipboard
- Aluminium pegs
- 20m tapes (4)
- 20m nylon cords
- Diameter tape
- Plant identification books

Strengths
- Provides good data for examining long-term changes in forest
- Widely used, so comparative data, and experience available

Weaknesses
- Relatively time-consuming to establish. This can result in the number of plots established being small, giving less statistically reliable results
- Less cost effective for examining short-term changes in forest understorey

Introduction

This method has been widely used in New Zealand and produces fairly reliable results, particularly for tree stems. The full method is described in *A permanent plot method for monitoring changes in indigenous forests,* R B Allen, published by Landcare Research Ltd, Christchurch NZ, 1993 (Allen 1993). You will need this publication if you are going to use this method.

Sampling

The number of plots established will depend on aspects such as variability in the forest and the precision required (*see* 'Design monitoring …' p.88 and 'Sampling' p.95). Several plots will usually be required to provide useful information.

Method

Square 20m by 20m plots are laid out, and all tree stems tagged and measured. Various counts of understorey stems are also undertaken. The full method is provided in Allen 1993.

Records

Standard plot sheets provide hard copy records, in addition to maps and other information (*see* Allen 1993).

Analysis and presentation

Data can be used to examine a wide range of indicators such as plant abundance, composition, population structure and biomass.

Landcare Research NZ Ltd has several standard computer programmes for initial analysis of data.

RECCE – FOR VEGETATION DESCRIPTION

Purpose

To describe vegetation communities and examine differences in the composition and diversity of forest vegetation, often in relation to environmental differences between areas. This is an overview only – see Allen 1992 for the full method.

Summary

Indicators
- Species composition and diversity
- Relative abundance of indicator species

Skills
- Good plant identification knowledge

Time
- 0.5 hours-2 hours per description

Sampling
- Depends on features such as variability
- Needs to be determined when planning monitoring

Equipment and people
- 1-2 fieldworkers
- Map
- Aerial photograph
- Pencils
- Eraser
- Compass
- Altimeter
- Hand held level or other device to measure slope
- RECCE description sheet
- Soil probe (aluminium or steel stake)
- Clipboard
- Aluminium pegs
- Plastic bags (for plant specimens)
- Labels for specimens
- Plant identification books

Strengths
- Provides a relatively quick and consistent approach to describing vegetation
- Useful in analysis of vegetation composition and differences in composition between forest communities

Weaknesses
- Involves visual estimation of variables related to abundance, leading to differences between observers and surveys
- Not designed to pick up changes in abundance. Only very broad changes in communities can be detected.

Introduction

This method has been widely used in New Zealand. It has been used for purposes such as describing the species and communities present in particular reserves, and identifying differences in species composition between different forest communities.The full method is described in *RECCE – An Inventory Method for Describing New Zealand Vegetation*, R B Allen, published by Landcare Research Ltd, Christchurch NZ, 1992 (Allen 1992). You will need this publication if you are going to use this method.

Sampling

The approach to sampling and the locations where descriptions are undertaken will depend on the particular monitoring questions (*see* 'Design monitoring …' p.88 and 'Sampling' p.95). Designing ways to use the RECCE method is discussed in Allen 1992.

Method

A standard description sheet is filled in for a particular area. Plant species present in tiers from emergent trees down to the forest floor, are recorded. The abundance of species is estimated in percentage cover classes. A variety of other information such as soil depth is recorded. A full description of the method is provided in Allen 1992.

Records

Standard description sheets provide hard copy records, in addition to maps and other information (*see* Allen 1992).

Analysis and presentation

Species present and their relative abundance in different areas can be examined. Some computer programs can be used to group similar descriptions to identify forest communities.

Frequency of re-measurement

RECCE descriptions are often a one-off survey to describe vegetation.Any re-measurement to examine big changes in communities would need to occur over an extended period of years.

FOLIAR BROWSE INDEX FOR POSSUM-RELATED DAMAGE

Purpose

To assess aspects of the condition of individual tree canopies of certain indicator species that have been damaged by possums. This is an overview only – see Payton et al 1999 for the full method.

Summary

Indicators
- Canopy cover and condition
- Fruiting and flowering of key species
- Vegetation mortality

Skills
- Identification of all main tree species

Time
- 5-15 trees per hour

Sampling
- Depends on features such as variability
- Needs to be determined when planning monitoring
- About 50 individual trees of a particular species may need to be assessed to pick up useful changes

Equipment and people
- 2 fieldworkers
- Map
- Aerial photograph
- Pencils
- Eraser
- Compass
- Altimeter
- Binoculars
- Hand held level or other device to measure slope.
- Foliar browse index plot sheet.
- Clipboard
- Foliage cover scale
- Indicator species assessment sheet
- Tape – 20m
- Nylon cord – 50m
- Numbered tree tags
- Nails – flathead, galvanised
- Hammer
- Flagging (permolat)

Strengths
- Focused directly on assessing aspects of forest condition likely to be impacted by possums
- Relatively straightforward method, requiring little equipment

Weaknesses
- All variables are estimated visually, resulting in relatively low levels of precision
- Variation between observers is large
- Method can be difficult in complex, multi-tiered forests, due to difficulty in observing trees

Introduction

This method has been used in New Zealand since about the mid 1990s to assess the impacts of possums on the forest canopy. The full method is described in *Foliar Browse Index: A Method for Monitoring Possum (Trichosurus vulpecula) Damage to Plant Species And Forest Communities,* Payton et al 1999. You will need this publication if you are going to use this method.

Sampling

The exact approach to sampling and the location of plots where trees are assessed by the Foliar Browse Index (FBI) will depend on the particular monitoring questions (*see* 'Design monitoring …' p.88 and 'Sampling' p.95). Sampling in relation to the FBI is discussed in Payton et al 1999. It is suggested that assessment of about 50 individuals of a particular species is likely to be required to detect changes of around 10 percent in estimated foliage cover. Assessing this number of trees of a particular species can be difficult in practice.

Method

The method involves visually assessing the following:

- Foliage cover
- Dieback
- Conspicuous recovery (regrowth after damage)
- Possum browsed leaves
- Possum use of the trunk or stem
- Presence or abundance of flowers or fruit

Each of these is estimated in abundance classes.The full method is described in Payton et al 1999.

Records

Standard Foliar Browse Index plot sheets provide hard copy records, in addition to any maps or other location information (*see* Payton et al 1999).

Analysis and presentation

Relative abundance of the different variables listed under the method above can be reported for different species. Changes between measurements in these different variables between assessments of the same trees can be examined.

Frequency of re-measurement

Trees are likely to be assessed every one to three years. Re-assessment should always take place at the same time of year because of seasonal changes.

EPICORMIC SHOOT COUNTS

Purpose

To monitor changes in the abundance of shoots from the trunk of particular tree species likely to be impacted by browsing animals.

Summary

Indicators
- Understorey abundance
- Abundance of indicator species

Skills
- Ability to identify key indicator tree species used
- Identification of animal browse on shoots

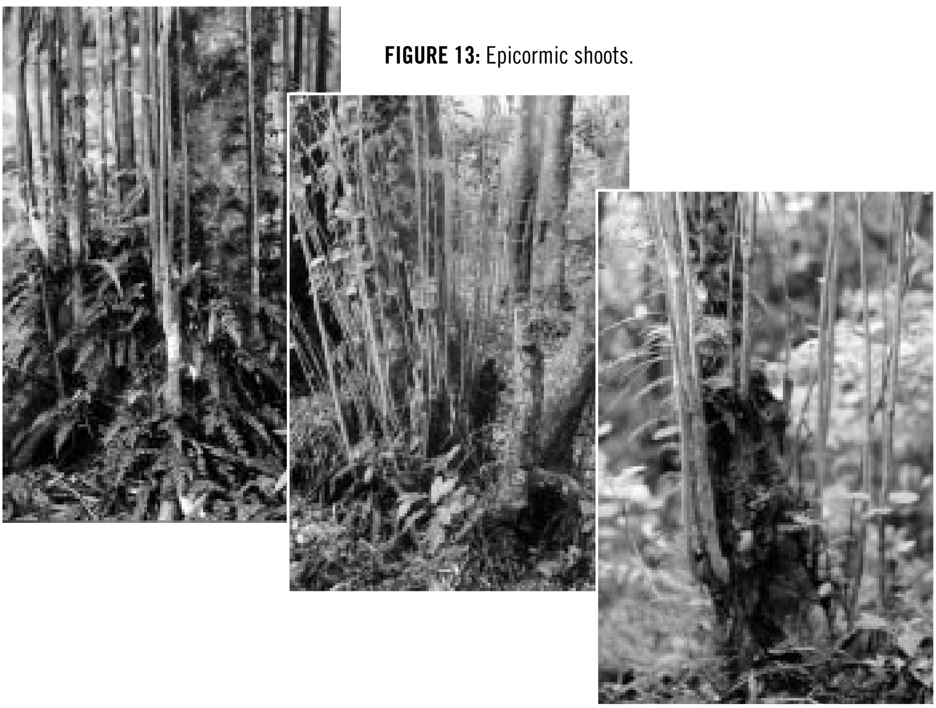
Time
- 10-20 trees / hour, depending on how common the target tree species is.

Sampling
- Depends on features such as variability, and tree density
- Needs to be determined when planning monitoring
- Likely to need around 20-50 trees of each species studied

Equipment and people
- 1-2 fieldworkers
- Map
- Aerial photograph
- Pencils
- Standard field sheet
- Clipboard
- Hip chain and cotton
- Aluminium tree tags (consecutively numbered)
- 5m nylon cord with a peg on one end
- Diameter tape

Strengths
- Easy to assess
- Potential rapid response on key species

Weaknesses
- Not widely trialled and used in NZ
- Only provides information on species that produce epicormic shoots



PHOTOS: PETER HANDFORD

FIGURE 13: Epicormic shoots.

Introduction

This method has not been widely used, but it offers considerable potential to pick up rapid changes on key species. Epicormic shoots are defined as shoots less than 3cm in diameter sprouting from below 1.35m in height on the trunk.These shoots grow from existing trees so they do not rely on a seed source, or good seed production and germination conditions to grow. They can respond rapidly over a year. Only certain tree species produce epicormic shoots. Some species producing epicormic shoots, such as kamahi (*Weinmannia racemosa*), pigeonwood (*Hedycarya arborea*), mahoe (*Melicytus ramiflorus*) and broadleaf (*Griselinia littoralis*), are also browsed heavily by deer and goats. Shoots from these species can respond quickly to a reduction in browsing.

Sampling

Transects are run out from a random or systematically selected start point (*see* 'How to select the sample', p.95) using a compass and a hip chain.

The number of transects established, and trees measured, will depend on aspects such as variability in the forest and the precision required (*see* 'Design monitoring …', p.88 and 'Sampling', p.95). It is likely that 20-50 trees of each species will need to be assessed.

Transects where these trees are assessed should cover the range of forest habitat in the area being studied.

Method

- From the transect start point, walk along the transect line, looking for target tree species >=10 cm in diameter, within 5 m either side of the line.
- Check trees close to the 5m distance by pushing a peg into the ground on the transect line and running a 5m cord out at right angles to the line. If the cord reaches past the centre of the stem at ground level, then it is included.
- Measure the diameter at breast height of the tree stem. If the tree consists of multiple stems (*see* the definition in the Quick plot method … p.31), measure the diameter of each stem.
- Tag the stem by nailing a numbered aluminium tree marker tag to it. Trees should be numbered consecutively from the start of the transect. If a tree consists of multiple stems, tag the largest stem.
- Count the number of shoots that sprout from the tree below 1.35m from the ground, and are less than 3cm in diameter (measured at 1.35m above ground level). The number of shoots are counted in three height classes, 0.15m-0.45m, 0.45m-1.35m, > 1.35m.
- Count the number of shoots in each class that have either fresh or old animal browse (*see* definitions below).
- Record the distance measured on the hip chain from the transect start to the point on the transect line adjacent to the tree.
- Once each tree is assessed, continue along the transect until the next tree within 5m is encountered, and repeat the assessment.

Definitions

- Epicormic shoot: A live shoot arising from the tree stem below 1.35m height, that is less than 3cm in diameter at a point 1.35m above the ground. The shoot length from where it arises from the stem to green tip must be greater than 0.15m (15cm). Note that if the shoot is dead from its base to tip, it is not recorded.

- Dealing with forked shoots: Epicormic shoots may often fork to form a number of growing points. Only shoots that are separately attached to the tree stem, or fork from another shoot within 5 cm of the tree stem are counted as separate epicormic shoots.
- Shoots from multiple stem trees: Where a tree forks below 1.35 m to give two or more stems, the DBH (diameter at breast height – 1.35 m) is recorded for each stem, but they are identified as linked on the data sheet. Epicormic shoots are then counted as the total for the group of stems.
- Height measurement: Height is measured from ground level on the uphill side of the tree stem. This applies for all height measurement, such as measuring the height of shoots, or the height for diameter measurement. Shoot heights are measured from ground level to the highest live point on the shoot.
- Shoot height classes: The following classes are used.
  >0.15m and <= 0.45
  >0.45m and <=1.35m
  >1.35m and < 3.0 cm in diameter at 1.35m
- Animal browse: Browse damage to the leaves or shoot stem that is caused by vertebrate pests such as deer, goats or possum.

Records

- Maps, location data and descriptions for the transects.
- Location of trees along the transects.
- Standard field sheets provide hard copy records of assessments.

Analysis and presentation

Examine the number of shoots in each height class, and the number of browsed shoots in each height class.

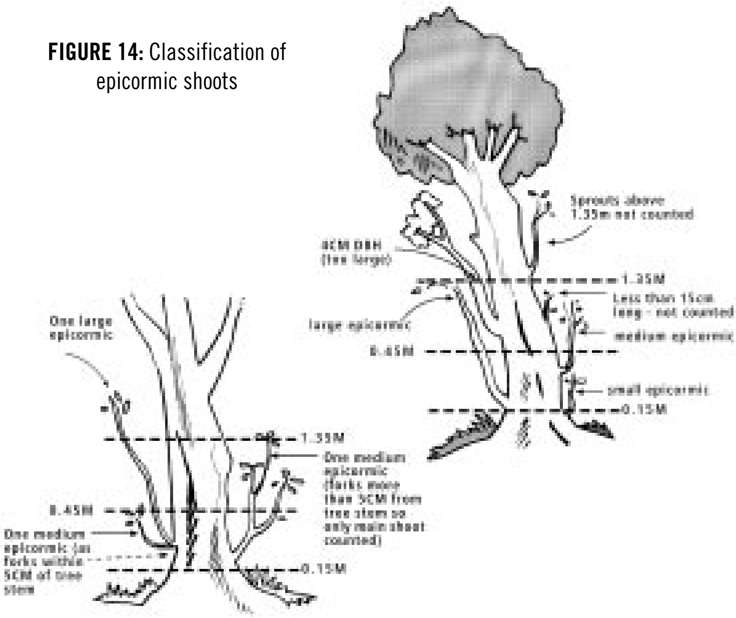
The mean number of shoots per tree in each height class and the mean number browsed can be examined.

Changes between assessments can be examined and tested for statistically significant difference.

Frequency of re-measurement

Trees are likely to be reassessed at one to two year intervals.

FIGURE 14: Classification of epicormic shoots



EPICORMIC SHOOTS

Location name: POROPORO Bush	**Date:** 17-2-00
Fieldworker names: John Hammond, Bill Syme	

Transect origin

Grid reference: S25 918 433	Bearing: 280°

Location diagram

Shoot counts

Species	Distance from start of transect (m)	Tree tag no.	DBH (cm)	Epicormic shoots (count the total number of all shoots in each size class)			Number of shoots with browse		
				Small epicormic (>15cm long, tip <45 cm from ground)	Medium epicormic (>15cm long, tip >45 cm & <1.35 m from ground)	Large epicormic (>15cm long, tip >1.35 m from ground and <3cm diameter at 1.35 m)	Record the number of browsed shoots in each size		
				No.	No.	No.	Sm	Med	Lge
MELRAM	10	1891	32.4	–	7	2	–	2	–
HEDARB	16	1892	20.5	–	–	2	–	–	–
WEIRAC	23	1893	46.2	5	8	–	3	5	–
MELRAM	28	1894	15.3	3	6	3	–	3	–
MELRAM	28	1895	32.7						
MELRAM	28	1896	21.3						
HEDARB	42	1897	15.6	–	–	–	–	–	–
WEIRAC	51	1898	35.1	–	–	–	–	–	–
MELRAM	64	1899	40.6	–	5	1	–	1	–
MELRAM	64	1900	18.3						
WEIRAC	80	1901	27.8	2	3	–	1	1	–
HEDARB	117	1902	15.9	–	–	–	–	–	–
HEDARB	127	1903	22.7						
MELRAM	152	1904	35.7	–	2	–	–	–	–

) = Stems joined

Shoots must be:

- >15 cm long from point attached to stem to end of live growing tip
- <3cm in diameter at breast height (1.35m above ground).
- Alive – dead shoots not counted
- Attached to stems 10cm or greater in diameter at breast height
- Either:
  - Separately attached to the main stem, or
  - Forking from another shoot less than 5 cm from its point of attachment to the main stem

Blank copies of these forms can be obtained at www.fronz.net.nz or under SMF project 5073 at www.smf.govt.nz

CYLINDER INTERCEPT ASSESSMENT OF FOREST STRUCTURE

Purpose

To assess the vertical structure of a forest and allow comparison of structural diversity.

Summary

Indicators
- Vertical vegetation structure
- Species diversity/composition (particularly of subcanopy and canopy layers)

Skills
- Ability to identify main plant species

Time
- 20-40 points per hour

Sampling
- Depends on feature such as variability and precision required
- Needs to be determined when planning monitoring
- Points can be combined with Quick plot, with assessment at 0m, 5m, 10m, 15m and 20m along the plot

Equipment and people
- 1-2 fieldworkers
- Topographical map
- Pencil and eraser
- Clipboard
- Instruction sheet
- Tape measure or hip chain for locating points.
- 2m height pole
- Field form
- Plastic bags and labels (to collect plant specimens for identification)
- Aluminium stakes and permolat (venetian blind) – if points are to be permanently marked
- Plant identification books

Strengths
- Can be done without special skills or equipment
- Provides information on forest structure and composition

Weaknesses
- Relies on visual assessments so measurement precision is not high
- Results are sometimes difficult to interpret

Introduction

This method provides a simple approach to achieve an indication of structural diversity. Other methods are available to provide greater detail (*see* 'Vertical and horizontal vegetation structure', p.121).

Assessment of structural diversity in this way may be useful for comparing the structural diversity of different forest areas on a broad scale. This method is unlikely to be useful in identifying changes in vertical structure occurring in the short term.

Sampling

Each individual point at which overhead vegetation structure is assessed forms a sample point. These sample points can be located in conjunction with a vegetation plot technique. The points can be easily undertaken in conjunction with the quick plot monitoring method, by assessing points at 0m, 5m, 10m, 15m and 20m marks along the plot.

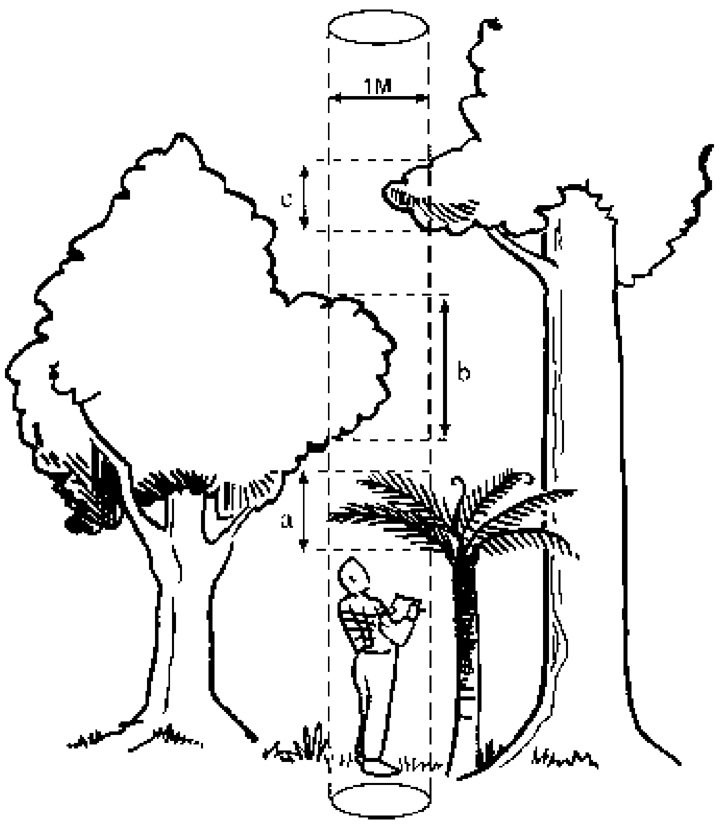
Measurement points may be located at fixed intervals along a survey line. For example, a line could be run out on a fixed bearing (*see* 'Sampling', p. 95), and the vertical structure assessed using this method at 5m or 10m intervals along the line.

The number of survey lines and points that are assessed will need to be determined depending on the precision you require and the amount of time you have. The points measured should cover the full variety of the forest area you are assessing.

Method

- Visualise a 1m diameter vertical cylinder, centred on the assessment point (*see* Figure 15).
- Identify each point at which a 'vegetation layer' intercepts the cylinder.
- Layers must be greater than 2m above ground.
- Vegetation includes any live plant material, for example, foliage, branch, stem.
- They must be from a separate plant, that is, the same individual plant cannot be counted more than once per point. Note that there may be more than one individual of the same species present so the same species may occur more than once at a point.
- Record the species and estimate the height of range of each 'layer'. Recording the lower height (H1) and the upper height (H2) in metres. Where a single branch enters the cylinder, H1 and H2 may be the same.
- If points are being permanently marked for future re-measurement. This can be done using an aluminium stake and 'permolat'.

FIGURE 15: Cylinder intercept assessment.



Records

An example of a format for recording cylinder intercept data is given on the cylinder intercept form on page 52. For each data point, ensure that the following is recorded:

- Header information, including:
  - ~ location: description, diagram, and grid reference
  - ~ date
  - ~ observer: record who was doing the assessment, and who recorded the information
- Species and estimated height (to nearest 0.5m) of each layer intercepting at the point in ascending order (*see* Figure 15).

Analysis and presentation

Depending on the monitoring question, information from this method can be analysed and presented in several ways, including:

- Structural diversity: This could be broadly examined by considering the number of plant intercepts recorded for each point. An area with a larger number of intercepts may have greater structural diversity. The presence of absence of intercepts within height classes can be considered. For example, examine the data for each point against the following sequence of height classes: 2m-5m, 5m-10m, 10m-15m, 15m-20m, 20m-25m, >25m. Identify the number of these height ranges that had vegetation present at each point. An area with intercepts present in a greater number of height classes may have greater structural diversity.
- Examine diversity in relation to the number or species detected at each point, and over the sample as a whole. The number of species within certain height ranges, as described in the above point, could also be examined.
- For a particular plant species, the number of points at which the species occurs can be examined.

Frequency of re-measurement

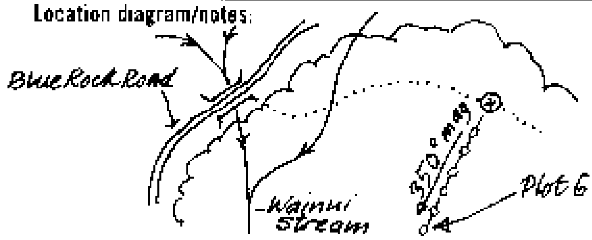
Changes in forest structure will normally only occur over a relatively long period. Depending on the objectives of monitoring, and the amount of change occurring, re-measurement every five to 10 years may be appropriate.

CYLINDER INTERCEPT – FOR FOREST STRUCTURE

Location

Date: 18-11-99	Plot no: 6
Recorded by: John Hansen	Measured by: Duncan Jones
Location name: Blue Gully Reserve	Grid reference: R 27 535 942

Location diagram/notes:



- Transect starts from 400m from start of Sullivans Track.
- Transect on bearing of 350°
- Plot 6, 600m along transect.
- Assessed at 5m intervals on 20m 'quick plot'

Site

Landscape: Face	Aspect: 160°	Altitude: 180m	Drainage: Good

Cylinder Intercept Assessments

Point	Species	H1	H2	Species	H1	H2	Species	H1	H2	Species	H1	H2	Species	H1	H2	Species	H1	H2	Species	H1	H2	Species	H1	H2
0m	CYADEA	3·5	4·0	MELRAM	7·0	9·0																		
5m	CYADEA	4·5	5·0	ELADEN	9·0	12·0	DACCUP	25·0	30·0															
10m	MELRAM	5·0	6·0	ELADEN	10·0	12·0	DACCUP	25·0	30·0															
15m	CYASM1	6·0	6·0	MELRAM	7·0	8·0																		
20m	CYADEA	3·5	4·0	ELADEN	6·5	7·5																		

H1 = lower height limit H2 = upper height limit

Notes

- Tree ferns throughout area.

Blank copies of these forms can be obtained at www.fronz.net.nz or under SMF project 5073 at www.smf.govt.nz

POINT INTERCEPT – FOR FOREST GROUND COVER ASSESSMENT

Purpose

To assess the proportion of the forest floor in classes of cover.

Summary

Indicators
- Ground cover

Skills
- Ability to identify main plant species

Time
- 100-200 points per hour

Sampling
- Each series of points assessed along a line forms an individual sample unit
- The number of lines in a sample depends on features such as variability and precision required
- Needs to be determined when planning monitoring
- Points can be combined with Quick plot, with assessment at 1m or 0.5m intervals along the plot

Equipment and people
- 1-2 fieldworkers
- Topographical map
- Pencil and eraser
- Instruction sheet
- Clipboard
- Tape measure for locating points
- Hip chain or long tape for locating plots
- Compass
- Field form
- Plastic bags and labels (to collect plant specimens for identification)
- Aluminium stakes and permolat (venetian blind) – if lines are being permanently marked
- Plant identification books

Strengths
- Simple to undertake without special skills or equipment
- Data is easy to interpret
- Quick and easy to measure

Weaknesses
- Only provides information on one indicator
- Considerable number of plots may be required to provide good results

Introduction

This method is used to assess the percentage of different types of ground cover on a forest floor. It may commonly be used in conjunction with the quick plot or other vegetation plot method.

Sampling

If your monitoring questions mean that you need to establish vegetation plots, establish point intercept measurements in conjunction with the quick plot or other vegetation plot. If it is undertaken in conjunction with the quick plot, point intercept can be assessed at 1m intervals along the 20m plot.

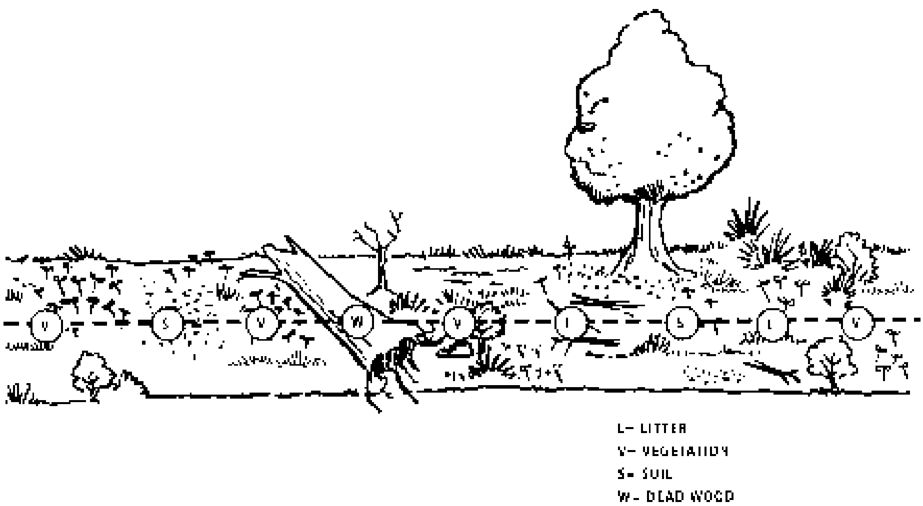
Point intercept can be assessed separately from other monitoring, at fixed intervals along a tape measure or other survey line. A 20m measuring tape can be run out, and then ground cover assessed at the point under each 1m interval of the tape. This series of point intercepts forms an individual sample. A number of these sample measurements are then undertaken through the area being assessed, up to the required sample size, for example, a sample of 20 lines might be assessed.

For information on identifying sample size, refer to 'What size sample?', p.98.

Method

- Run out a measuring tape on the set bearing. If used in conjunction with the quick plot, this tape will be 20m long.
- Record the ground cover, including low stature vegetation <15cm high, which is covered by the width of the tape at each metre mark using appropriate standard classifications, such as:
  - ~ *Vegetation (V):* Any vegetation less than 15cm in height other than moss or ferns. Includes woody seedlings, herbaceous vegetation, and grasses. It does not include live tree roots and trunks.
  - ~ *Root (T):* Live tree roots.
  - ~ *Moss (M)*
  - ~ *Fern (F):* Any ferns less than 15cm in height.
  - ~ *Leaf Litter (L):* Including dead sticks < 3cm in diameter.
  - ~ *Wood (W):* Dead wood, branches and logs, >= 3cm in diameter.
  - ~ *Soil (S):* Bare exposed soil where the litter layer has been removed.
  - ~ *Rock (R):* Exposed bare rock or gravel.
- Only one classification can be recorded at each point. *See* Figure 16 below.
- Where vegetation or fern is present, also record the species. If you are unable to identify the species, record it by type of vegetation, that is, grass, fern, woody seedling or herb.
- If the measurement plot is being permanently marked, aluminium pegs can be placed at 5m intervals along the tape. This allows the tape to be laid out in the same location for re-measurement.

FIGURE 16: Point intercept assessment undertaken at fixed intervals along a tape.



Records

An example of a format for recording point intercept field data is given on page 56. For each sample plot where point intercept data is collected, ensure that the following is recorded:

- Header information including:
  - ~ location: Description, diagram, and grid reference
  - ~ date
  - ~ observer: record who was doing the assessment, and who recorded the information
- The ground cover classification at each point
- Identification of each point, for example, its distance along a 20m measuring tape

Analysis and presentation

The percentage of ground cover in each of the ground cover classes for the study area is presented. This can be simply turned into a graph as a pie chart.

Changes in the proportion of ground cover in different classes can be examined. Differences between different areas can also be examined (*see* 'Examining difference' p.106).

Frequency of re-measurement

This will depend on the nature of the study, and the amount of change likely to be occurring. Re-measurement after two years may be appropriate where a moderate level of change is likely.

FIGURE 17: Tape on forest floor for point intercept assessment. The point in the middle of this photo would be classified as fern.

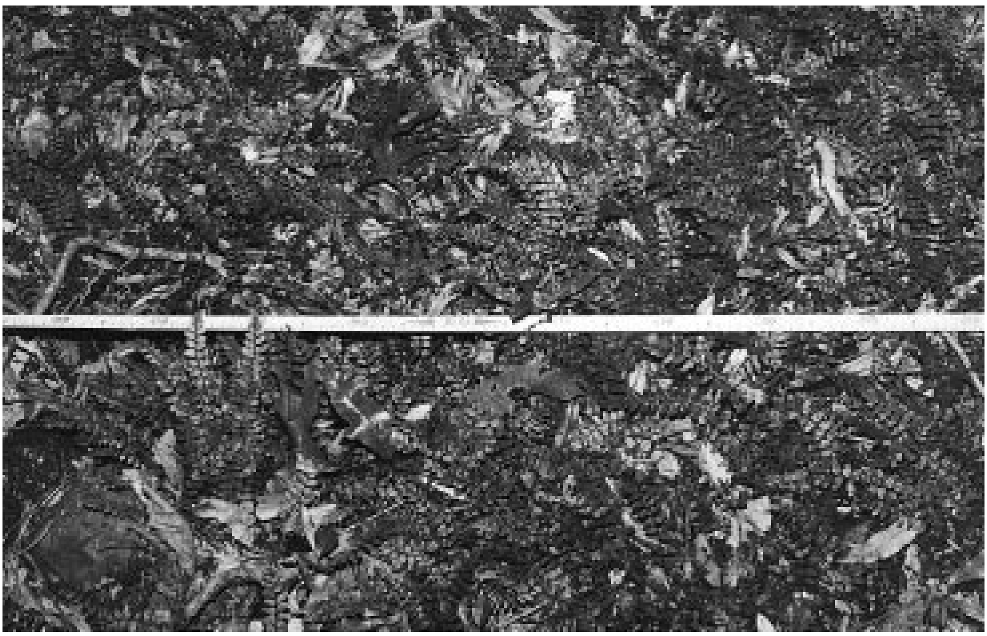


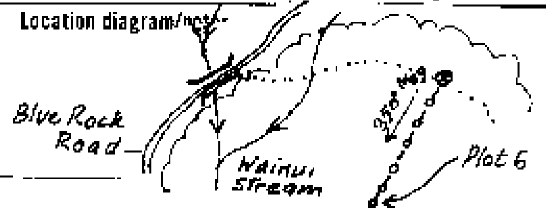
PHOTO: PETER HANDFORD

POINT INTERCEPT – FOR FOREST GROUND COVER

Location

Date: 18.11.99	Plot no: 6
Recorded by: John Hansen	Measured by: Duncan Jones
Location name: Blue Reserve Gully	Grid reference: R27 535 942

Location diagram/notes



- Transect starts 400m from the start of Sullivans Track.
- Transect on bearing of 350°
- Plot 6, 600m along transect
- Assessed along 20m Quickplot

Site

Landscape: Face	Aspect: 160°	Altitude: 180m	Drainage: Good

Point Intercept Assessments

Point (m)	Ground Cover Class	Plant Species (if ground cover is V or F)
0	L	
1	L	
2	L	
3	L	
4	L	
5	F	BLECHA
6	F	BLECHA
7	L	
8	L	
9	L	
10	R	
11	S	
12	L	
13	L	
14	L	
15	L	
16	L	
17	L	
18	L	
19	L	
20	L	

Notes

Generally thick litter under tree fern and kiekie. One deer track runs across area.

Ground Cover Classes

Fern (F): Any fern less than 15cm in height
Leaf Litter (L): Dead leaves and twigs, including branches up to 3cm in diameter
Moss (M)
Rock (R): Exposed bare rock or gravel
Root (T): Live tree roots
Soil (S): Bare, exposed soil, where the litter layer has been removed
Vegetation (V): Any vegetation, other than moss or ferns, less than 15 cm in height
Wood (W): Dead wood, branches and logs, >= 3 cm in diameter
Note: Only one classification can be recorded at each point.

Blank copies of these forms can be obtained at www.fronz.net.nz or under SMF project 5073 at www.smf.govt.nz

FLOWERING AND FRUITING OBSERVATION RECORD

Purpose

To provide records of the timing of fruiting and flowering of key species, and identify peak fruiting and flowering years.

Summary

Indicators
- Fruiting and flowering

Skills
- Ability to identify main plant species

Time
- Depends on size of area assessed

Sampling
- Can be assessed in relation to individual marked trees, or as the average of the fruiting or flowering present along a track or transect. Can also be assessed in this general way across a small reserve area
- The assessment should aim to cover a range of individual plants and trees of each species studied, which is likely to include the usual variation in the area
- Examine up to 10 key species. These species should be important, for example, major canopy trees, important source of bird food (*see* appendix 2) etc

Equipment and people
- 1 fieldworker
- Topographical map
- Aerial photograph
- Clipboard
- Instruction sheet
- Fruiting and flowering record form
- Camera and film for photographing levels of fruiting and flowering
- Numbered aluminium tree tags and permolat (venetian blind) – if individual trees are being permanently marked
- Plant identification books

Strengths
- Can be undertaken without special skills or equipment
- Provides useful information to examine relationships to other indicators.
- Gives a simple record

Weaknesses
- Estimating flowering and fruiting levels can be difficult
- Visual estimates are used so detailed comparisons of fruiting and flowering levels are difficult
- Needs ongoing commitment so regular records are kept

FIGURE 18: Records are kept of the timing and intensity of fruiting and flowering.

PHOTOS: DOC

PHOTO: PETER HANDFORD

Introduction

This method provides a standard form for keeping records of observations of fruiting and flowering for selected species. It identifies the timing of important events such as flowering and fruiting, and allows levels of flowering and fruiting to be compared between years.

There can be difficulties with observations of fruiting and flowering and other aspects of phenology (i.e the timing of various recurring plant growth phases). These should be considered before you undertake this type of study.

- Make sure you can clearly identify different stages, for example, flower buds, flowers, ripe and unripe fruit.
- Be aware that birds and animal pests can remove large quantities of fruit between observations. Record any signs of this occurring.
- As the abundance of flowering and fruiting varies greatly between years, take photographs that represent maximum abundance occurring that year. This helps you to identify high and low flowering and fruiting years.

Sampling

This record system can potentially be used in a variety of ways:

- Tagging of individual trees. Where a detailed study is being undertaken, records can be kept for individual marked trees.
- Assessment along a transect. This may be the same transect that was used to assess birds ('Forest bird slow walk transects'. p.68), or a track or walkway. Each month, fruiting and flowering of the species of interest along the 'transect' is assessed as the average of all the individuals present.
- General assessment of a forest area, for example, a reserve or park area. Again, a general monthly assessment of the area is undertaken in a similar way to that for the 'transect' approach.

Timing

A quick assessment of flowering, fruiting, and other growth phases should be recorded monthly, at a similar time each month.

Method

- Decide which of the sampling approaches above will be used. In many cases this will involve assessment along a transect or general assessment of a defined area.
- If individual tree results are being recorded, tag individual trees and record location details.
- For assessment of transects or area, define the location of the area assessed.
- Decide on the species to be monitored. These should be species that are:
  - Relatively important or common in the forest area, for example, an important canopy tree, or relatively abundant subcanopy tree or shrub.
  - Known to be sources of bird food (*see* appendix 3) in the area, and possibly important to pest animals.
  - Possibly important because of their limited numbers.
- Using the attached form, examine these species in the study area once a month, and record the following:
  - Date of assessment.
  - Species being assessed.

- ~ Relative abundance of the different phenology characteristics (*see* definitions below).
- ~ Notes: include any general observations on the level of fruiting, flowering, etc, presence of any birds or other animals feeding on flowers or fruit.

Definitions

Abundance

Record abundance in the classes given below: Take photographs of the levels of abundance you have assessed. Record the date of the photograph and the abundance category you assigned. This allows your records to be re-examined in future, and the abundance classes corrected if future levels suggest that you over or underestimated.

Abundance is recorded in the following categories:

Class		Description	% of canopy covered
0	None	None	0%
1	Rare	Few visible, often only in part of canopy	<5%
2	Occasional	Sparse throughout the canopy	5%-25%
3	Common	Common throughout the canopy	25%-50%
4	Abundant	Heavy and highly visible throughout the canopy	50%-75%
5	Very Abundant	Tree canopy covered in flowers or fruit, branches weighed down with an unusually large amount of fruit or flowers	75%-100%

Characteristics

The following characteristics and definitions are used:

- New leaf buds: green live buds that are not open.
- New leaves or shoots: expanding leaves or shoots that have not yet reached full size.
- Flower buds: unopened flower buds, including developing cones or ovules in the podocarps.
- Flowers: Open flowers or fully mature ovules and male cones.
- Immature/unripe fruit: Not yet mature, colour, etc.
- Ripe fruit: Fruit has reached full size, colour and ripeness.

Records

Records should be maintained and include the information in the following phenology observation field form.

Analysis and presentation

Records can be presented in various ways, including:

- Graphs showing the monthly abundance scores for different phenology characteristics , such as flowering and fruiting, for a particular species. This will identify the timing of stages such as fruiting or flowering.
- Annual summaries of abundance scores for a species. This will identify years of maximum or close to maximum abundance of flowering or fruiting for different species. For example, show the major fruiting years for kahikatea.

Frequency of re-measurement

Simple records such as this are most useful if kept as an ongoing monthly sequence.

FLOWERING, FRUITING & GENERAL PHENOLOGY RECORD: JANUARY – JUNE

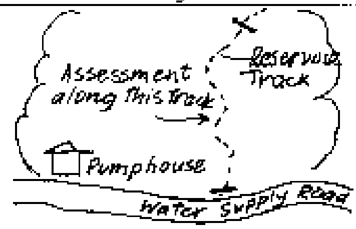
Year: 1999

Location name: RESERVOIR Track

Grid Reference: S25 045563

Species: 1 WEIRAC, 2 BEITAW

Locat on notes/diagram



Month		1 WEIRAC	2 BEITAW	3	4	5	6	7	8	9	10
Jan	New leaf buds	1	2								
	New leaves or shoots	2	3								
	Flower buds	0	1								
	Open flowers	1	2								
	Immature fruit	3	4								
	Mature/ripe fruit	2	2								

Date of check: 10.1.99
Fieldworker: Dave Wilson
Notes: Tawa has much green fruit.

Month		1	2	3	4	5	6	7	8	9	10
Feb	New leaf buds	1	2								
	New leaves or shoots	2	3								
	Flower buds	0	0								
	Open flowers	0	1								
	Immature fruit	3	3								
	Mature/ripe fruit	3	4								

Date of check: 12.2.99
Fieldworker: Dave Wilson
Notes: Tawa fruit becoming ripe.

Month		1	2	3	4	5	6	7	8	9	10
Mar	New leaf buds	1	1								
	New leaves or shoots	2	2								
	Flower buds	0	0								
	Open flowers	0	0								
	Immature fruit	1	2								
	Mature/ripe fruit	3	4								

Date of check: 15.3.99
Fieldworker: Sarah Wilson
Notes: Tawa fruit mostly ripe. Several Kereru feeding on fruit in the area.

Month		1	2	3	4	5	6	7	8	9	10
April	New leaf buds	0	0								
	New leaves or shoots	1	1								
	Flower buds	0	0								
	Open flowers	0	0								
	Immature fruit	0	0								
	Mature/ripe fruit	2	2								

Date of check: 9.4.99
Fieldworker: Dave Wilson
Notes:

Month		1	2	3	4	5	6	7	8	9	10
May	New leaf buds	0	0								
	New leaves or shoots	0	0								
	Flower buds	0	0								
	Open flowers	0	0								
	Immature fruit	0	0								
	Mature/ripe fruit	0	0								

Date of check: 7.5.99
Fieldworker: Dave Wilson
Notes: No new growth or flowers

Month		1	2	3	4	5	6	7	8	9	10
June	New leaf buds	0	0								
	New leaves or shoots	0	0								
	Flower buds	0	0								
	Open flowers	0	0								
	Immature fruit	0	0								
	Mature/ripe fruit	0	0								

Date of check: 11.6.99
Fieldworker: Dave Wilson
Notes: No new growth or flowers

Classes: 0=none, 1=rare, 2=occasional, 3=common, 4=abundant, 5=very abundant

Blank copies of these forms can be obtained at www.fronz.net.nz or under SMF project 5073 at www.smf.govt.nz

FLOWERING, FRUITING & GENERAL PHENOLOGY RECORD: JULY – DECEMBER

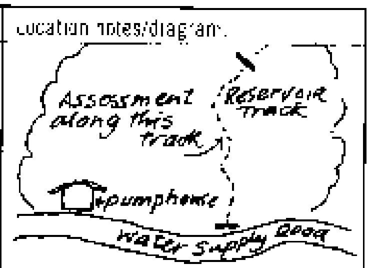
Year: 1999

Location name: Reservoir Track

Grid Reference: S25 045563

Species: 1 2 3 4 5 6 7 8 9 10

Location notes/diagram:



Month		1	2	3	4	5	6	7	8	9	10
July	New leaf buds	0	0								
	New leaves or shoots	0	0								
	Flower buds	0	0								
	Open flowers	0	0								
	Immature fruit	0	0								
	Mature/ripe fruit	0	0								

Date of check: 15·7·99
Fieldworker: Dave Wilson
Notes.

Month		1	2	3	4	5	6	7	8	9	10
Aug	New leaf buds	0	0								
	New leaves or shoots	0	0								
	Flower buds	0	0								
	Open flowers	0	0								
	Immature fruit	0	0								
	Mature/ripe fruit	0	0								

Date of check: 18-8-99
Fieldworker: Dave Wilson
Notes.

Month		1	2	3	4	5	6	7	8	9	10
Sept	New leaf buds	2	0								
	New leaves or shoots	0	2								
	Flower buds	0	1								
	Open flowers	0	0								
	Immature fruit	0	0								
	Mature/ripe fruit	0	0								

Date of check: 10-9-99
Fieldworker: Dave Wilson
Notes: Tawa leaf buds developing

Month		1	2	3	4	5	6	7	8	9	10
Oct	New leaf buds	3	0								
	New leaves or shoots	1	3								
	Flower buds	0	1								
	Open flowers	0	0								
	Immature fruit	0	1								
	Mature/ripe fruit	0	0								

Date of check: 10-10-99
Fieldworker: Dave Wilson
Notes:

Month		1	2	3	4	5	6	7	8	9	10
Nov	New leaf buds	3	3								
	New leaves or shoots	4	4								
	Flower buds	1	1								
	Open flowers	0	1								
	Immature fruit	0	1								
	Mature/ripe fruit	0	0								

Date of check: 15-11-99
Fieldworker: Dave Wilson
Notes: Very few flowers on tawa.

Month		1	2	3	4	5	6	7	8	9	10
Dec	New leaf buds	1	2								
	New leaves or shoots	3	3								
	Flower buds	1	1								
	Open flowers	2	2								
	Immature fruit	2	1								
	Mature/ripe fruit	1	0								

Date of check: 17·12·99
Fieldworker: Dave Wilson
Notes: Only small amounts of fruit on flowers on tawa

Classes 0=none, 1=rare, 2=occasional, 3=common, 4=abundant, 5=very abundant

Blank copies of these forms can be obtained at www.fronz.net.nz or under SMF project 5073 at www.smf.govt.nz

GROUND PLOT MONITORING OF SEED AND FRUIT-FALL

Purpose

To monitor annual fruit and seed production by key tree species and assess levels of damage to fallen fruit by predators.

Summary

Indicators
- Fruiting and flowering

Skills
- Ability to identify main plant species
- Ability to identify different types of animal damage

Time
- 1-3 trees per hour when establishing and measuring
- 2-6 trees per hour when re-measuring

Sampling
- The number of trees in a sample depends on features such as variability and precision required
- Needs to be determined when planning monitoring
- Trees need to be selected for examination throughout the area
- Initial results suggest assessment of 10- 20 trees may be enough in many cases

Equipment and people
- 1-2 fieldworkers
- Topographical map
- Aerial photograph
- Clipboard
- Instruction sheet
- Fruit-fall plot form
- Numbered aluminium tree tags and permolat (venetian blind) for marking trees
- Aluminium stakes and permolat (venetian blind) for marking plot centres
- Nylon cord with a loop on one end, and a knot 0.5m from the loop end
- Compass
- Tape measure for locating plots around the tree
- Long tape or hip chain for locating trees
- Random number tables (*see* appendix 6)
- Last year's location records (if re-measuring)
- Sorting tray (a plastic cutlery tray with different compartments is good)

Strengths
- Can be undertaken without special skills or equipment
- Provides a precise, objective measure of fruiting for key species
- Simple to assess and analyse
- Can provide information on fruit predation as well as level of fruiting

Weaknesses
- Care is required in classifying different types of damage to fruit
- Can be influenced by birds feeding on fruit

Introduction

This method sets out an approach to monitoring fruit-fall and predation of fruit for tree species with large edible fruits such as tawa and hinau.

Many native species vary in the amount of fruit they produce each year. Relationships between fruiting and the abundance of native bird species, browsers and predators have been found in some areas. This method allows simple quantitative monitoring of the level of fruiting, by counting fruit on the ground.

Sampling

- A sample of individual trees of the species is selected within the study area. This sample should include the range of tree sizes and growing sites present in the study area.
- Initial work suggests a minimum of 10 trees should be sampled.
- In small forest areas, where the numbers of the species are very limited, it may be appropriate to sample all trees, otherwise some form of sampling, as set out in 'Sampling', p.95, will be required.

Timing

- Measurement must occur at the end of the fruiting period. See appendix 4 for an indication of timing of the fruiting period, but you will need to identify the best time for your area.
- If it is your first year of measurement, ideally you should establish the measurement plots before the start of fruit-fall, and clear them of any old fruit or seeds present from the previous year. If this is not done, the first year's results may be inflated.
- For species such as tawa, where possums are eating the whole kernel before the fruit is ripe, and only leaving a thin husk, it is important to assess seed-fall twice in a season. One measurement should be made at the start of the period when ripe fruit is available, followed by another measurement at the end of the fruiting period. The data from the two measurements for each tree is added together to give the year's measurement.

Species

The following is a list of species suitable to assess using this monitoring method. The method may also be used to assess other species.

SPECIES KNOWN TO BE SUITABLE FOR ASSESSMENT			
Scientific name	**Common name**	**Approx fruit size (mm)**	**Ripe fruit colour**
Beilschmiedia tarairi	tarairi	20-30	Purple
Beilschmiedia tawa	tawa	20-30	Purple
Corynocarpus laevigatus	karaka	20-30	Orange
Elaeocarpus dentatus	hinau	10-15	Purple
Prumnopitys ferruginea	miro	15-20	Orange
OTHER SPECIES THAT MAY BE SUITABLE			
Scientific name	**Common name**	**Approx fruit size (mm)**	**Ripe fruit colour**
Nestegis lanceolata	white maire	10	Red
Vitex lucens	puriri	15-20	Red
Alectryon excelsus	titoki	10-15	Red
Dysoxylum spectabile	kohekohe	8-15	Orange
Hedycarya arborea	pigeonwood	10-15	Red

FIGURE 19: Searching plots for fruit.

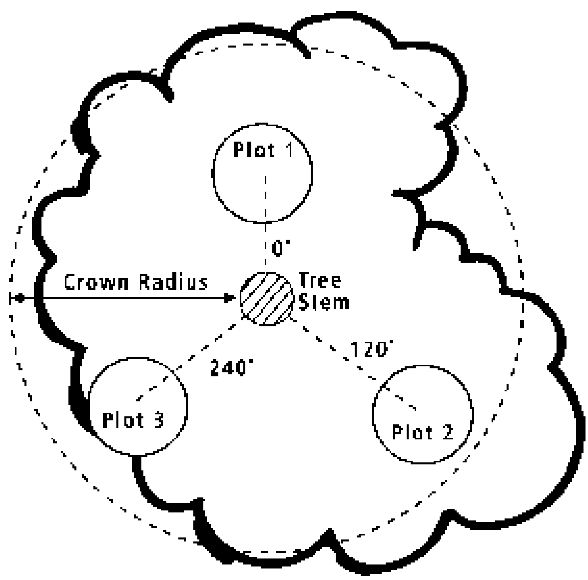
PHOTO: PETER HANDFORD

Method

Measurement

- Tag or uniquely identify each tree being assessed.
- Provide enough location information for each tree so someone else could easily locate it. This will include giving bearing and distance from easily identifiable points to each sample point. A good way to do this, if trees are not too distant from each other, is to locate the first tree using a bearing and distance from a known, well marked point, and then locate each subsequent tree by a bearing and distance from the previous one.
- Measure the diameter at breast height (1.35m).
- Measure the distance from the trunk to the dripline (outer limits of the tree crown). To do this, look up at the tree crown and stand at a position where you are on the average edge of the tree's live crown (*see* Figure 20). Measure the distance from that position to the outside of the tree stem.
- Use random-number tables in appendix 6 to select three, two-digit random distances between 0.5m and the outer limit of the crown. For example, if the distance to dripline was 3.0m, move along a line in the random number table, looking at each two digits and select the first three to be between 05 and 30. For example, moving along the first row of random numbers in the table of random numbers, the first three, two digit numbers between 05 and 30 are 30, 23, and 13. These equate to distances of 3.0 m, 2.3 m, and 1.3 m.
- Take bearings from the centre of the tree trunk at 0, 120, and 240 degrees (magnetic).
- Measure the random distance from the outer surface of the tree trunk on each of the three bearings and put a stake in the ground to mark each plot centre permanently. Number each plot from 1 to 3, with 1 being the plot at 0 degrees, 2=120 degrees, and 3=240 degrees (*see* Figure 20).

FIGURE 20: Layout of seed-fall plots under a tree. Distance from tree stem to each plot centre is selected from random number tables, but must be a number between 0.5 and the crown radius.



- If the plot centre falls on a tree trunk or a large log, select the next random number distance in the series that misses this obstruction.
- Count all fallen fruit of the tree species being monitored within a 0.5m radius of each plot centre.
  - ~ Search through fresh litter down to the top of the humus layer (*see* Figure 19).
  - ~ Count whole and damaged fruit.
  - ~ Do not count part fruit if it is less than half a full fruit (this avoids double counting the two halves).
- Classify each fruit into the fruit classes (defined below) on the attached field form. A plastic cutlery tray is useful so fruit classes can be sorted into the different compartments as they are collected.
- Place counted fruit well clear of the plot so it is not re-counted accidentally.
- Record all recognisable possum faecal pellets. If several pellets are clumped together in one group obviously deposited at the same time, record the whole group as one pellet.

Definitions

Fruit Classes

- *Immature:* Usually predominantly green, hard and not ripe.
- *Ripe:* Well coloured (for example, tawa = purple / black, hinau = purplish) and soft.
- *Withered/Dry:* Flesh has gone and husk is dry and brown/black.
- *Possum damaged:* Tawa = whole outer skin removed in large cuts leaving portions of the husk, or the whole husk with the centre cleanly scooped out.
- *Rat damaged:* Many ragged edges with signs of small teeth marks. Often part of the kernel remains. Rats tend to attack ripe fruit on the ground.
- *Insect damaged:* Generally one or more small entry holes about the size of a pencil lead. Normally only present in fully mature fruit that are starting to dry out or rot. Inner kernel is eaten out, commonly leaving just the husk, which when squeezed has nothing inside. Husk is full of frass (powdery or granular insect chewed material).
- *Rotten:* Mature fruit is soft and rotten when squeezed and does not contain any insect frass, or insect entry holes.

PHOTOS: PETER HANDFORD

Ripe, undamaged tawa fruit

Possum damaged tawa fruit

Rat damaged tawa fruit

Definitions for searching

- Fresh litter: This consists of all loose whole or largely intact leaves that have not significantly broken down. The layer is loose and can be relatively easily moved by picking up large pieces and moving the side of the hand lightly across the ground.
- Humus layer: A more compact dark layer under the litter with many well broken down plant fragments.

Records

- Maps and other location information identifying how to find the survey trees.
- Record details of the counts, as set out on attached form

Analysis and presentation

Information can include:

- Fruit density (fruit/m^2) for each tree and average for the sample in each year. The 0.5m radius plots give a search area of about 0.8m^2 each. Histograms can be provided for each tree and for the average of the whole sample. These can show the total seed-fall as the cumulative total of the different fruit classes. This can be used to identify higher and lower-than-usual fruiting years. It can also show differences in the impact of fruit predators between years and areas of forest.
- The percentage of fruit damaged by different predators from year to year to study the ongoing impact of different fruit predators.

Frequency of re-measurement

Measurement should occur every year at the same time, at the end of the fruiting season. Appendix 4 provides an indication of the fruiting seasons for some important species.

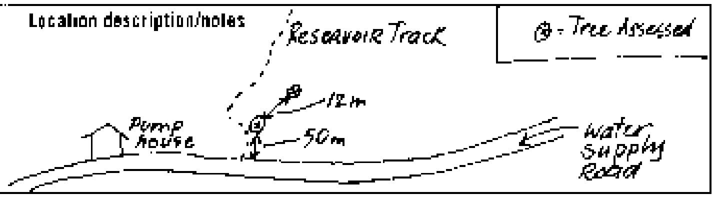
FRUITFALL PLOT FORM

Date: 10 - 5 - 99

Location name.
RESERVOIR TRACK

Grid reference: 525 045563

Location description/notes



Fieldworkers: John Symes, Sam Harvey

Tree Location	Tree ID No	Crown radius (m)	DBH (cm)	Plot	Bearing (magnetic)	Distance (m)	Immature: Whole	Immature Damaged: Possum	Rodent	Insect	Bird	Unidentified	Ripe: Whole	Ripe Damaged: Possum	Rodent	Insect	Bird	Unidentified	Withered / dry: Whole	Withered / dry Damaged: Possum	Rodent	Insect	Bird	Unidentified
BEI TAW Adjacent to track 50m from road	164	5.5	63.2	1	0	1.0	0	3	0	0	0	0	7	0	1	0	0	3	35	12	2	21	8	4
				2	120	3.7	1	2	0	0	0	0	3	0	2	0	0	1	16	8	1	6	1	2
				3	240	0.6	0	4	0	0	0	0	6	0	1	0	0	2	21	11	1	32	7	3
BEI TAW 12m on 200° mag from 164	165	5.0	83.0	1	0	1.4	0	0	0	0	0	0	2	0	0	0	0	0	5	8	0	2	0	0
				2	120	3.4	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
				3	240	4.7	0	0	0	0	0	0	1	0	0	0	0	0	4	0	0	1	0	0

Blank copies of these forms can be obtained at www.fronz.net.nz or under SMF project 5073 at www.smf.govt.nz

FOREST BIRD SLOW WALK TRANSECTS

Purpose

To assess relative abundance of different bird species.

Summary

Indicators
- Bird relative abundance
- Bird species composition & diversity

Skills
- Ability to identify bird species, both visually and from their calls. As a minimum, observers must be able to reliably identify the species they are intending to study
- Good hearing and eyesight

Time
- 1 hour per transect when establishing it for the first time
- 20 minutes per transect when re-measuring

Sampling
- The number of transects will depend on features such as variability and precision required
- Bird data commonly has a lot of variation, which can make it difficult to achieve good levels of precision
- Transects are assessed several (5-15) times at the same time each year

Equipment and people
- 1 fieldworker
- Topographical map
- Aerial photograph
- Clipboard
- Instruction sheet
- Bird transect form
- Binoculars
- 20m measuring tape (for measuring 10m from the transect – to calibrate your estimates)
- Hip chain or long measuring tape when setting up the transect for the first time
- Wristwatch to record start and finish times
- Aluminium permolat (venetian blind) for marking out the transect centre line
- Flagging tape to occasionally mark 10m distance either side of transect
- Hammer
- Nails
- Bird identification books.

Strengths
- A large proportion of birds can be identified by sight
- A fixed area is assessed, giving an indication of density

Weaknesses
- Has the usual bird assessment difficulties, resulting from variation in conspicuousness between species, time of day, and time of year
- Requires good bird knowledge

Introduction

This protocol provides a standard method for assessing bird presence and abundance along a walking transect.

Assessment of bird abundance can be difficult because observers need to be able to recognise different bird species by sight and from their calls. There is also seasonal variation in the amount of birdcalls and activity. All these need to be taken into account when designing monitoring of birds.

The method presented here is a reasonable compromise, balancing the level of skill required and the ability to provide an indication of abundance.

Sampling

As discussed above, seasonal fluctuations in bird records can occur. Birds may be active and vocal during the early breeding season, but be secretive during moulting. The abundance of a certain species in one area will vary greatly depending on the availability of seasonal food sources such as nectar and fruit from particular plant species.

Fluctuations during the day also occur – from peaks during early morning (dawn chorus) to much reduced activity in the heat of midday.

If longer term trends need to be examined, these fluctuations must be removed as much as possible through design of sampling. The following points should be considered:

Timing

- Most birds are most conspicuous from early September to late November. During these months, numbers are less likely to be influenced by new fledglings, which may not be a stable part of the population, so this is the best time to assess.
- Try to survey between flowering periods of key species, for example, in a northern coastal area after the kowhai has finished flowering but before the pohutukawa comes into flower. This will avoid you hitting a peak in numbers one year because of birds flocking to a food source, then missing it in another year. If you do strike a peak flowering period – record this and try to repeat conditions next time you measure.
- Undertake a series of measurements of the survey transects over perhaps a month, rather than intensively over a few days. This will help reduce the chance of short-term influences on numbers affecting the result.
- Do not assess the same transect twice in the same day because these assessments are not 'independent'. That is, the same birds may still be present at the same locations on the transect when it is quickly re-assessed. It is better to set up other transects than to re-measure the same transect again.
- Assess transects on calm fine days.
- Assess transects between one hour after dawn and midday.

Transect establishment

- Identify a site where a transect of about 500m in length can be run across an area. If there are many possible locations, see the sampling section ('Sampling', p.95) to decide how to select a location.
- Where multiple transects are being established, there should be sufficient separation between them. If transects are running approximately parallel, they should stay about 200m apart. However, it is acceptable for one transect to lead almost directly into another when they are running in the same direction, such as along a track or route.
- Ensure this transect is well marked so you can follow the same path each time and will be able to relocate it in subsequent years.
- Measure out the transect with a hip chain or measuring tape, and mark each 100m point.
- At occasional intervals, about 50m to 100m, where convenient, mark points that are 10m either side of the transect. This will ensure that observers are frequently able to calibrate their estimates of 10m from the transect.

Intensity

- The number of transects you establish will depend on sampling requirements (*see* 'Sampling', p.95), and on your resources. It is often better to have a small number (even one) of transects that you measure every year than many transects that are only very infrequently assessed.
- For each period of measurement – for example, each year, assess each transect five to 15 times. If you have a small number of transects, it will be important to assess them a greater number of times.
- For a more detailed discussion of sample size, see 'What size sample?', p.98.

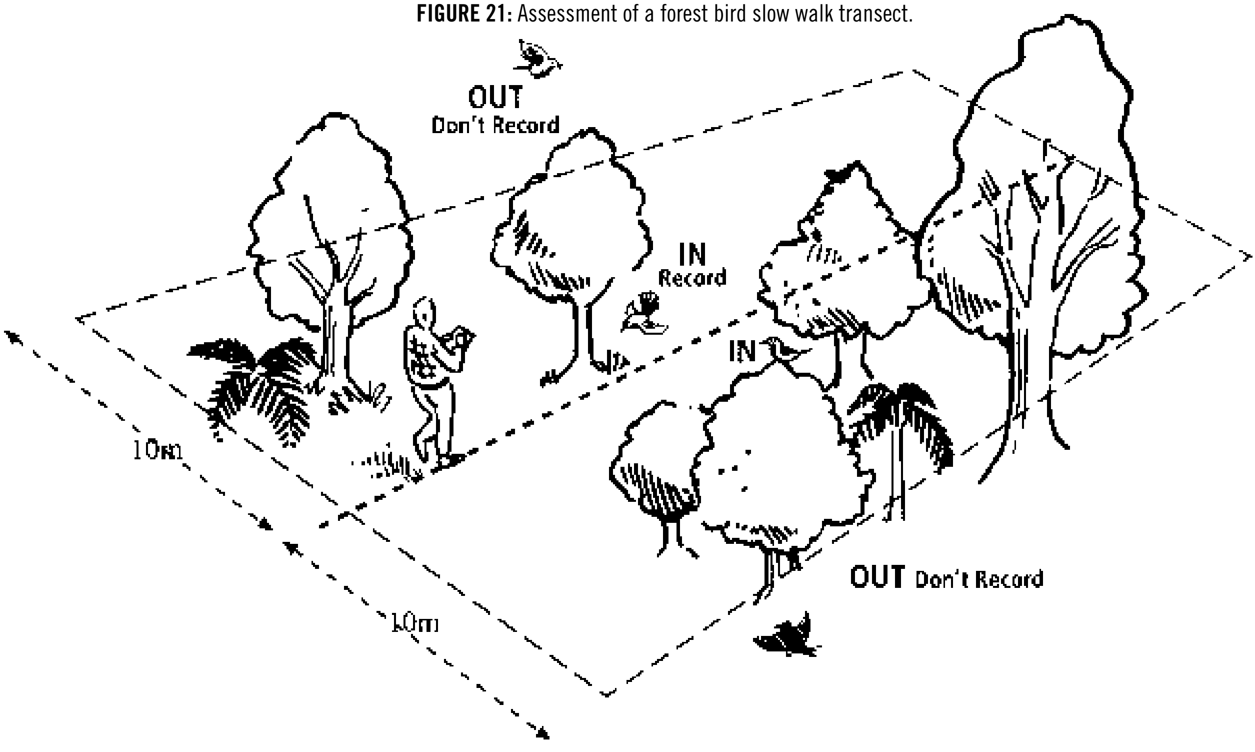
Method

- Walk slowly along the transect, recording all birds seen and heard within 10m either side of the transect on a 'moving front' as you travel along the transect (*see* Figure 21).
- Birds that are seen clearly to move into the transect area in front or behind you, within 20m of your current position, are included.
- It should take about 20 minutes to assess the transect.
- Use binoculars to identify birds if necessary.
- It is often most efficient to walk a transect in one direction, then reassess walking back along the transect so two assessments are obtained in the same visit. However, as discussed above, these assessments are not statistically independent. It is more beneficial to increase the number of transects by, for example, creating a loop containing several transects that can be measured consecutively.
- Record birds as seen or heard. If a bird is seen and heard – record it only as seen.
- Never knowingly record an individual bird more than once. For example, if a bird moves in and out of the transect a number of times, only record it once.
- If you are uncertain of identification of birds, concentrate on the species you can positively identify, and record descriptive notes about other species, for example: 'striped plumage, call: a repeat note trailing off at end'.
- It is often difficult to distinguish bellbird and tui calls. If you are uncertain record as bellbird/tui.

Records

- Record number of birds of each species seen or heard on the form shown on page 72.
- Record all additional climate and other information on the form.

FIGURE 21: Assessment of a forest bird slow walk transect.



Analysis and presentation

The following options are available:

- List the total number of species recorded.
- Plot mean total number of birds for each transect and combined transect data for each year. (*see* 'Data points and means, … ', p.104)
- Examine differences between mean totals for each year (*see* 'Comparison of datasets', p.105).
- Undertake the above two steps individually for the more common species.

Frequency of re-measurement

Transects should ideally be measured once a year, under the guidelines relating to timing discussed under sampling above.

BIRD TRANSECT RECORD

Location name: Reservoir Track	Grid reference: 525 045563	Date: 7-10-99	Fieldworker: Dave Wilson
Transect: 2	Start time: 0905	Finish time: 0925	

Species	Tally Seen*	Tally Heard*	Total Number
Grey Warbler	1		1
Silver Eye	8	2	10
Tomtit	1		1
Kereru	1		1
Rifleman		1	1
Fantail	2		2
Chaffinch		2	2
Blackbird		1	1

* if seen and heard, record it only as seen

Notes: (eg. uncommon species observed outside the transect)
Several black swans in reservoir lake

Temperature *(circle appropriate number)*

1 Freezing <0 C
2 Cold 0-5 C
3 Coo 5-11 C
4 Mild 11-16 C
5 Warm 16-22 C
6 Hot >22 C

Rain: Mist (M), Rain (R), Hail (H), Snow (S) *(Circle one – and grade on following scale)*

0 None
1 Dripping foliage
2 Drizzle
3 Light
4 Moderate *abandon assessment*
5 Heavy – *abandon assessment*

Wind *(circle appropriate number)*

0 Leaves still or move without noise (Beaufort 0 & 1)
1 Leaves rustle (Beaufort 2)
2 Leaves and branches in constant motion (Beaufort 3 & 4) – *abandon assessment*
3 Branches or trees sway (Beaufort 5, 6 & 7) – *abandon assessment*

Flowering, fruiting – *record details*

Plant species	Fruit or flowers	Rare, occasional, common, abundant, or very abundant	Notes

Blank copies of these forms can be obtained at www.fronz.net.nz or under SMF project 5073 at www.smf.govt.nz

WEED MAP MONITORING

Purpose

To examine and describe the distribution of particular weeds, and monitor changes in distribution.

Summary

Indicators
- Distribution of weeds

Skills
- Ability to identify important weed species

Time
- Depends on size of area assessed

Sampling
- For small areas, search the entire area
- In larger areas, or if resources are limited, concentrate effort where weed invasions are most likely (eg, edges of reserves, along roads and railways, along waterways)

Equipment and people
- 1-2 fieldworkers
- Topographical map
- Aerial photograph
- Pencil and eraser (including a Chinagraph pencil if marks need to be made directly on to an aerial photo)
- Clipboard
- Instruction sheet
- Pest plant infestation record.
- Camera and film for photographing infestations.
- Plastic bags and labels (to collect weed specimens for identification)
- Aluminium stakes and permolat (venetian blind) or other permanent marker pegs – if small areas of infestation are being permanently marked
- Weed identification references

Strengths
- Easy to understand
- Simple to undertake without special skills or equipment
- Can identify issues quickly – for management action

Weaknesses
- Comparing changes over time can be difficult due to differences in search intensity
- Use of visual estimates of abundance etc also makes precise monitoring of changes difficult

Introduction

Weeds are invasive species that threaten to spread through areas of native forest and potentially out-compete native plant species. Maintaining records of their distribution and picking up any new occurrences allow effective targeting of control.

This monitoring instruction presents a standard approach for recording the distribution and qualitative information on weeds, and for ensuring new weed sightings are recorded. Contact your local regional council and Department of Conservation experts for more information on weeds in your area.

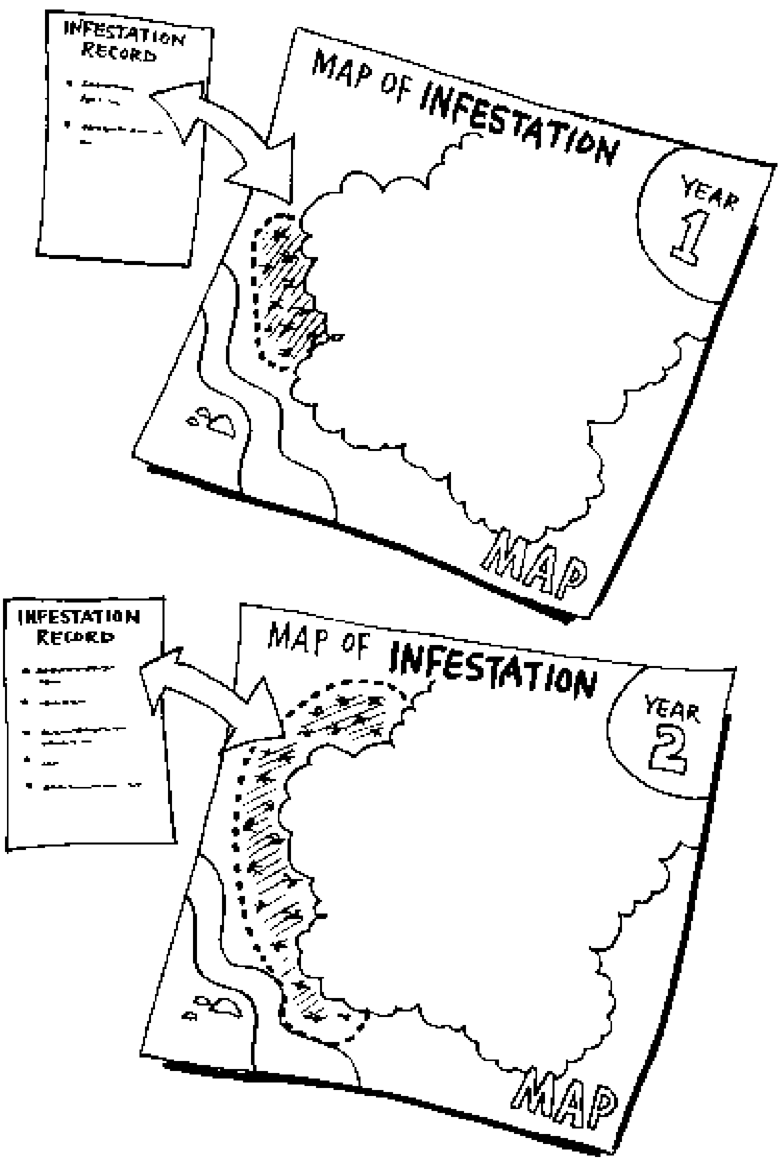
Sampling

Approach will depend on size and nature of forest area. In small forest reserves it may be possible to examine the whole area thoroughly. In large areas, when resources are limited, effort should be concentrated in the following ways:

- Focus on looking for weeds known to be the most significant, and potentially damaging. Information on the relative importance of weeds can be found in Owen (1997), and talk to experts.

- Focus on places where weed invasions are most likely (DOC 1999):
  - ~ The edges of reserves – particularly when near to settlement.
  - ~ Along roads and railways.
  - ~ Near any areas of rubbish dumping.
  - ~ Where there are areas of low or disturbed vegetation.
  - ~ Along waterways – rivers and streams, lakes and the coast.
  - ~ On slips or cliffs.
- Focus on areas that have a high conservation status or are potentially vulnerable to weed invasions.

FIGURE 22: Infestation is remapped to examine spread



Method

- If possible, obtain a large-scale aerial photograph of the area being examined at a scale of 1:10,000 or 1:5000.
- If this is not possible, a less accurate approach is to obtain a copy of a 1:50,000 map and enlarge it on a photocopier.
- Walk the boundary and any likely weed spread areas such as roads and riverbeds.
- Mark the general extent of different weed species on the photo or map.
- Fill out a "pest plant infestation record" for each distinct infestation. If a species is scattered around and through the whole area, just fill out one record per species. The infestation record notes the presence of mature and immature plants. This can provide early indications of whether the weed is spreading.
- Mark on the map the infestation identified in the infestation record form, if it relates to a distinct infestation, and cross-reference this to a number on the record.
- When undertaking surveillance, consider carrying a small grubber or similar to remove individual rare weed plants (after you have recorded them). Make brief notes on plants that are removed.

Records

Photo or map with details written on it and any associated key or explanation.
Plant pest infestation records (*see* form on page 76).

Analysis and presentation

The information collected can be presented in several ways:

- Basic summary information, giving the number of reserve areas containing particular weed species may be useful. Weed infestation information (such as size and distribution of the infestation) from the infestation record form can be presented in a table comparing the different reserves.
- Summary maps showing weed locations throughout the area.
- Visual comparisons of current and past distribution maps for a particular reserve to identify any spread.

Frequency of re-measurement

Areas with high conservation values and a high risk of weed spread or new places with introductions will need to be re-assessed most frequently. Weed species that have been recently introduced, or have potential to spread, will also need to be assessed most frequently.

PEST PLANT INFESTATION RECORD

Completed by: Sam Jones	**Date:** 17 – 2 – 2000
Location name: Scot's Creek Reserve	**Grid reference:** 525 062551

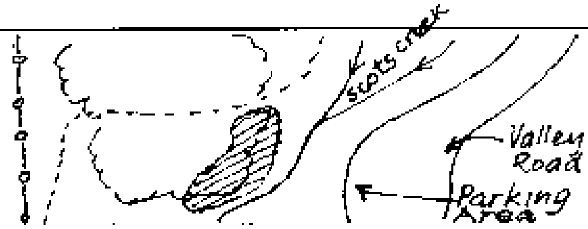
Pest Plant

Common name: Wandering Jew	Tentative name:
Scientific name: Tradescantia fluminensis	Sample taken:

Infestation

Description/Sketch of infestation location:

Adjacent to parking area beside Scots Creek



Vegetation description (predominant species in the area) Tawa, Kohekohe, Titoki

Feature	Rating estimate (Tick appropriate level or write estimate)	Notes
Size of infestation	Estimate size in m² or hectares 100 m²	
Distribution of infestation	1 ☑ One small patch 2 ☐ Locally scattered 3 ☐ Local patches 4 ☐ Scattered throughout 5 ☐ Patches throughout 6 ☐ Common throughout	
Adult/juvenile ratio	% Juvenile NA % Adult NA	
Presence of flowers seeds or propagules	Flowers ☐ Y ☑ N Seeds ☐ Y ☑ N Propagules (suckers, runners etc) ☑ Y ☐ N	
Access to the site	1 ☐ Difficult access, several kilometres from roads, no easy helicopter landing sites 2 ☐ Several kilometres to road, but good helicopter landing site 3 ☑ Short walk to road suitable for two-wheel drive 4 ☐ Vehicle access right to the site	Close to road, but must cross Scots Creek
Likely mechanism of arrival	1 ☐ Unknown 5 ☐ Carried downstream 2 ☐ Wind 6 ☐ Intentional introduction by humans 3 ☐ Birds 7 ☐ Accidental introduction by humans 4 ☑ Rubbish dumping 8 ☐ Other (specify in notes)	
Likelihood of spread	What is the likelihood the plant pest will spread: 1 ☐ None 2 ☐ Low 3 ☐ Moderate 4 ☑ High 5 ☐ Unknown	
Likelihood of re-invasion	What is the likelihood the plant pest will re-invade if removed 1 ☐ None 2 ☑ Low 3 ☐ Moderate 4 ☐ High 5 ☐ Unknown	chance of reintroduction by dumping

Notes: Possible Control, etc Control appears feasible if done now

Blank copies of these forms can be obtained at www.fronz.net.nz or under SMF project 5073 at www.smf.govt.nz

POSSUM PERCENTAGE TRAP CATCH

Purpose

To monitor changes in possum relative abundance. This is an overview only – see NPCA 2000 for the full method.

Summary

Indicators • Possum abundance **Skills** • Possum trapping experience **Time** • 2 – 4 hours/line to establish, much less to check **Sampling** • Sampling designs are provided in trap catch design protocol (NPCA 2000)	**Equipment and people** • 1-2 fieldworkers • Map – with line locations • Aerial photograph • Pencils • Eraser • Compass • Standard trap catch record sheets • Clipboard • Possum leg hold traps (Victor No 1 unpadded, or Bridger traps) • Staples • Wire • Hammer • Lure (*see* recipe below)

Strengths • Provides a relatively precise and consistent approach to assessing changes in possum populations • Is widely used and has published protocols • Considerable data is available for comparison	**Weaknesses** • Considerable work in establishing and running traplines • May not be a safe and acceptable monitoring method in and around urban areas • Can have impacts on non-target species

Introduction

This method is widely used in New Zealand to assess the effectiveness of possum control operations. It is the main form of monitoring the effectiveness of both aerial and ground control operations.A detailed specification for the method can be obtained from the National Possum Control Agencies (NPCA) PO Box 11461 Wellington, phone 04 499 7559.This is in three parts.

- The protocol for designers includes details about selecting the number of traplines to achieve a required level of precision, and issues such as stratification and line location.
- The protocol for planners includes details about planning the field operation.
- The protocol for field operatives covers specific trapline establishment and assessment requirements.

Sampling

The approach to sampling and the locations where descriptions are undertaken will depend on the particular monitoring questions (*see* 'Design monitoring … ', p.88 and 'Sampling', p.95). Detailed information on sampling design is provided in the NPCA protocol for designers.

The standard approach is to use lines of 20 traps spaced at 20m intervals. Samples of 10-15 lines are used in blocks of 500-2000 ha in size. In areas of less than 50ha, it is recommended that trapping be used as the control method.The level of kill is then assessed from the reduction in catch resulting from the control trapping.

Method

- Trapline starting points are randomly selected, and all traplines run out on the same bearing (often 0 degrees magnetic).
- The first trap is placed 20m from the starting point and, thereafter, traps are placed at 20m intervals.
- Victor No 1 unpadded traps or Bridger traps are used. If other makes of leg hold trap are used, they should be used consistently in all monitoring.
- The trap is set against the nearest tree or fence post that will hold a fence staple. Where species such as ponga are present that will not hold a staple, wire can be used to attach the trap.
- Traps are lured with a mixture of plain white flour and icing sugar (10kg flour to 2kg of icing sugar). No flavours are added. Lure is spread up the trunk behind the trap from 10cm to 50cm high.
- Traps are run for three fine nights, and must be checked every day.

Records

- Maps and location data for the traplines.
- Trap-catch monitoring protocols contain standard record sheets.
- The possums caught in each trap over the three nights are recorded. Their sex and maturity are recorded. Traps sprung and empty, or with evidence of a possum escape, are recorded. Non-target species caught are also recorded.

Analysis and presentation

The mean trap catch for each line is calculated over the three nights. The process for doing this and calculating percentage kill are in the NPCA protocol for designers.
The process is broadly:

1. For each line, calculate the total number of possums by adding the number of possums caught and the number of possum escapes.
2. For each line, calculate the number of trap-nights by removing one half trap-night for each non-target catch and sprung but empty trap.
3. Divide the total number of possums on each line (step 1) by the number of trap-nights on the line (step 2). This will give you the mean number of possums captured per trap-night.

Frequency of re-measurement

The same traplines are not usually assessed over time because the removal of possums by the traplines will impact on subsequent assessments. Instead different, randomly located lines are used in the same area when assessing change over time.

When assessing control operations, monitoring occurs immediately before, and immediately after the control operation.

Possums can often return to their pre control abundance in around four to six years after control. Frequency of re-measurement will depend on your monitoring objectives and questions.

TRACKING TUNNELS FOR RODENTS AND STOATS

Purpose

To assess the relative abundance of rodents and stoats.

Summary

Indicators
- Rodent abundance
- Stoat abundance

Skills
- Identification of different animal foot prints

Time
- 0.5 – 1 hr per line to check once established.

Sampling
- Depends on particular study design
- Needs to be determined when planning monitoring
- A monitoring design for large areas involves 10 tunnel lines in both the treatment and non-treatment areas; 10 tunnels on each line at 50m spacing

Equipment and people
- 1-2 fieldworkers
- Map
- Aerial photograph
- Pencils
- Eraser
- Standard forms or notebook
- Clipboard
- Tracking tunnels (*see* design below)
- Food colouring
- Small hand held garden sprayer for applying food colouring
- Tracking papers
- Peanut butter
- Hammer
- Flagging (permolat)

Strengths
- Does not directly influence the population, eg, by killing individuals
- Can deal with several species at once, eg, rats, mice and stoats
- Tracking papers can be retained for re-analysis
- Safe, harmless method – will not impact non-target species

Weaknesses
- It can be difficult to identify differences between footprints of similar sized animal species
- Requires construction of tracking tunnels (possibly around $5-$10 each)
- Considerable work can be involved installing and using tunnels
- Effective sampling unlikely to be possible in small forest areas

Introduction

This method has been used in a variety of scientific studies since the 1980s and is now being used more widely for general monitoring. A tracking tunnel is simply a run-through tunnel with a paper bed on each side of a central sponge which is soaked in food colouring. As an animal passes through, it picks up the food colouring on its feet and transfers it to the paper, leaving footprints. The paper can then be removed and the animal identified from its footprints.

Sampling

A suggested sampling design uses 10 lines of 10 tracking tunnels in the treatment area where you are applying some management or study and another 10 lines in the non-treatment area for comparison. The tracking tunnels should be spaced at 50m intervals along the lines for sampling rodents, or at 100m spacing for stoats. If lines are being used to assess stoat abundance, they need to be at least 1km apart.

The location of each line should be selected in some random or systematic way to minimise bias (*see* 'How to select the sample', p.95). The approach that is to be taken needs to be decided before you start setting out the lines, and then be used for all lines. One simple way of doing this is to identify on a map the start points at regular intervals along some easy access such as a track, the forest edge or river valley. The compass bearing on which the line will run is then selected by rolling a six-sided die, as follows.

Die Roll	Angle of tunnel line (magnetic)
1	285, or 105
2	315, or 135
3	345, or 165
4	15, or 195
5	45, or 225
6	75, or 255

Two bearings are possible for each die throw. If it is clear that only one of these is appropriate then this is selected. For example, one may head into open farmland from a forest edge, or across a river from the valley bottom, and not be suitable for measurement. If either bearing is possible, the die is rolled and if an even number is rolled, the first bearing is taken, if odd, the second.

PHOTO: T LILLEBY, DOC

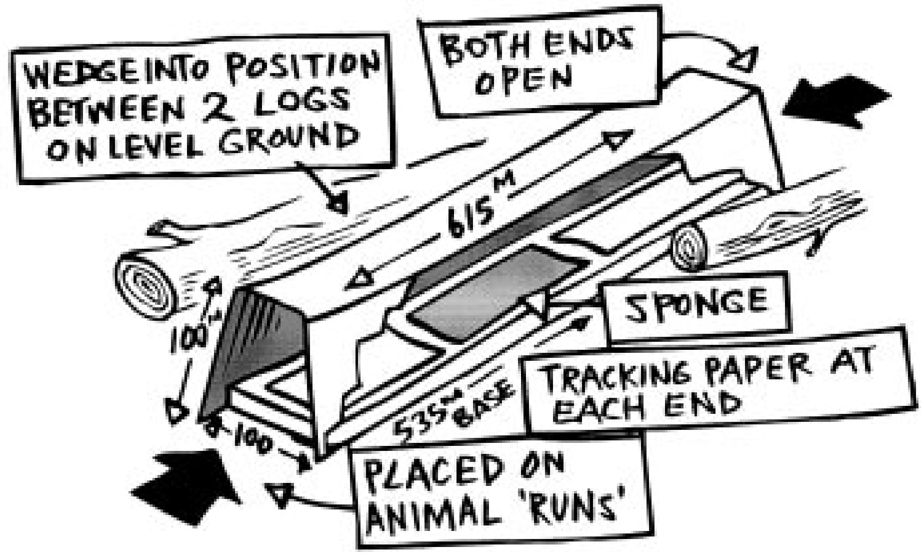
FIGURE 23: The presence of tracks of rats, stoats or mice is identified.

Method

- Each tunnel is set in the best practical spot within 5m of the planned location (for example, the 50m mark on the tunnel line). If there is an obvious place within this 5m radius, place the tunnel there.
- Tunnels should be set out level and secure, with both ends free of obstruction.
- Tunnels should ideally be set out for about three weeks before the first sampling and be left in place between samplings. This ensures animals are familiar with them, and less likely to avoid them.
- For rodents:
  - ~ Tunnels are run for one fine night.
  - ~ Each tunnel is baited with a small (1-2cm) blob of peanut butter smeared on the wooden base at each end of the tunnel.
  - ~ Fresh tracking papers are installed, and 'ink' applied to the sponge. The date, number of the tracking tunnel, and the direction of the closest tunnel entrance are marked, one for each tracking paper.
- For stoats:
  - ~ Bait each tunnel with a small (2-3 cm^3) chunk of skinned rabbit meat placed in the centre of the tracking sponge. Placing this on a 3cm x 3cm square of polythene keeps maggots out.
  - ~ Fresh tracking papers are installed, and 'ink' applied to the sponge. The date, number of the tracking tunnel, and the direction of the closest tunnel entrance are marked, one for each tracking paper.
  - ~ Once baited, tunnels are left for three fine nights before the tracking papers are collected.
- Combining rodent and stoat sampling.

  Install tunnels at 50m intervals as for rodents, and do the one-night rodent sample. Then clear the tunnels and in every second tunnel install new papers and re-bait for stoats. Tunnels are then left for the three-night stoat sample.

FIGURE 24: Tracking tunnel design



Tunnel construction details (*see* Figure 24 above)

- Wooden base of 25mm thick plywood or rough sawn pine. Base is 100mm wide x 535mm long.
- Black plastic 'corflute' cover, stapled or nailed to base. This should be 615mm long to allow for an overhang at each end of the wooden base. Internal clearance height in the tunnel should be 100mm.
- Polycarbonate tray (that slides in on the wooden base), 520mm long x 95mm wide. The tray has partitions, dividing it equally into three 173mm-long sections. These trays can be obtained from Jurgen Fielder Plastics (Rotorua), phone 07-347 5542.
- Papers and sponge fit into the partitioned areas of the polycarbonate tray, and are cut to fit the size of these sections. Papers should be sufficiently absorbent to retain the food colouring animal prints. Heavy brown wrapping paper, such as 110 g 'Sandow' wrapping paper, seems to work well.
- Tracking 'ink' is made of liquid food colouring at 1:4 dilution in water. If freezing may be a problem, use the food colouring without dilution. In extremely dry conditions, mix the food colouring and water with 20 percent polyethelene glycol. The tracking ink is best applied to sponges in the field using a small handheld garden sprayer bottle.

Records

- Maps, location data and descriptions for the tunnel lines and individual tunnels.
- Tracking papers for each tunnel should be stored with the data.
- Record of the date, species identified for each tracking tunnel, and people undertaking the fieldwork.

Analysis and presentation

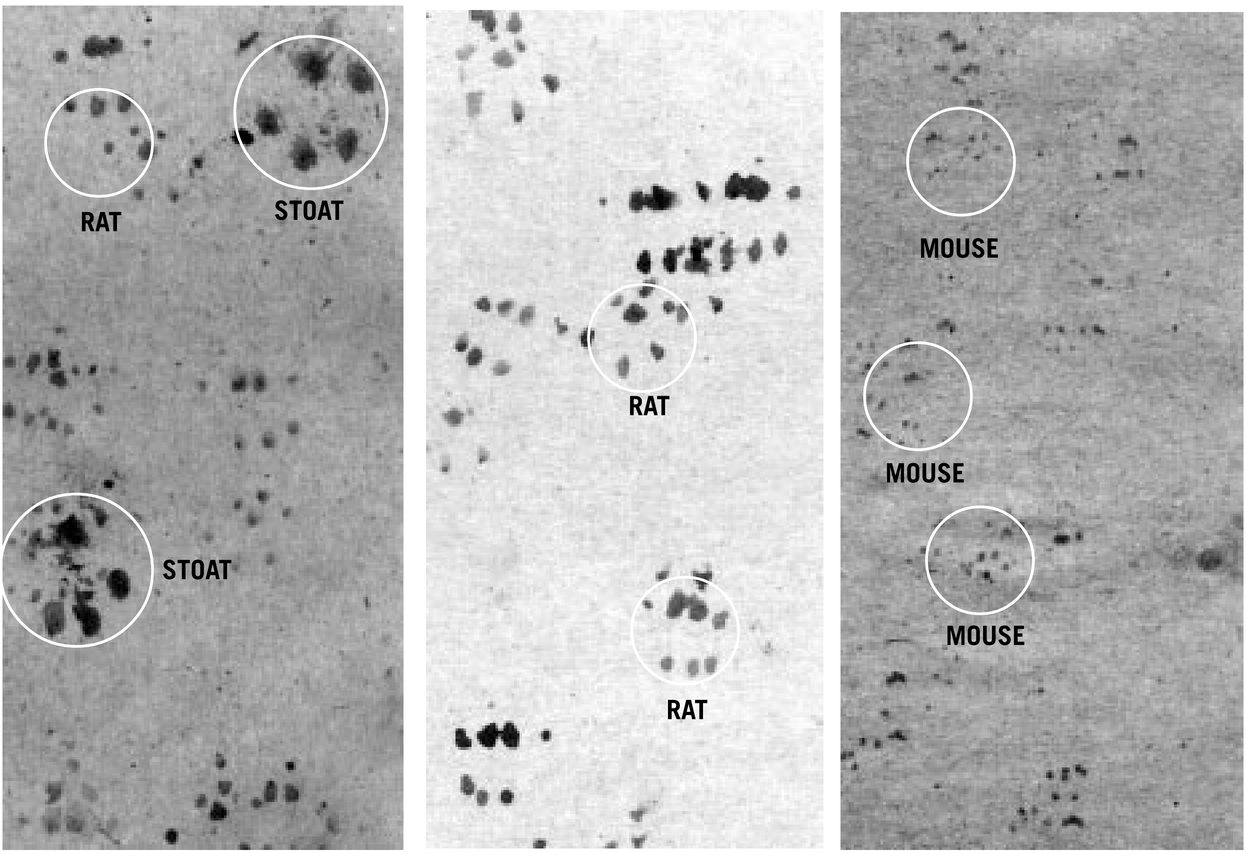
- The number of tunnels tracked by each species on each line is identified.
- If tunnels are badly disturbed (for example, by possums) and are unlikely to have been accessible to the target animals, they should be removed from the analysis.
- The mean percentage of tunnels tracked per line can be presented and changes examined over time.
- Statistical comparisons of change over time and differences between the treatment and non-treatment area can be undertaken.

Frequency of re-measurement

The abundance and habits of these animals change greatly through the year so tunnels need to be run several times a year.

As a minimum, tunnels should be sampled four times a year in February, May, August and November. If it is not possible to run tunnels more than once a year, great care is needed to run them at the same time of year when populations are at a similar stage of their annual cycle. Population levels are likely to be highest around February.

FIGURE 25: Animal tracks, left stoat and rat, centre rat, right mouse.



RALPH POWLESLAND, DOC

RODENT 'GNAW BLOCK' BAIT INTERFERENCE

Purpose

To assess the presence and relative abundance of different rodent species.

Summary

Indicators • Rodent abundance **Skills** • Identification of different animal gnaw marks **Time** • 1-2 hours / line **Sampling** • Depends on particular study design • Needs to be determined when planning monitoring • A common design involves five lines of 40 blocks at 10m intervals	**Equipment and people** • 1-2 fieldworkers • Map • Aerial photograph • Pencils • Eraser • Standard forms or notebook • Clipboard • Wax gnaw blocks (*see* recipe below) • Temporary flagging – tape • Hammer • Flagging (permolat)

Strengths • Does not directly influence the population, eg, by killing individuals • Can deal with rats and mice • Safe, harmless method – will not impact non-target species	**Weaknesses** • It can be difficult to identify differences between tooth marks of rats and mice • Some biases can occur due to animals visiting several baits or following lines of baits

Introduction

Various forms of this method have been used in several areas in New Zealand. It has been mainly used on rodent-free islands to detect re-infestation. It can also provide a simple indication of relative rodent numbers. However, there can be some complications due to rodents visiting several baits, and problems in remembering the location of baits.

Sampling

As with all sampling, consideration should be given to the particular monitoring questions, and the precision required (*see* 'Design monitoring … ' p.88 and 'Sampling' p.95).

A suggested sampling scenario involves:

- Lay 5-10 lines of 40 blocks, with blocks spaced at 10m intervals on the lines. Lines should ideally be at least 200m apart.
- Leave blocks out for two fine nights.
- Check blocks daily and replace any chewed blocks.

The location of each line should be selected in some random or systematic way to minimise bias (*see* 'How to select the sample?' p.95). The approach needs to be decided before setting out the lines so it can be used for all lines. A simple way of doing this is to identify on a map the start points at regular intervals along some easy access such as a track, the forest edge or river valley. The compass bearing on which the line will run is then selected by rolling a six-sided die, as follows:

Die Roll	Angle of Tunnel Line (magnetic)
1	285, or 105
2	315, or 135
3	345, or 165
4	15, or 195
5	45, or 225
6	75, or 255

Two bearings are possible for each die throw. If it is clear that only one of these is appropriate then this is selected. For example, one may head into open farmland from a forest edge, or across a river from the valley bottom, and not be suitable for measurement. If either bearing is possible, the die is rolled and if an even number is rolled, the first bearing is taken, if odd, the second.

Method

- Place the wax blocks at 10m intervals on the line. Temporarily flagging the location with marking tape is useful to allow relocation.
- Run the lines for two fine nights.
- Check the blocks daily and record all blocks that are chewed. Identify the toothmarks using the following guide:
  - ~ Possum – two grooves, each about 3mm wide.
  - ~ Rat – two grooves with a total width of about 3mm.
  - ~ Mouse – two grooves that fit into one rat groove.
- Replace chewed blocks with fresh blocks.

Making wax gnaw sticks/blocks

- Melt candle wax (paraffin wax) and add red food colouring and rose oil.
- Poor the wax mixture into iceblock trays, and add an iceblock stick to each one.
- The iceblock stick is pushed into the ground when laying out the gnaw blocks.

Records

- Maps, location data and descriptions for the lines.
- For each of the two nights, record which blocks were chewed or unchewed on the different lines.
- Record of the date, species identified for each chewed block, and the people undertaking the fieldwork.

Analysis and presentation

- The number of blocks chewed by each species on each line over the two nights is identified.
- The mean percentage of blocks chewed per 'block night' for each line can then be presented and changes examined over time.
- Statistical comparisons of change over time and differences between the treatment and non-treatment area can be undertaken.

Frequency of re-measurement

The abundance and habits of these animals change greatly through the year so, ideally, blocks should be laid out several times a year. Setting blocks on the same lines, four times a year in February, May, August and November is suggested.

If it is only possible to set blocks once a year this should be done at the same time of year when re-measuring. In this case, it is suggested that blocks are run in March when rodent numbers are likely to be close to their peak.

3. UNDERSTANDING NATIVE FOREST MONITORING

This part is recommended if you are planning and managing a monitoring programme. Topics covered are:

- Introduction to native forest monitoring
- Designing a monitoring programme
- Sampling
- Fieldwork
- Analysis
- Data storage

INTRODUCTION TO NATIVE FOREST MONITORING

Why monitor native forest ecosystems?

The condition of native forests is important because of their value to us. Native forests are reservoirs of plant and animal biodiversity, and they provide many other values such as the maintenance of high water quality, protection of soils from erosion, and a high quality visual landscape. They are also important to recreation and tourism.

Native forests and their components are continually changing and are exposed to threats such as browsing and predation by introduced animals, human development, and changes in climate. New Zealand native forests evolved without the presence of many of these threats, some of which have only been present for the past 100 years or less.

Without some form of monitoring, we have no idea of the condition of forest ecosystems. Ecosystems can become degraded, gradually or rapidly, before managers identify a need for action. Monitoring can identify if management is needed to prevent a decline in biodiversity. It can also show the impact of current management practices and justify continued action such as pest control.

Monitoring provides a means of targeting and justifying management to maintain forest ecosystems. It provides a 'feedback loop' between management and what is happening in the forest so management can be improved.

So what are we talking about?

Forest ecosystem condition is made up of many different parts, from the health of canopy trees to the presence of different bird species, weeds *or* pests (*see* Figure 1, page 10). Because of this, there is no single feature of a forest that we can measure to assess the forest's overall condition. For example, assessment of canopy trees may show they are in good condition while an examination of the understorey shows that browsing by animal pests has removed most seedlings.

Indicators are features or characteristics that we can measure to give an 'indication' of the condition of part of the forest ecosystem. There are many possible indicators, as set out in Part 4, including characteristics such as forest canopy cover or the abundance of certain indicator plant species.

Monitoring is the measurement of change in these indicators.

Monitoring can involve anything from keeping records of your visits and observations through to detailed assessments of bird populations.

There are different reasons to monitor, different indicators to monitor and different ways to monitor them.

DESIGNING A MONITORING PROGRAMME

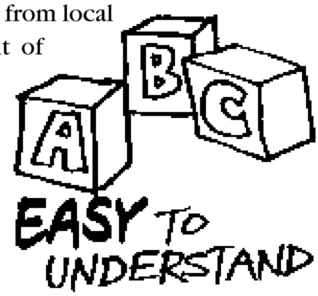
Introduction

Good design of a monitoring programme is essential. Poorly designed monitoring may provide a lot of expensive data that is of little use.

The best monitoring collects simple information to answer a clear and important question.

This part outlines the points that need to be considered in monitoring design. The flow chart in Figure 5, page 16 summarises the key steps in undertaking worthwhile monitoring.

Because of the variety of indigenous forest ecosystems and individual monitoring objectives, professional advice may be required to develop a monitoring programme that is practical, scientifically valid, and cost-effective. Advice can be obtained from local authorities, government departments (particularly the Department of Conservation), universities, ecological consultants and Crown Research Institutes.



Why do you want to monitor?

Before beginning monitoring, it should be possible to state, simply and clearly, why you are doing it. Time spent before you begin a project thinking about what you are trying to achieve will save time and money later.

There are commonly three broad objectives of monitoring (DOC 1999, Norton 1996, Ferris-Kaan & Patterson 1992).

- To keep a 'watching brief' on general forest condition – Generalist Surveillance Monitoring: This involves keeping an ongoing watch of a wide range of indicators to check if any immediate threats are present that require intervention to maintain forest condition. An example of generalist surveillance monitoring is the use of the checklist in the Monitoring Toolbox – *see* 'General surveillance checklist … ', p. 23-24.
- To keep a 'watching brief' on specific indicators – Specialist Surveillance Monitoring: This involves keeping an ongoing watch on a specific indicator or small group of indicators to examine changes in the ecosystem that may not be related to a specific management input. This may operate as an early warning system to measure against some threshold at which management is applied (*see* the specialist surveillance monitoring example below).
- To assess outcome or impact – Conservation Outcome Monitoring: To examine the outcome of a specific management input on some aspect of forest condition, for example, change in foliage density of northern rata in a possum control area, or change in abundance of palatable species in the understorey after deer or goat control.
- To assess management operations – Operational Monitoring: To measure the effect of a particular management operation on the part of the ecosystem it targeted. For example, the percentage of possums killed or percentage of weeds removed.

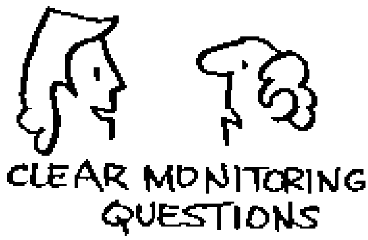
Examples

- Outcome Monitoring: A forest owner is about to undertake an intensive possum poisoning operation in a small forest area and wants to see what impact it will have on the condition of certain tree species that possums appear to have been damaging.
- Operational Monitoring : A forest manager is hiring a contractor to undertake an intensive operation to hunt goats in an area of forest. The manager wants to assess what reduction in the goat population the contractor will achieve.
- Specialist Surveillance Monitoring: A manager is looking after a reserve that is known to be home to a species of uncommon land snail. The manager wants to track the population over time so he can respond if numbers start to fall.
- Generalist Surveillance Monitoring A local authority officer is responsible for looking after many small reserve areas. The authority needs to keep an eye on the general condition of these reserves so it can respond to any threats to them . This is a situation where the use of a checksheet, such as the 'General Surveillance checklist … ', p. 23-24, could be useful.

What is the monitoring question?

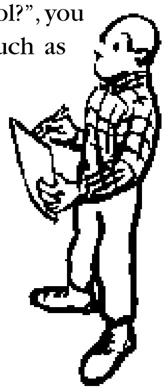
To design and set up useful monitoring, it is important to precisely define your monitoring question. For example, is the information you seek:

- A general indication of the key issues and management requirements for a forest area.
- Impact of possums.
- Impact of large pest animals – deer, goats, pigs.
- Changes in pest animal populations.
- Changes in weed populations.
- Impact of weeds.
- The forest understorey and regeneration.
- Condition of the forest canopy.
- Forest bird populations.
- Particular uncommon plant populations.
- Soil disturbance and erosion on the forest floor.
- Changes in abundance of insects.



Make sure your questions are simple and specific. Some examples of questions are provided in Tables 2 and 3 on page 91.

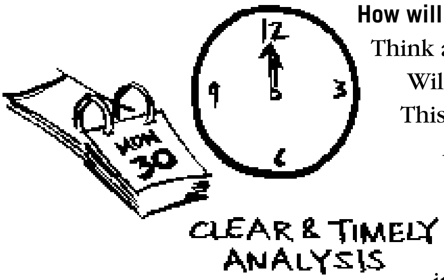
If you are not sure – do general surveillance first. If you don't have a specific monitoring question, such as: "How are seedling numbers changing following goat control?", you may be best to start with a general surveillance assessment of the area, such as outlined in the toolbox instruction – 'General surveillance checklist … ', p.23-24. This will help answer the general question: "Are there any immediate threats to forest condition that I need to act on?" It will also identify if there are issues developing that you need to monitor.



What will you do with the answer?

Once you have answered the question, what will this enable you to do? This is your reason for asking the question. It can range from:

- To provide a guide of management priorities, or
- To determine whether a particular management operation was successful and could be more widely applied (*see* examples in Table 2 on page 91).
- If you are not sure what you will do with the answer, you may not have asked the right question, or you may not need to do any monitoring.



How will you present the results?

Think about how you will need to present the results – keep it simple! Will you need to provide a detailed analysis or just notes on key issues? This will depend on the type of situation you are working in.

Are you keeping simple information for your own use or is it part of an examination of management that will provide public information, or justify expenditure?

Try to think of the simplest, clearest way to present the information, and in a way that will require the least amount of work.

Make sure you can clearly state to your peers the question you want answered, what you intend to do with the answer, and how you will present the results. See examples in Tables 2 and 3 on page 91.

What sort of difference needs to be detected?

Based on the question or questions developed, identify whether you need to pick up small differences over a short timeframe, or only relatively large differences over an extended timeframe. Identify the coarsest difference that will allow you to answer your question. The level of differences range from:

- *General identification of issues and threats:* You don't need to get involved in detailed monitoring now, but need to be able to identify any important threats or management issues facing the forest area. These can be addressed, or monitored in more detail later.
- *Large difference:* You only need to pick up large changes, such as a major decline in canopy condition over a 10-year period, or a large increase in seedlings in a reserve following fencing to remove stock.
- *Small difference:* You need to pick up small changes, such as a relatively small increase in seedling numbers in the forest understorey over a two-year period following a reduction in browsing animal numbers.

Design monitoring to answer the question

Initially, it is important to consider the general monitoring design in relation to the level of difference you need to detect:

General identification of issues and threats

If you are only interested in identifying key issues and threats from a generalist assessment of the forest area, detailed consideration of design is not warranted. An example of a generalist forest monitoring checklist is supplied in 'General surveillance checklist …', p.21. Broad monitoring of the distribution of pests such as weeds can be undertaken without detailed design. When undertaking these types of monitoring, refer to the monitoring instructions for general design (*see* 'General surveillance checklist … ', p.21 and 'Weed map monitoring, p.73).

Large difference

If you are only interested in large changes over a considerable time period, it may be possible to use less precise measurement methods, and/or smaller sample sizes (*see* 'What is precision', p.96). However, care is still required to make sure you can pick up differences at the level required. When picking up large changes, it may be possible to use unmarked sample points if the extra variation involved will not seriously affect the detection of change.

Small difference

If you need to be able to detect small differences or changes, extra care will be required in selecting measurement methods that are likely to have low measurement error, and big enough sample sizes to let you pick up these differences (*see* 'What sample size?', p.98). The use of permanently marked sample points is likely to be required to reduce variation (*see* '… in marked plots or individuals?', p.97).

What will you measure?

Select the right indicators to measure.

When selecting indicators, consider:

- *Is it relevant to your monitoring questions:* Will measuring it help you answer your monitoring question? For example, if you are interested in changes in the understorey following reduction in deer populations, you will need to measure indicators related to the understorey, rather than birds.
- *Is it likely to show change within a useful timeframe:* Is it an indicator that responds in the short term or longer term? Make sure this matches up with the time period over which you are examining changes, for example, change in new shoots of northern rata will be much more useful in the short term than a tree's diameter growth.
- *Is it able to be measured in a way that provides sufficient measurement precision:* An indicator that is difficult to measure precisely should not be used to examine small changes.
- *Are the skills and resources available to monitor it:* If you don't really understand an indicator, and don't feel confident to measure it, involve an expert, or look for other suitable indicators.
- *Is it easily understood:* Make sure that the indicator can be easily understood by everyone who sees the results of your monitoring.

Examples of monitoring questions and some relevant indicators are provided in table 3.

Select measurement methods

Many indicators can be measured by a wide range of different methods (*see* Part 4)

Identify potential measurements methods for the indicators that could give suitable levels of:

- *Measurement error:* Select measurements methods that will be precise enough to allow you to pick up the level of difference you want.

  Some measurement methods, such as visual assessment, potentially will have relatively large measurement errors. If the same assessment of, for example, percentage cover of seedlings is made several times, the measurements will be slightly different because people's visual estimates vary. Methods with large measurement error can make it harder to pick up small differences. Methods using tightly controlled measurements, such as counting of seedling stems in a vegetation plot, will have smaller measurement error and may be able to pick up smaller changes.

- *Skill requirement:* Make sure you have the skills to undertake the measurement methods. Some methods are suitable for people with a basic general knowledge of forest ecosystems, whereas others are better for people with specific technical skills. Don't select complex technical methods, such as assessing nesting survival of birds if you or others in your group don't have the skills to undertake them.
- *Resources:* Make sure you have adequate resources, such as equipment and people, for the methods you require. If a method is costly, make sure you are able sustain this cost in future when the monitoring needs to be repeated.

If monitoring is to compare two indicators such as canopy condition and possum abundance, try to ensure that the measurement methods used for these indicators will be able to provide a similar level of precision. Part 4 identifies a selection of measurement methods for different indicators.

Once measurement methods have been selected, make sure they have measurement instructions that accurately describe exactly what you will measure. Only measure the minimum necessary to answer your question.

Where and when will you measure?

Monitoring often needs to be designed to allow comparison of different sites, or of the same site over time, to look at differences and changes. Important points to remember are:

- *Consider the monitoring question.*
- *Understand the site:* It is essential to understand the site and its management history when designing your monitoring, including the selection of sites for study and comparison. Gather information on:
  - ~ *History:* What previous impacts have occurred, such as land clearance, logging, wind damage, and high browsing animal numbers. What management operations have taken place, for example, animal or plant pest control.
  - ~ *Previous monitoring:* Have there been any previous studies?
  - ~ *Local knowledge on issues and impacts:* What do local landowners, managers and others know about current and previous issues and impacts?
  - ~ *Studies and knowledge from similar areas:* Are there studies of similar areas or issues that help you?
  - ~ *Vegetation types, values, uncommon species, etc.:* What information is available on the location and extent of different forest types? Is there information on the presence of uncommon plant or animal species?
  - ~ *Visit, walk through the area:* For small areas of forest make sure you walk through the area and identify some of the important issues and impacts? The 'General surveillance checklist … ', p.23-24 can be used to gather this information.
- *Consider how you will examine change.* To examine change, you need to compare, and test for differences between different areas or times of measurement. A common way of doing this is through what is called a BACI – Before-After, Control-Impact design.

  This means that you design your monitoring so you are measuring before and after some impact, such as a possum poisoning operation, and that you measure both the area that has been impacted, for example, the poisoned area, and an area that has not been impacted (the 'control' area). This allows useful comparisons to be made to examine change.

  We can compare the changes that occurred on the impacted area with those on the non-impacted or 'control' area. For example, if there was a major response in the forest

TABLE 2: Examples of monitoring questions and how they might be used				
Question	**Use of Answer**	**Presentation**	**Difference necessary to detect**	**Measurement and Sample: Level of precision required**
What impact will reducing numbers of large browsing animals (deer, goats, pigs) have on the species they eat in the understorey?	The answer will be used to help confirm that money spent on control operations is justified.	Figures comparing changes in understorey plant measurements with changes in animal populations.	Small	High
What are the major differences between the understoreys of a reserve that has been fenced for several years and a forest area constantly browsed by stock?	The answer will be used to demonstrate the value of fencing forest remnants.	Simple bar charts comparing numbers of seedlings in the understorey, and photographs of the two areas.	Large	Moderate
Are there any obvious immediate threats to the health of various small forest areas that need to be dealt with?	The information will be used to identify any high priority management tasks for the areas.	Files of field sheets, and notes on particular areas will be sufficient.	General identification of issues and threats.	Low

TABLE 3: Examples of monitoring questions and useful indicators	
Question	**Possible indicators may include:**
What impact will reducing possum numbers have on species that possums eat in the forest canopy?	Canopy cover and condition, Species composition and diversity, abundance of indicator species, distribution of key species/uncommon species, fruiting and flowering of key species, possum abundance.
What impact will reducing the numbers of large browsing animals (deer, goats, pigs) have on species that they eat in the understorey?	Understorey abundance, vertical and horizontal vegetation structure, species composition and diversity, abundance of indicator species, abundance of large vertebrate pests.
What reduction in relative possum numbers will a proposed poisoning operation achieve?	Possum abundance.
How quickly is *Tradescantia* spreading into the reserve?	Weed distribution, weed abundance.
How is the spread of *Tradescantia* into the reserve affecting the forest understorey?	Understorey abundance, species composition and diversity, population structure, mortality, ground cover, weed distribution, weed abundance.
Do key canopy species appear to be regenerating?	Understorey abundance, abundance of indicator species, fruiting and flowering of key species, population structure.
Are there any obvious immediate threats to the ongoing health of my forest?	Quick examination of a wide range of indicators using a generalist monitoring checksheet.
Is the population of the rare plant *Pittosporum patulum* increasing of decreasing within the forest area?	Distribution of key species/uncommon species, population structure, mortality, fruiting and flowering of key species.
What is the current condition of the forest floor in streamside areas that may impact on water quality?	Ground cover, understorey abundance, large vertebrate pest abundance.

understorey following a poisoning operation, we would expect to *see* an increase in certain types of species when comparing the before and after measurements for the poisoned area. If this same change did not occur on the non-poisoned 'control' area, this would help confirm our conclusion.

To apply a BACI design, it is important to identify a suitable 'control' area that can be compared with the main area of interest. The two areas should be as similar as possible in terms of size, vegetation type and altitude.

Using marked or unmarked measurements

Decide whether marked or unmarked field measurements will be taken. Marked measurements involve randomly locating and marking individual plots, trees, etc so that the identical area can be re-measured. In the unmarked situation, plots or other measurement points are randomly located through an area, but are not marked. Re-measurement then requires another set of random measurements through the same area. The unmarked approach is often quicker and cheaper, but it should only be used where large changes are expected and a low level of precision is required (*see* '…unmarked survey comparisons?', p.97).

Appropriate sampling

Selection of appropriate sample size and the way you select a sample of measurements are important to getting useful monitoring results. 'Sampling', p.95 provides an explanation of sampling. You may need to refer to experts to develop an appropriate approach to sampling.

Can you afford the monitoring design you have chosen?

It is important to make sure the monitoring design is practical and affordable. It should take into account the amount of the money and other resources required for the monitoring to be carried out on a regular basis. If the monitoring design is outside your resources of money and time, you may need to:

- Find alternatives to the indicators, measurement methods, and sampling you have chosen that would be lower cost options.
- Reconsider the monitoring question you are asking and make it less ambitious.

Pilot trial of design

For a sizable monitoring project, always undertake a small amount of measurement first as a trial. The results can be examined and any design problems corrected before major effort is put into fieldwork.

An example of effective monitoring design

A small group of people has been involved in a ground-based poisoning operation in a reserve area. The operation has been running for 18 months, and the group is interested in undertaking some monitoring to see if they can identify any benefits to the forest from their efforts.

They realise that it is important to think carefully through the monitoring they are going to undertake. They decide the key thing they want to do is to examine the outcome of their poisoning operation on the condition of the forest. They believe the most direct way to do this is to measure any improvements in the condition of the large northern rata trees in the reserve and in the numbers of seedlings in the understorey which are likely to be eaten by possums. If they can show useful benefits of their control programme, it is likely they may be able to obtain funding for a control operation in another nearby reserve. This means they will need to show differences within a year or two, so they may need to have quite precise monitoring.

They talk to some experts about how they should set up the monitoring. It is decided to run parallel measurements in the reserve where they have controlled the possums and in the similar nearby reserve that has had no control. They will need to be careful comparing the reserves because there may be something other than just possums resulting in differences, but they will also be able to compare changes over time in the two reserves. They select a photographic monitoring technique for the rata trees that will allow them to pick up changes reliably, and a simplified system of small plots to measure the understorey. They work out the number of rata trees they will need to assess, and the number of understorey plots to measure to give them estimates that should be precise enough to pick up a difference of around 30 percent between measurements.

Before they start the fieldwork, protocols defining how the different measurements are to be taken are found. The group then goes over these in the field to make sure they all understand them. They also measure several understorey plots and use this data to make sure the method will work, and to see if their sample sizes are about right.

They take the field measurements, and check and file the data. They get some help with the analysis. This analysis shows higher seedling numbers in the reserve with possum control, compared with the reserve where there was no possum control, though the results for the rata do not show clear differences. Two years later, the same trees and plots are measured. The same people undertake the measurements, and they again first check that they understand the measurement protocols. This time the results again show a clear difference in the understoreys of the two areas. They also show that the numbers of species that possums eat have increased in the reserve where possums are controlled, but they appear to be the same or possibly declining in the uncontrolled area. Results for the northern rata show an increase in the foliage density of the rata trees in the reserve with possum control, and a slight decline in foliage density in the area without control.

These results are submitted to the funding agency, and a grant to undertake control in two more reserves is received.

In summary – some good aspects of their approach were:

- They carefully planned the monitoring and sought advice.
- They selected indicators that were relatively easy to measure and could pick up useful differences.
- They designed the monitoring so they could compare changes to those in other areas.
- They planned the sampling so they could pick up useful changes.
- They made sure the fieldwork was consistently undertaken, so re-measurements would be comparable.
- They got help with the analysis so results were effectively analysed and presented.

An example of insufficient monitoring design

Meanwhile, in a reserve in another part of the same district, another group has been undertaking some ground-based possum control operations. They are also interested in looking at any benefits to the forest reserve from their efforts.

They don't have a lot of time to look into monitoring. One member of the group suggests that looking at bird populations in the reserve would be interesting. They could also put some traplines through the reserve to see how many possums they get. This will give an idea of possum numbers in the reserve. Then if they do the same again next year, they can see if the number of birds has gone up and the number of possums has gone down.

One member of the group has done some bird monitoring in the past so they arrange to visit the reserve and record the birds they hear in five-minute counts at a number of points in the reserve. When they arrive at the reserve, it is a fine, still day, and there are lots of birds calling and flying about. They do as many counts as they can in a day.

Another member of the group has 40 possum traps, so they set them out on four lines through the reserve, at fixed intervals of 50m. They run the traps for three nights, but unfortunately the weather is cold and showery for the first two nights.

The following year, some members of the group have left the area. The person who did the bird monitoring is still around, but the group are busy at the time of year when the monitoring was done previously, so it is delayed until January. When they arrive at the reserve to do the bird monitoring, it is windy and during the day there are a couple of showers of rain. They start at a different end of the reserve, because the access is easier, so some of their listening points are in a new area. They have a feeling they may not have recorded as many birds as last year.

The person who did the traplines previously has left the area. However, there is an experienced possum trapper locally who can do the trapping. This person watches the weather forecast, and can see a fine spell of weather coming up so they take 40 traps to the reserve and lay them out. They are not sure where they were set last year so they move through the reserve setting the traps in places they know from experiences are likely to trap possums. Over the three nights, a number of possums are caught.

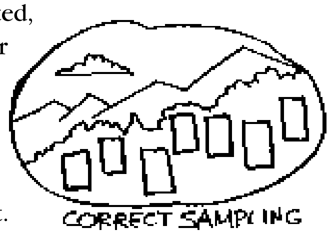
The group get together to look over the monitoring data to see what it shows. They have been working consistently on the possum control and feel there has been an improvement in the forest. When they look at the data, considerably less birds were recorded this year than last year, and more possums were caught in the traps this year. This seems to suggest that the situation is deteriorating, but they all feel this is not really the case. Disappointed by the fact the results don't appear to follow what is happening in the reserve, they start talking about what could have caused this. They agree that it appears there are some positive changes occurring in the reserve, particularly an increase in some species in the understorey. However, they have no monitoring data to show this.

In summary, some reasons they were left with unsatisfactory results were:

- They didn't spend enough time planning the best way to design the monitoring.
- They didn't select good indicators for their situation. The bird abundance indicator was probably not appropriate in this case. It is often difficult to assess and requires a lot of work to identify small differences.
- They didn't identify the appropriate level of sampling to be able to pick up useful differences. Numbers of traplines and bird assessments were based on 'gut feel' alone.
- They didn't undertake fieldwork in a consistent way – bird counts were at different times and in different places. Traplines were not measured consistently. This had a major impact on the results.

SAMPLING

When measuring forest indicators it is not usually possible to measure the entire forest canopy, count every bird, every understorey seedling, etc. Consequently, a small portion of the individuals in the whole forest that we are able to measure are selected, and these measurements are used to estimate the likely situation for the whole forest.



This process of selecting a small portion to measure is known as sampling and it is extremely important. If sampling is not well planned, you could end up just assessing an area beside the road that had many more possums and weeds than the rest of the forest. It would be completely wrong to conclude that the whole forest area had this same number of weeds and possums. Set out below are some fundamentals to apply when deciding how to sample.

How to select the sample?

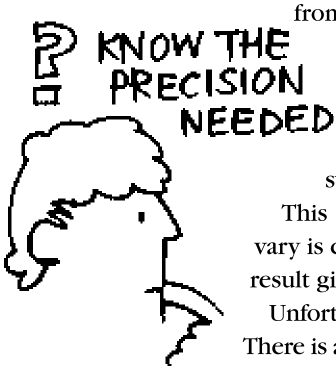
Bearing in mind the comments above, there are several ways of selecting samples. These methods and their merits are set out below.

- *Subjective – Generally the Worst – Least Reliable.* This involves just selecting plot locations, trap sites, etc using your judgment about what is representative of the greater area. This method should be avoided because the results cannot be reliably applied to the wider area. Bias is almost inevitable and is undetectable.
- *Random – The Best – But Practical Difficulties.* Under this method, sample points are located totally at random within the area being sampled. For example, if locating vegetation plots, a grid is placed over a map or photo, and random number tables are used to locate the points on the grid that will be sampled. This method is less commonly used in forest areas because it is more difficult and time consuming to locate the points in the field.
- *Systematic – OK – But Be Careful!* Sample points are laid out on a grid or transect lines across the area. This is probably the most commonly used form of sampling because it allows points to be relatively easily located in the field and allows more efficient movement between regularly spaced sampling points. It also has the advantage of ensuring that sample points are spread across an area. The biggest issue with this method is that the systematic layout may correspond with some feature, resulting in biased sampling. For example a grid is laid over a forested catchment to locate vegetation plots, but the size and orientation of the grid mean it lines up with the stream pattern and a large number of the plots end up in gullies.
- *Systematic random – Good – A Good Compromise.* The most common form of this approach is to locate randomly the starting point of a transect line. Plots or other measurement points, such as traps, are then systematically located at some set distance along this transect. This approach is used for possum percentage trap catch lines and tracking tunnels (*see* Monitoring Toolbox ,'Possum catch', p.77 and 'Tracking tunnels …', p.79), and often for locating permanent vegetation plots (*see* Allen, R.B 1993).

It is often important to stratify the area before applying one of the above sampling approaches (*see* 'Breaking areas into blocks …', p.97). Different areas such as different vegetation types, for example, tall podocarp hardwood forest and regenerating native scrubland, can be identified and sampled separately. This can help ensure that all the areas, forest types, etc you are interested in are sampled to allow later comparisons between areas. It also means differences associated with different forest types or areas can be separated out. This can prevent these differences obscuring changes resulting from some management input, such as a pest control.

What is precision?

As discussed, in almost all cases, it is necessary to use measurements from a sample to estimate the situation for the whole forest area. The estimate that you produce from measuring one sample will inevitably be different from that obtained from another similar sample from the same area.



It is important to understand how much the results from different samples might vary. This will identify how sure you are that an estimate actually represents what is going on in the whole forest area. For example, if two samples of the amount of foliage cover in an area give estimates that differ by 60 percent, you cannot be sure about the true situation for the whole forest.

This measurement of how much the results from different samples are likely to vary is called precision, and it identifies how much faith you can have that a sample result gives the true picture.

Unfortunately, it will often take more time, effort and money to get a precise estimate. There is a trade-off between cost/resources and precision. Decide at the planning stage what level of precision is required.

There are some important factors that determine the precision of a sample estimate:

- *Amount of natural variation in the population:* If the indicator being measured is variable through the population you are examining, this will result in lower precision. For example, if the density of seedlings varies greatly throughout the forest, then for a given size of sample, you will be less likely to get a precise estimate of the average density for the whole forest than you would if it were relatively uniform.

  If the natural variation is large, but related to some other characteristic, you can divide up the population, or 'stratify' it, in relation to that other characteristic to reduce variation (*see* 'Breaking areas into blocks … ', p.97). For example, if you look at areas with high and low deer numbers separately, the variation in seedling density within each area may be less.
- *Measurement error:* This can impact on precision by affecting the variability of the data collected. Variability can sometimes be reduced by increasing the accuracy of the way you take measurements. Certain measurement methods will be less accurate and introduce greater variation than others. For example, measuring foliage cover through image analysis of photographs will provide an estimate with less measurement error compared with visual estimation of foliage density. For a given sample size, the image analysis result will give a more precise estimate.
- *Sample size:* If you increase the number of individuals you select to measure, you will be more likely to get a better estimate of the actual situation, increasing precision (*see* 'What size sample?', p.98).

What is bias?

Bias occurs where measurement of a sample consistently gives an underestimate or overestimate of the true situation.

This can commonly occur due to poor sampling or location of measurement points in the field. There may be a tendency to locate plots in easily accessed areas, rather than random/ systematic locations. For example, if a field crew shifted plot locations away from areas of dense understorey into clearer areas to make measurement easier, the sample would be biased and tend to underestimate true understorey density.

Bias can also occur in measurement. This is most common when some form of subjective observation or assessment is involved because different observers can have a tendency to under or overestimate. For example, an observer may have a tendency to underestimate canopy cover.

Always try to identify if bias is present and remove it if possible. If bias cannot be removed, it should be recorded. If bias is known, it can be repeated in future measurements so it is consistent and true change can still be identified. In the above example, the same observer can be used to undertake estimates.

What is the advantage of re-measuring marked plots or individuals?

Often managers are interested in change occurring over time, either as part of ongoing surveillance of condition or to examine changes resulting from a specific management input such as an animal control operation. In these situations it is often best to establish marked measurement points, where possible, and re-measure them at regular intervals. Examples of this are marked vegetation plots, pellet survey lines, and individual seed-fall plots.

Permanently marking involves additional work in setting up the plot, but it has a big advantage in allowing paired comparisons between measurements. By re-measuring the same 'plot' in this way, it is possible just to examine change at each plot, and isolate this from the major variation that will occur between different measurement plots and different samples. If the natural variability between plots is large (which it often is), this results in a dramatic improvement in the precision of estimating change. This allows changes to be picked up that would not have been identified by comparing two different samples taken at different points in time.

When is it appropriate to use unmarked survey comparisons?

There is often considerably less effort if sample points do not need to be permanently marked and described. Situations where using unmarked sample points should be considered include:

- One-off comparison between different areas: Sometimes you may not be interested in changes over time, but just how one area compares with another, for example, a one-off comparison of the understorey condition may be undertaken between a fenced reserve area and an area of grazed forest, but there is no intention to continue to monitor the areas.

Think carefully in these situations because accurate re-measurement may be useful to track changes in future.

Breaking areas into blocks for sampling – stratification

Areas may be different

When you want to sample an area of forest for some indicator such as canopy condition, understorey condition, weeds, etc, you may already have an idea that certain areas are different. They may have, for example, a more wind-exposed and open canopy, higher weed densities, etc. In these situations, it is valuable to separate these areas as different blocks and sample them separately. This can improve the precision of overall results and also allow comparison between areas.

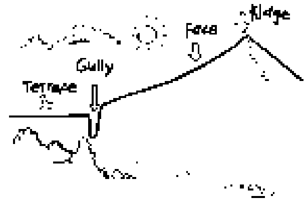
Always provide location information

Data should always be collected in a way that allows later stratification if necessary. The most obvious and important way to do this is to ensure that all data always contains accurate information on its location so that it can be accurately plotted on a suitable scale map. This allows potential comparison with other data that may be available or may become available in future – for example, environmental domains developed by Landcare NZ and the NZ Land Cover Data Base that identifies land cover from satellite imagery.

Consider using landscape and site type units

Classifying sample points in relation to landscape units is a common and useful method of stratifying an area. Identifying the site type of a sample point can provide valuable information for analysis and comparison of areas.

Commonly used landscape units include:



- ridge
- face
- gully
- terrace

Site types provide a further level of detail, and may identify site issues that are particularly important to your monitoring. For example, in a weed monitoring study, you may wish to identify sites close to residential areas or public roads. In forest monitoring, the level of disturbance, such as landslips or canopy gaps, occurring on the site is often important because it affects how much vegetation change can be expected, and also can make areas more prone to weed and pest animal impacts. Some useful site types to consider include:

- slip
- canopy gap

What size sample?

How large should each sample point be as opposed to how many?

When talking about sample size, there are generally two issues. First, how large should each sample point be and second, how many such sample points should there be? For example, if you are assessing the density of a tree weed species in a forest area, should you measure a lot of small plots or a smaller number of large plots? If you are examining ground cover should you examine a lot of small areas or fewer large areas?

There is no single answer to these questions. There will almost always be a trade-off between statistical requirements and the practicalities of carrying out fieldwork. In almost all cases (providing sample points are not unrealistically small), getting the best result statistically will require measuring the largest possible number of sample points. From a practical point of view, it may often be more efficient to measure a smaller number of large sample points because this can reduce the time travelling between sample points, and setting up any measurements. You need to consider these requirements and find a compromise that will give enough statistical precision and still be practical to measure with your resources. Doing some quick trials in the field is often necessary to find the best approach.

These issues are discussed in relation to plot size, in 'What plot size', p.99.

Determining the number of samples needed

Once you have decided how large the sample points will be, you need to determine how many you need. The steps in determining your sample size are:

- Identify the lowest level of precision you can live with: This will depend firstly on what level of precision is required. Do you need to be able to estimate the true mean within ± 5 percent to pick up a small change between measurements, or do you only want to pick up very broad changes such as a doubling of weed cover? (*see* 'What sort of difference needs to be detected?', p.88).

- Identify the likely sample variation that will occur:The second aspect influencing sample size is the amount of natural variation in the indicator you are sampling. If it is something uniform you will need less samples than if it is highly variable. Unless you already have some previous measurements, the best way to do this is measure a small number of sample points so you get an idea of the likely variation.
- Determine what size sample will be needed to estimate the true (population) situation to your level of precision. The best way to explain how to do this is with an example:

  A person involved in local authority monitoring for a weed control programme wants to identify if there have been improvements in the abundance of seedlings of canopy species in the understorey following the control of a ground-covering weed species. The local authority has decided it only needs to measure the density of canopy seedlings to within ± 15 percent of the true value.

  The person spends a day in the reserve to get some initial data, measuring the 12 plots given as an example in 'Data points and means, standard deviation and standard error', p.104. The measurements obtained and calculation of sample size are as follows:

  ~ Numbers of canopy seedlings in each of the 12 plots: 3, 9, 17, 10, 7, 5, 9, 10, 18, 14, 12, 6
  ~ Mean (p. 104) = 10
  ~ Variance (p. 105) = 21.27
  ~ Standard deviation (p. 104) = 4.61
  ~ Standard error of the mean (p.105) = 1.33
  ~ Requirement to achieve estimate to ± 15 percent of the mean, or 10 ± 1.5, at a 95 percent level of certainty

  A probability distribution, the students t distribution, provides information on how likely it is that the true estimate will be within a certain number of standard errors of the sample mean (Goulding & Lawrence 1992). As a general rule of thumb, if you are expecting to have a reasonable sized final sample of about 20 or more, you can use a t value of around 2. If sample size is more likely to be about 10, a t value of 2.3 should be used.

  To calculate the required sample size to achieve a suitable standard error so the true mean could be expected to be within the required precision of the sample mean, the following formula can be used:

  sample size = variance / (mean x precision / t value)^2

  In our example:

  Sample size = 21.27 / (10 x 0.15 / 2)^2
  = 21.27 / (0.75)^2
  = 37.81, ie, a sample of 38.

What plot size?

When planning sample plot measurements, such as with the use of vegetation plots, it is sometimes necessary to select the plot size that will be used. Some points to be considered in determining plot size are set out below.

- Plot size should not be changed within a sample strata (*see* 'Breaking into blocks…' p.97). Different plot sizes may be used in separate strata. A plot size should be selected and then used for all plots within a strata.
- The appropriate plot size will depend on density and what is specifically of interest. If presence/ absence is being examined to provide a frequency estimate, plot size should be big enough so that between 10 percent and 60 percent of plots sampled will contain the species, or group of species, that are of interest. When examining density, plots should ideally contain between 15 and 25 individuals of the species or group of interest.

- When assessing density, there is a trade-off between shorter time to measure smaller plots, meaning a greater number of plots can be measured to increase precision, and the likelihood of lower variation if larger plots are measured.

> *Plot size example (Goldilocks and the three plots)*
>
> **Too big**
>
> A 20m X 20m plot in an area of weeds had a large number of weed plants in it and took a long time to measure. Because of this, the field crew was only able to measure five plots. Four of these randomly located plots happened to be measured in areas of high density weeds, even though the reserve had only about half its area in high density weeds.
>
> **Too small**
>
> A 2m X 2m plot was measured in the same reserve. These plots were very quick to measure, and consequently, the field crew was able to measure 40 of them. However, these plots were very small so many fell in open space with no weeds, some fell in the middle of a weed patch, and some fell on the edge of a patch. This resulted in a large variation in the number of weed plants in each plot, meaning the statistical precision around the estimate was not good.
>
> **About right**
>
> A 4m x 20m plot was measured in the same reserve. These plots were quick to measure so the field crew was able to measure 15 plots. All the plots had some weeds in them, and represented a relatively even area of high density and low density weeds that gave an acceptable estimate of weed density.

Sampling different indicators on the same sites

As shown in Figure 1, page 10 the forest ecosystem involves a large number of interactions between its different parts. Sometimes, you may want to measure several of these different indicators and examine the relationships between them.

One way to do this is to concentrate on a variety of indicator measurements on one site. The site area is selected and then measurements are sampled within this area (*see* 'How to select the sample', p.95). This allows efficiency in measuring a range of indicators and also direct relationships between different indicators on the same site.

These indicator sites can be used to examine relationships between different indicators. However, the selection of the particular indicator site may be subjective, so results from these sites should not be used to make precise estimates outside the area. Before drawing conclusions on wider areas of forest, sampling across these areas will be required to check that estimates or relationships hold true.

A benefit of such indicator sites is that they potentially provide a relatively cost-effective way of monitoring to identify possible specific issues that can then be examined across wider areas. This allows wider monitoring to be specific and targeted – potentially reducing cost.

Links to other regional and national sampling sites

A well-designed monitoring system and associated sampling system can ensure that monitoring by individual managers is also potentially useful as a basis for regional or national monitoring of forest ecosystems. The following should be considered in making sure data is useful at this level:

- Use published indicators that are directly useful at a management level.
- Use indicators that other people are using (as long as they are useful to you) because this provides access to a bigger dataset.

- Use well-designed methods, ideally incorporating well-accepted measurement protocols, and effective sampling to give appropriate precision.
- Incorporate accurate location data of measurement points. This can be recorded as grid references on NZMS 260 series maps (1:50,000 scale), or captured using GPS equipment.
- Consider sampling in relation to nationally defined strata, including bioclimatic zones (for example, Environmental Domains, now being developed by Landcare Research Ltd) and the Land Cover Data Base (landcover mapping of NZ based on satellite imagery).
- Incorporate landscape unit and site-type information (*see* 'Breaking areas into blocks …', p.97) to allow comparison with other datasets.

Comparing treatment and non-treatment areas

These are areas of similar forest type and other conditions but in the treatment area some management input has been undertaken (such as controlling possums). This treatment is not applied in the non-treatment area. Individual measurements and trends in the indicators that are examined can then be compared between the treatment and non-treatment areas to examine impacts of the management. The significance of these areas was outlined under 'Design Monitoring, p. 88, in relation to BACI (Before-After, Control-Impact) designs.

It is often difficult to find a suitable non-treatment area because of variations in aspects such as forest vegetation and animal populations that make sites not directly comparable. Ideally, the non-treatment area should be as big or bigger than the treatment area to ensure these aspects of natural variation are included within the non-treatment area.

Try to ensure similar measurements on a range of sites and management inputs to allow comparison.

If you are trying to conclusively determine the impact of a management operation, ideally, you should examine several different treatment and non-treatment areas. This allows the variation occurring among the treatment and non-treatment areas to be examined to provide greater certainty that the differences between treatment and non-treatment areas are a result of management and not related to other differences within those areas.

Summary – sampling In practice

Decide on your sample size and sampling system before the main project.

- Look at your objectives and your monitoring question and identify what level of precision is required.
- Examine the literature for examples of similar monitoring studies – what magnitude of change can be expected?
- Consider the monitoring method you are using and the area of forest and look at the practicality of different sampling systems, for example, will you be able to efficiently establish randomly located plots? Are there different areas that should form different strata for sampling?
- Give your sampling approach a quick try-out in the field to see if it is going to work.
- Determine the likely sample variation: This will involve a pilot study to obtain a small number of measurements, or gathering information from past studies.
- Determine the appropriate sample size. Use your information on likely sample variation to decide on a sample size that will meet your requirement for precision (*see* 'What size sample?', p.98.)

GENERAL NOTES ON UNDERTAKING FIELDWORK

Always record sufficient information so others can repeat what you have done

Monitoring will often need to be repeated over time – possibly long after you have ceased to be involved. It is essential others can pick up on your work and continue it, otherwise all your work may be wasted.

Plot/sample point location

When using a random, systematic, or systematic random sampling system (*see* 'How to select the sample', p.95), sample sites should be pre-located, and not selected in the field. Sampling sites location/ layout should be identified before laying them out in the field. Depending on the type of sampling, this may involve marking of individual sites on a map or aerial photograph. Alternatively, it may consist of having the starts of transects marked on a map or described, and the systematic layout along the transects specified, for example, 50m between traps.

In some situations, sampling may be based on measuring site types that need to be located in the field. An example of this is sampling in canopy gaps, or on slips. In this case, it may be necessary to identify the sample location in the field, rather than pre-locate it on a map or photo.

Marking sample points/plots so they can be relocated

If plots are to be permanently marked so ongoing repeat measurements can be undertaken, care needs to be taken because marking will need to withstand the rigours of the environment for many years. To relocate sample points reliably, it is essential the following are present:

- A location description and/or diagram directing the observer to the point.
- A geographical location through a grid reference or a mark on a 1:50,000 scale topographical map, or a good quality aerial photograph.
- Physical marking in the field. Commonly used and effective forms of permanent marking include:
  - ~ Coated aluminium sheet (for example, venetian blind) nailed to a tree trunk. Details of the measurement site – number, etc, can be scratched on this marker. The nail head should always be at least 1-2cm out from the tree trunk to allow for growth.
  - ~ Individual numbered small aluminium tags for identifying individual tree stems for re-measurement. As outlined above, the nail head should always be out from the tree stem.
  - ~ Coated aluminium sheet on an aluminium stake, (*see* Figure 8, p. 33) or a tanalised wooden stake.
  - ~ Temporary marking with flagging tape (surveyors plastic tape) tied to vegetation can be very useful in marking out survey lines and directing observers to measurement sites.

It is important that if plots are no longer being used, markers should be removed to avoid confusion with other monitoring sites nearby, and unnecessary litter.

Ensure you have a plan before you begin

- Working through the standard monitoring plan sheet in the Monitoring Toolbox (*see* 'Monitoring plan', p.20) will help with this. This sheet can be followed through to record important aspects of your monitoring project and become the cover sheet for the batch of survey data.
- Have the indicators and measurement methods sorted out before you start.
- Have specific measurement protocols for these methods (as in Part 2).
- Have a plan of how you will go about the fieldwork, when you will do it, and in what sequence – so you get the job done efficiently.
- Think about the timing of fieldwork. Is the timing suitable? For example: northern rata flowers in December so you cannot assess flowering in May; weather is likely to be bad in winter so it will be difficult to complete fieldwork; and how will timing clash with other monitoring work you need to complete?

Do a quick trial first

Where possible on smaller projects, and always on large projects, do a small part of the fieldwork first as a trial. You can then look at how things went in the field, check that the data you are retrieving is useful, and can be analysed and presented in the way you require. It is essential to identify any problems with your approach at this stage, then you can sort them out before you put in more time and effort. There is nothing more frustrating than completing days of measuring in the field, then discovering it would have been far more useful if you had just changed it slightly.

Ensure fieldworkers have adequate knowledge, training or supervision

This is essential to gain useful information. Some important points to consider are:

- Make sure people doing the measurement understand the measurement protocol. Everyone needs to be measuring in a consistent way. It is useful to have a training field day, at the start of your monitoring so everyone is clear. It may be possible for the initial trial measurement to be done at this stage.
- Make sure everyone has enough knowledge to do the measurements; for example, if they are undertaking an understorey assessment, can they reliably identify the species present?
- Team up people with good knowledge with others who have less knowledge so they can pass on their skills.
- Get people back together occasionally to check each other's measurements – sort out any differences and problems in interpretation.

Keep notes on field measurements

Notes on your field measurements can be invaluable when it comes to looking at the data, and to yourself and others re-measuring sites in future. Think about keeping notes on the following:

- Anything different or unusual about the way a measurement was taken, for example, a tree diameter could not be accurately measured due to numerous large vines on the stem.
- Any significant points about the measurement or site, for example, pig rooting through much of the area, or many tui feeding on ripe kahikatea fruit.
- Obvious changes that have occurred since the last measurement, for example, a tree has fallen opening a light gap in the canopy, or a slip has occurred.

Checklist of field equipment

Use a checklist of the field equipment you will need for your monitoring fieldwork. You can run through this before you head off into the field. This avoids the stress of finding that your day's work is wasted because you have forgotten a crucial item.

Use standard forms where possible

Standard forms ensure that you are less likely to forget to record important information. Some examples of forms for particular measurement methods can be found in Part 2 Monitoring Toolbox.

Always record key background data

Key things that should be recorded in field measurements of all indicators include:

- date
- location
- names of people doing the fieldwork
- landscape unit and site type

Keep data tidy and safely stored

If you lose data at the field stage – it has all been for nothing.

ANALYSIS OF DATA

It is important to review the data collected regularly, to identify any interesting or important changes or trends that may be showing up and apply the results to management. Without regularly undertaking analysis and presentation of data, monitoring has little use and will be unlikely to influence management.

As described in the sampling section, it is not possible to measure everything so you are limited to drawing conclusions based on the sample of measurements that have been taken. Special care needs to be taken to avoid jumping to conclusions when the changes occurring could be just a feature of chance variation between samples. Expert advice will often be required.

This section explains the calculation of the simple statistics – mean, standard deviation, and standard error. Understanding of these is important to analysing your data. How to examine your data to identify if change or relationships are present is outlined.

Types of data

There are two broad types of numeric data that are encountered:

- *Measurement or count data* that can be any number or fraction. Examples of this type would include counts of birds, measurement of the percentage of canopy cover, seedling counts in bounded plots, etc.
- *Categorical and presence/absence data.* This is where the assessment at a data point can only be that something is present or absent, or that it is one of a small number of categories. Examples of this are presence or absence of a particular plant species within a series of vegetation plots, or rating of an indicator such as possum abundance against a number of subjective descriptions (*see* 'General surveillance checklist …', p.21).

The concepts in the analysis of these two types of data are similar, but some calculations are different.

Data points and means, standard deviation and standard error

- *Data or sample point:* An individual measurement point, for example, the stem count from one vegetation plot, or the presence/absence of a bird species at a particular point.
- *Sample size (n):* The number of individual sample points in your sample. For example, if 12 vegetation plots are measured in a forest area, the sample size is 12.
- *Mean:* This is the average of the data measurements in the sample. It is used to represent or provide an estimate of what that measurement will be for the whole forest population, for example, 12 vegetation plots were measured in a forest area and the number of seedlings between 0.45m and 1.35m height in each plot recorded. This gave 3, 9, 17, 10, 7, 5, 9, 10, 18, 14, 12, and 6 seedlings per plot. The average of these plot measurements was then calculated by adding the individual plot measurements and dividing them by the total number of plots. That is: 3+9+17+10+7+5+9+10+18+14+12+6 = 120, then 120/12 = 10. Therefore the mean number of seedlings per plot is 10. This is an estimate of the number of seedlings per plot for the whole forest area.
- *Standard deviation:* This is a measure of the variability of the data. It measures how much the individual values vary around the mean – are they all close to the mean, or do they vary widely above and below it? The standard deviation is calculated by first calculating the variance, then taking the square root of this to get the standard deviation.

For example, using the data above, subtract the mean from each plot measure.

Data point minus mean	equals	squared
3-10	-7	49
9-10	-1	1
17-10	7	49
10-10	0	0
7-10	-3	9
5-10	-5	25
9-10	-1	1
10-10	0	0
18-10	8	64
14-10	4	16
12-10	2	4
6-10	-4	16
	Total	234

The variance is then calculated by dividing the total by one less than the total number of sample points. That is 234/11 = 21.27
The standard deviation is then the square root of this. Square root of 21.27 = 4.61.

- *Standard error of the mean:* This is a measure of the amount of variation there is likely to be between different samples from the same population, or in our case the forest. In 'What is precision', p.96, this feature of variation between samples is discussed, and the fact that this determines the precision of the estimate for the whole population. In this way, a large standard error shows that the estimate of the mean will be less precise.
  To calculate the standard error, divide the standard deviation by the square root of the number of sample points.
  In our example, this is 4.61 divided by the square root of 12, or 4.61 / 3.46, giving a standard error of 1.33.

Comparison of datasets

As you measure different areas or different years, you build a set of data from which you can compare the means of different measurements and examine the datasets. When examining the data you have collected, you are likely to want to examine one or more of the following:

- *Difference between two places:* Is there a difference between measurements in two places so the means are significantly different? (*see* 'Examining difference', p.106).
- *Change over time:* Has there been a change between the years, or other time periods, measured so the means are significantly different (*see* 'Examining difference', p.106). Or has there been a gradual increase or decrease in the mean over a number of years, or other time periods that shows a trend (*see* 'Examining trend, p.106).
- *Relationships:* Data is often obtained from a range of different indicators and measurement methods for the same area and time. As these joint datasets are built up for different years and areas, you can examine the relationships between the different indicators (*see* 'Examining relationships', p.106). For example, you may be measuring hinau seed-fall, assessing possum abundance, and obtaining climate data. Studies have found that high

summer temperature the year before fruiting can indicate increased fruiting, and high fruiting of hinau can result in increased possum populations in the following year due to higher reproduction and survival (Brockie 1992, Cowan & Waddington 1990).

Examining difference

As discussed under 'Sampling', p.95, and in relation to the standard error above, the means of two samples will be different. Therefore when you try to compare two means to see if there is a difference between areas or years, etc, you have to decide if the difference occurring is larger than you would expect from just everyday chance differences between samples.

Standard deviation measures how variable the data in the sample is and standard error gives an idea of the sort of everyday variation likely to occur between samples.

Examination of differences between means requires some knowledge of statistics, and the advice of an expert may need to be sought if you are unsure how to conduct a statistical analysis.

If you are having a first look at the data, some broad rules of thumb can be considered. If there are more than four standard errors between two means, then it is likely there is a real difference. If there are two to four standard errors then it is possible there could be a difference – but you will need to seek advice or do more involved statistical testing. If there are fewer than two standard errors, then it is unlikely you can identify any difference with the current data.

Taking the example above, in the same area, an intensive deer control operation was undertaken to maintain low population levels, shortly after the above measurements were obtained. A sample of 12 plots were then measured two years later, which gave a mean of 11.33 seedlings per plot, with a standard error of 1.73. This is less than one standard error different from the previous mean of 10, so is unlikely to be statistically different. However, two years later, over which period intensive deer control had been maintained, another sample of 12 plots were measured, which gave a mean of 24.67 and a standard error of 1.72. Thus the difference between this and the original mean of 10 is 24.67–10=14.67. If we divide that by our larger standard error of around 1.7, there are more than eight standard errors between this mean and the original measurement – so it is likely that there has been a significant change.

Examining trend

The quickest and most effective way to get some idea if a trend is present is to graph the means from each of the different measurement times. The more measurements you have completed, and consequently points on the graph, the more useful the graph will be in indicating if there is any trend. Once you have four points on the graph you will start to see, when the points are joined, if they form a line that seems to be either sloping up or down. If you think one of these cases may apply, talk to an expert about doing some more statistical analyses.

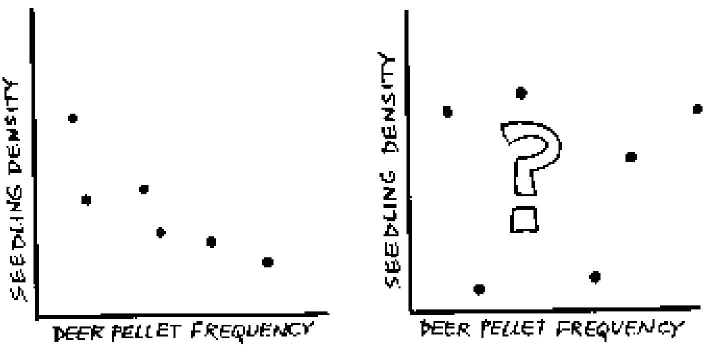
Remember a series of data points is much more powerful than just a couple of points. Keep on measuring even when you think things may have stopped changing. Fluctuations may occur, perhaps once in five years, and if measuring has ceased, they may be missed. If resources are limited, it is better to have a simple system of measurements that you can repeat regularly, to examine trend, than precise measurements at only 2 points in time.

Examining relationships

Is there some relationship between two indicators or measures? When one is low is the other low? When one is low is the other high? Again, the quickest and most effective way to get a feel for this is to graph the data. This can be done initially using a 'scatter plot', that is, graph each data point in relation to the two measures you are comparing, for example, for each survey point you may be plotting palatable seedling density against deer pellet frequency. You can then see if the points seem to line up along a straight line or curve that suggests there may be a relationship (*see* Figure 26).

Another approach to graphing the data is to compare separate plots of the two indicators on the same graph. The x axis must be the same for the different data you are graphing – so you can compare them. This could be time (for example, a number of different months or years of measurement) or location – that is, a number of points along the x axis could represent different study areas in which the different indicators have been measured. Graph the different indicators and compare them. This may show that the graphs for the two sets of data rise and fall together so they may be related.

FIGURE 26: A 'scatter plot' of two sets of data is a good way of having a first look to see if there may be a relationship between them. The plot on the left below suggests there may be some relationship. The plot on the right suggests there is no obvious relationship.



Fluctuations that 'don't mean anything'

It is important to be aware that different indicators can experience fluctuations that may be part of ongoing cycles or normal climatic variation, and it may not necessarily have any great significance for management. It is important to collect and understand this data.

Comparing data with regional and national datasets – relationships to the national indicators programme?

As discussed under 'Links to other sites', p.100, if data are carefully collected, there are opportunities to use this as part of a national monitoring database.

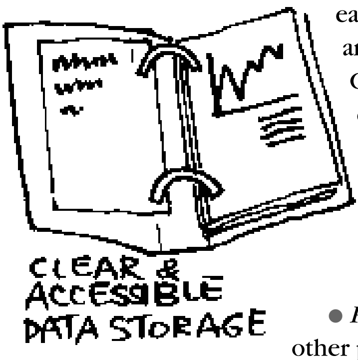
This also provides opportunities to undertake wider interpretation of data and examination of relationships between different indicators. Linking of data to Geographic Information Systems (GIS) provides opportunities to examine links between a large number of different 'layers'. For example, relationships between animal abundance and understorey condition, between understorey condition and bird abundance etc.

A final word of advice about analysis and presentation of data ... be very careful about conclusions – particularly causal ones. As a rule – seek expert advice.

RECORDS AND DATA STORAGE

The attention given to the type of information stored and the way it is stored can have a big impact on the usefulness of your monitoring.

Insufficient attention to adequate storage of monitoring records can result in information that is incomplete and stored in different places. This is difficult to analyse or use, and extremely difficult to pick up and re-measure in future. Historically, a large number of monitoring projects that could have provided valuable information have remained unreported, and knowledge of the monitoring has been lost (Norton 1996).



If good data storage and records are maintained, data can be presented quickly and easily, allowing application for a variety of uses, and the ability to be scaled up and combined with other datasets providing information on the same indicator. Good data records have ample background information and effectively link data to their geographic location. Some features of good monitoring records are:

- *Well described:* the details of monitoring design, what was measured, how it was measured, when and where it was measured are recorded.
- *Easily accessed:* Records are filed in some way so records for individual areas, plots etc can be easily located.
- *People know they exist:* For monitoring studies of any size, it is important other people know the data exists. This can allow valuable comparisons between areas, and prevent repetition of monitoring. Landcare Research Ltd operates a National Vegetation Survey database so registering vegetation survey data with this database is an option.
- *Standard:* Standard records, which contain information about key aspects such as sample design, measurement protocol, etc, will be more easily understood by future workers.
- *Well linked to geographical location and other descriptors:* Records should include important information such as map grid reference, landscape unit, site type etc, to allow data to be more easily related to other datasets.

Background forest information

It is important to ensure that you are aware of and have access to all relevant background information about the area you are monitoring. If appropriate, collate and store useful basic background information on the area you are studying. This will be an important reference, which can help you analyse current monitoring data and plan future monitoring. Useful information, depending on the level of your monitoring operation may be:

- Aerial photographs and maps.
- Land Cover Data Base (LCDB) information.
- Environmental Domains – (work now being undertaken by Landcare Research Ltd to classify land by biological and physical attributes).
- Forest typing information – maps of different vegetation types, etc.
- Published information such as Protected Natural Area survey reports that relate to your area.
- Data and analyses from any previous studies. It may be useful to check the Landcare Research Ltd National Vegetation Survey database for this.
- Historical information, both in published reports, and local knowledge from individuals and groups about previous impacts, influences, etc on the area. Make sure you get this information written down.

Monitoring records

As soon as each monitoring project is undertaken, information should be stored in a safe and usable way. Large amounts of data have been lost between its collection and first analysis. The monitoring information stored should include:

Monitoring objectives

A short statement of the broad monitoring objectives and the specific monitoring question being examined (*see* 'What is the monitoring question?', p.87). Use of a monitoring plan sheet as set out in 'Monitoring plan', p.19 is a useful way of summarising information on the monitoring as a cover sheet.

Measurement protocols used

Accurately record what was measured and the precise method used. Provide enough detail so someone else could re-measure in the same way Measurements may be many years apart, and people involved could change several times. In some cases, it may be sufficient to reference specific protocols, such as those for the possum percentage trap catch (NPCA 2000). If you make any alterations to an existing protocol – check with experts, have a good reason for doing it and make sure the change is well documented.

Location of sample points

Ensure that the location of individual sample points is accurately recorded as a map grid reference, GPS co-ordinates, or location on a map, and with a sufficiently detailed location description or diagram to relocate the points (*see* 'General notes on fieldwork', p.102). Having this data effectively recorded is essential to allow accurate relocation of sample points for re-measurement It also potentially allows wider uses of the data such as:

- Possible use of the data in a GIS-linked database, allowing it to be easily related to other datasets on different indicators.
- Relationship to datasets such as environmental domains, the NZ Land Cover Data Base, and other satellite imagery.

Measurement data

- Record data clearly on data sheets provided by the protocol you are using. If a new measurement method is being used, record data on simple sheets that you design.
- Photocopy data sheets and store a backup copy separate from main copy.
- Make sure that, as well as the required measurement information (*see* 'General notes on fieldwork', p.102), the data sheet includes:
  - ~ Location: sufficient information for someone else to be able to locate measurement points
  - ~ Date of measurement
  - ~ Field workers who made the measurements
- Always try to undertake analysis of the data immediately after you have collected it. This helps to ensure that it is quickly available in a form that is easy to access and interpret. It is always better to do this while it is fresh in your mind.

Analysis

Whenever any analysis, graphing, etc (*see* 'Analysis of data', p.104) is undertaken, store this as part of the records system.

Databases

Some organisations have access to computer databases of records for different forest areas. This is essential when organisations such as the QE II National Trust or Department of Conservation are managing many different forest areas. Entering monitoring data in conjunction with these databases (where appropriate) is very valuable because it provides a dataset that can be quickly summarised and the data extracted for analysis. As discussed above, under location records, inclusion of an accurate geographic/map reference for areas in such databases also opens the option of linking them to GIS (Geographic Information Systems) to allow greater use. GIS can potentially allow the comparison of overlapping map layers of indicators such as possum abundance and forest canopy condition, to allow relationships to be identified.

An important database that has been established by Landcare Research Ltd is the *National Vegetation Survey Database.* This database records and stores vegetation survey information from throughout New Zealand. It allows the identification of other vegetation surveys that may have been undertaken in your area. Information on vegetation monitoring that you carry out can be lodged on this database.

4. FOREST ECOSYSTEM INDICATORS AND MEASUREMENT

This part should be used to identify indicators appropriate for your monitoring programme and to select measurement methods to monitor change in these indicators. For important considerations in selecting indicators and measurement methods – refer to 'What will you measure', p.89 and 'Where and when will you measure', p.90.

USING PART 4

Indicators

This section provides a listing of some indicators that can be used to assess aspects of native forest condition. A description of each indicator is provided and some key issues associated with their use are identified.

This is a useful selection, but it is not an exhaustive list. You may discover new indicators to add to those listed here.

Measurement methods

Most of the indicators provided can be measured in a variety of ways. Some possible measurement methods for monitoring change in the indicator are listed under each indicator. You may also identify other measurement methods that should be tried and included if they meet your requirements.

Listing of measurement methods in the text

Listings of measurement methods are laid out in the following way:

Name of method	Skill requirements	Measurement precision
Discussion		
Comments	**Useful references**	
●		
●		

These listings are intended to provide an initial introduction to the method so potential users can identify if it is relevant to their work. They can then obtain more information on the specifics of this method by locating the listed 'useful references'. Some of these methods have suitable monitoring instructions provided in the Monitoring Toolbox listed under 'useful references'.

Skill requirements

The level of skill required to use each measurement method has been classified into one of two broad classes

– *community*  or *specialist* 

Those classed as 'community' require a basic general knowledge of forest ecosystems and are likely to be suitable for community groups and others without specialist knowledge. Those classed as 'specialist' may require specific technical skills or specialist knowledge.

Measurement precision

Some measurement methods, such as visual assessment, potentially have relatively large measurement errors. These methods are likely to be less precise. Other methods using tightly controlled measurements, such as counting of stems in a vegetation plot, will have smaller measurement error and greater precision. The measurement precision of each method has been broadly classified as

low   *low/medium*   *medium*   *medium/high*   or *high* .

These are general guidelines only because precision is affected by other factors, particularly sample size (*see* 'What is precision?', p.96).

CANOPY COVER AND CONDITION

The indicator

What is it?

The amount or proportion of canopy vegetation cover within a defined area of forest canopy. This area may be an individual tree crown.

Discussion

This indicator can be useful to examine forest condition for several reasons. There can be important relationships between this indicator and the impact of browsing by possums and insects, and climatic stresses, all of which may act to reduce cover, particularly on sensitive species. Condition of the forest canopy can be one of the more visually obvious impressions of forest condition and, consequently, it has an important impact on scenic value of the forest. The amount of canopy cover is important to determining the amount of light reaching the forest floor and protection of the forest floor from the impact of rainfall. They are often the physically largest component of the forest so canopy species are important in the supply of food to native invertebrates and birds.

Canopy cover and condition of some species has been shown to be quite responsive to changes in management (Brockie 1992).

Some key issues

- A range of different factors can affect canopy condition, for example, browsing animals, wind, salt spray, and insects. Care is required in assigning causes.

PHOTOS: ROBIN BLAKE

FIGURE 27: Condition of the forest canopy can be an important and visually obvious indicator.

- Variations occur with seasonal leaf growth, and sometimes seasonal browsing. It is important to understand these patterns and monitor in similar conditions. Re-measurement should occur at a similar time of year and stage of leaf growth. Leaf growth generally ceases in late summer, then begins again in spring. Ideally, the time of day and light conditions should be similar.
- Some species respond more slowly than others (for example, tawa is slower to respond than titoki) so try to pick species that respond well.
- With some measurement methods, care must be taken to avoid understorey growth preventing re-measurement of canopy condition.
- Canopy condition can be good while the understorey is suffering serious damage from browsing animals.

Measurement methods

The amount of overhead vegetation cover is measured. Particular protocols vary in whether they examine cover over an area of canopy or an individual tree. Individual tree assessments vary in whether all vegetation, or just foliage, is included. As long as you are consistent, and you don't change from one assessment to another, any of these approaches are useful. Possible measurement methods are set out below.

Visual assessment

The percentage of canopy cover is estimated, in certain percentage classes. A visual reference sheet can be used to assist in classification (*see* Figure 28). This method is relatively straightforward to undertake and it requires little equipment. However, it has a high level of measurement variation, particularly between different observers, often making changes difficult to identify. Payton et al 1999 found that a 20 percent variation in estimation of foliage cover, between observers, was not uncommon. Visual estimates are sufficiently precise to characterise communities and identify large changes in canopy cover, but they should be avoided for monitoring other changes (Ferris-Kaan & Patterson 1992).

Comments

- Relatively rapid and requires little equipment
- Large observer variation/measurement error
- Suitable where low level of precision required, such as in early indicative survey, or with large sample

References

'Foliar browse index for possum-related damage', p.43

Payton et al 1999

Denyer 1997

Dunn 1999

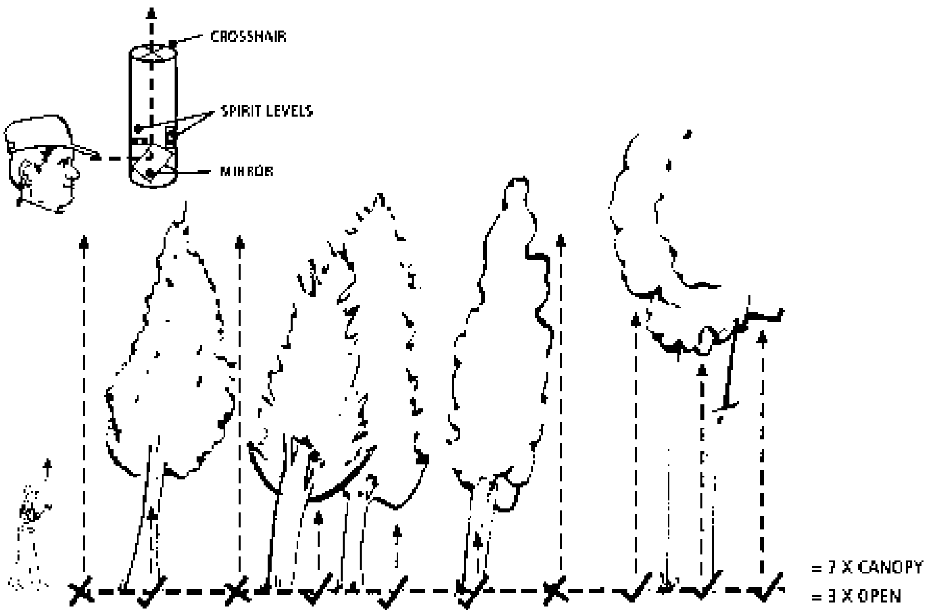
FIGURE 28: Visual assessment of percentage foliage cover using a guide sheet such as the Payton et al 1999 cover scale.

Point intercept

The presence or absence of cover at specific points is identified. Vertical sights are taken from a sample of points under the area of canopy being surveyed (*see* Figure 29). The percentage cover can be calculated from the proportion of 'hits' on the canopy as opposed to the points that fall in open space.

This method can be time-consuming to undertake accurately. It requires the use of some form of sighting device (*see* Figure 29) to reduce measurement error. A coarser form of this assessment can be undertaken using a 'vertical cylinder' rather than a point (*see* Figure 15). This is likely to be less sensitive to changes because it will only pick up larger gaps when the entire cylinder is directed on empty space.

FIGURE 29: Point intercept assessment of canopy cover. Points are classified as 'hitting' canopy cover or open space. In the example below, seven of the 10 points are canopy hits, giving a canopy cover of 70 percent. A periscope device such as that illustrated can be used or alternatively a vertically mounted telescope (2.5x) with cross hairs. This can allow more sophisticated categories, such as branches as opposed to foliage, to be recognised.



Comments

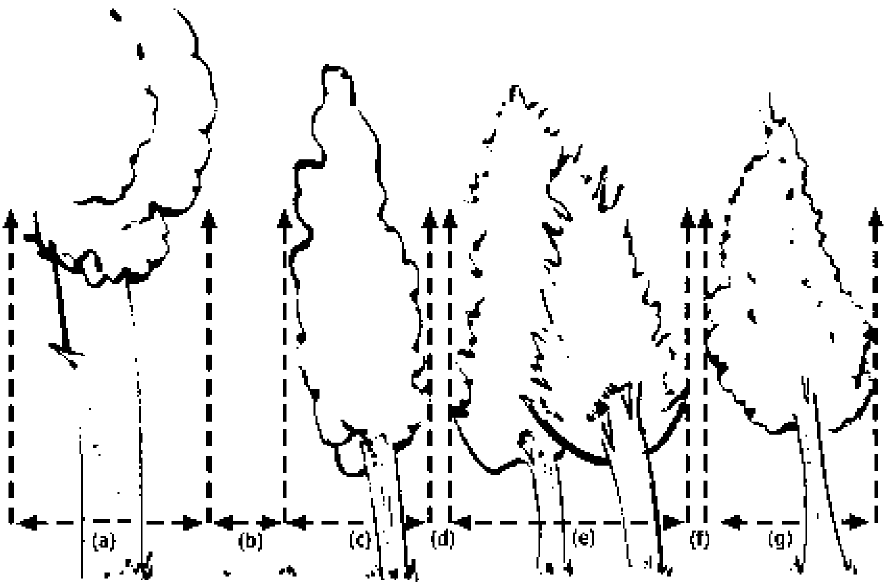
- Can be time consuming, depending on method
- Precise if carefully undertaken
- Suitable where good precision is required and conscientious, skilled field workers are available

References

Ferris-Kaan & Patterson 1992
Clout & Gaze 1984
'Cylinder intercept assessment of forest structure', p.49.

The cover occurring above a line under the canopy is classified.A percentage cover can then be calculated from the sum of lengths in each class. (*see* Figure 30).

FIGURE 30: Line intercept. This can be undertaken using a sighting device, as illustrated in Figure 5. Distances along the line occupied by canopy and open space are recorded. In the example below, distances a,c,e, and g relate to canopy cover. Distances b, d and f relate to open canopy holes. Percentage cover can be determined from the sum of a+c+e+g, divided by the entire length of line surveyed (in this case, a+b+c+d+e+f+g+h).



Comments

- Can be time consuming identifying boundaries, particularly in some vegetation types
- Can be precise if undertaken well
- Suitable where good level of precision required, and there is a simple forest structure with easily recognised gaps

References

Ferris-Kaan & Patterson 1992

Ground photography

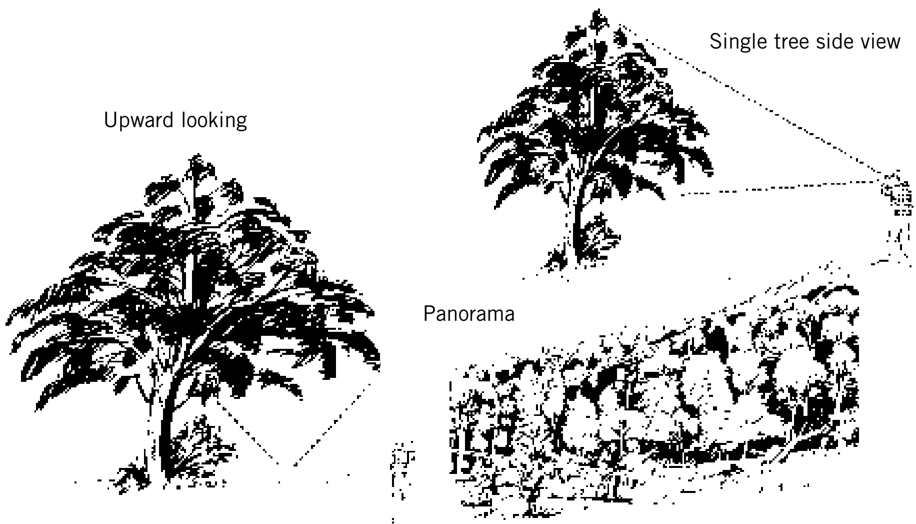
Photographic methods have several advantages, which include being relatively cheap and providing a permanent record that can be re-analysed in future. Photographs provide a good subjective demonstration of changes. With the advent of accessible digital image analysis technology, photography can also in certain situations be used to provide precise quantitative results.

The quality of photography, particularly the light conditions under which photographs are taken, are important to this method. A table of requirements for good photographs is provided in 'Ground photography … , p.25).

Upward looking, single tree side view, or panorama photographs (*see* Figure 31) can be taken. If photographs are of suitable quality, it is possible to use digital image analysis technology to identify the proportion of cover and sometimes to separate out the proportion of woody material.

A dot grid can be placed over photographs and the portion of dots falling on vegetation, sky, deadwood, etc assessed to give a less accurate measure. It is also possible to take pairs of photographs from slightly different locations on the same side of a tree so they have a two-thirds overlap, which allows them to be viewed in 3D using a stereoscope.

FIGURE 31: Different forms of ground photography.



Comments

- Relatively rapid and requires only standard camera equipment
- Photograph available for re-analysis, re-observation
- Care and effort required to get good quality photographs
- Image analysis can allow high levels of precision
- Allows visual demonstration of changes
- Requires similar weather/light conditions to work well

References

'Ground photography to monitor forest canopy cover', p.25

Elwood 1997

Large scale aerial photographs (for example, 1:5000) can be used to examine the extent of canopy dieback or collapse. Percentage of dieback or collapse in an area can be estimated.

Aerial photographs can also be used to assess changes in areas of different vegetation types. If photographs are being re-taken to monitor changes, they need to be taken to the same specifications including: same time of year; time of day; altitude; focal length; photo centre; and flight line bearing.

Estimation can be done by direct measurement of areas of different canopy condition from the photograph, or by using a point intercept or line intercept method on the photograph (*see* Figure 32).

Comments

- Can cover large areas rapidly
- Photographic record available for reobservation, re-analysis
- Can be expensive
- Good if results are required quickly over large and inaccessible areas

References

Pekelharing 1979

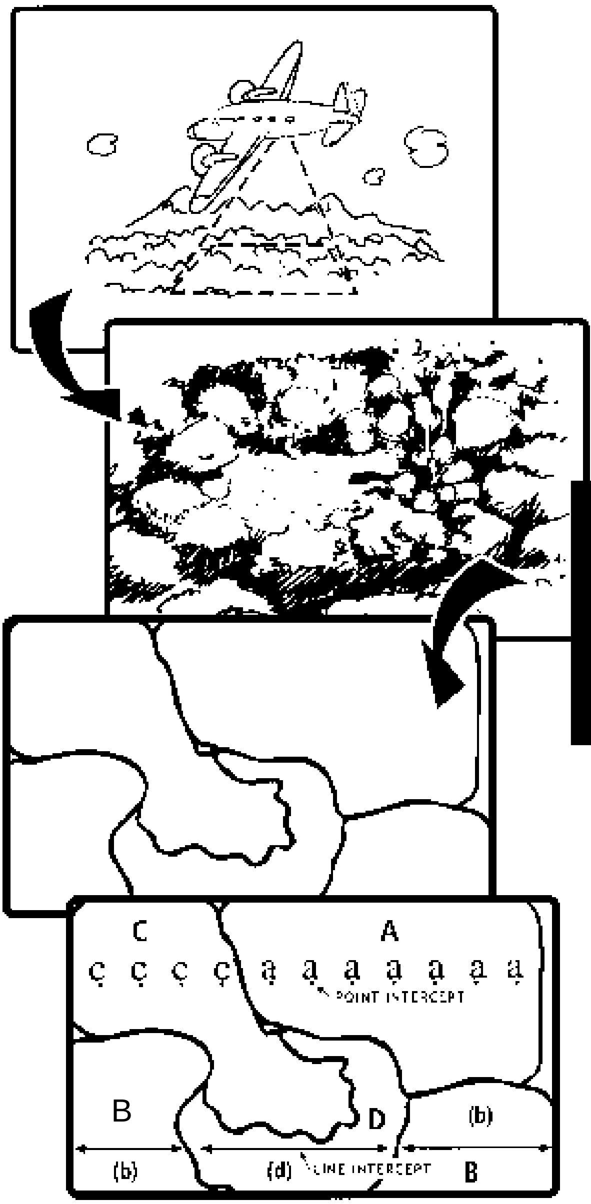


Figure 32: Aerial photographs can be used to assess changes in vegetation. As shown above, the area of different vegetation types on the photograph can be identified. Areas such as those shown as A, B, C and D can be measured approximately from the photograph using a planimeter. Point intercept and line intercept methods can also be used on the photograph to get an approximate proportion of different vegetation types. In the point intercept example, type C makes up four of the 11 points assessed, or around 36 percent. In the line intercept the lengths of the two lines assessed in type B could be expressed over the total length assessed in B and D to calculate a percentage of type B on the line.

Basal area

This is the cross sectional area of stems at 1.35m above the ground. It is usually assessed by measuring stem diameter at 1.35m, which is used to calculate basal area within a bounded plot. Live tree basal area per hectare provides an indication of site occupancy and associated canopy cover. Basal area is a well accepted indicator of long-term major changes in canopy cover. However, basal area is an indirect measure of cover, and alternative methods should be considered if shorter term changes in canopy cover are being examined. Problems with the use of basal area for this purpose include the fact that it will often change more slowly than canopy cover. For example browsing may result in a reduction in canopy cover/ density, but it will not result in a reduction in basal area until stems die. Studies have also found that basal area and total cover do not always relate well (Spurr & Warburton 1991).

Comments

- Relatively easy and reliable to measure
- Can be a poor relationship between basal area and canopy cover
- Can be useful if you are only looking at long-term trends and basal area data can be easily collected as part of other measurements

References

Allen 1993
'Quick plot method for vegetation assessment', p.31
Spurr & Warburton 1991

UNDERSTOREY ABUNDANCE

The indicator

What is it?

The abundance of plant species within various height tiers in the understorey.

Discussion

The understorey consists of individual plants from new germination, as well as epicormic shoots on mature stems, which form important vegetative regeneration in species such as kamahi and mahoe. It also includes ferns present on the forest floor, and tree ferns.

The forest understorey can be severely impacted by browsing pests including deer, goats, possums and stock. It can respond quite quickly (initial response in one to two years in some areas) to their removal, making it a useful indicator.

Examination of the abundance of seedlings and saplings of canopy species within the understorey can provide an indication of the current level of regeneration, and possible future forest composition.

Understorey shrub hardwood species produce considerable nectar and fruit of importance to birds (Clout & Gaze 1984, Williams et al 1996). They also provide food and habitat for invertebrates, and further protection of forest soils from the erosive effects of rainfall.

Examination of understoreys allows an indication of adequacy of canopy regeneration that is occurring.

Some key issues

- Definition of tiers is arbitrary – but make sure these are comparable with widely used NZ methods, such as Allen 1993.
- Identify key species to study in your area that respond to pressures/threats you are interested in, or have other significance to management. For example, look at results from exclosures to identify which species respond to reduced browsing.

PHOTO: PETER HANDFORD

FIGURE 33: Abundant understorey growth.

Measurement methods

Assessment of this indicator is of significance in New Zealand because of the importance of the impacts of introduced browsing animals, such as deer, goats, possums, rodents and domestic stock.

The advantage of this indicator is that it can respond relatively quickly to management involving the removal of browsing animals or ground cover weeds. It is also fairly straightforward to measure using one of the approaches discussed in 'Abundance of indicator species' p. 127. It can generally be measured more accurately than the canopy because you are closer to it. Species composition and diversity (*see* p.124) and population structure (p. 136) of the forest understorey can also be examined.

Plants within the understorey can be broken into a number of height/size classes to allow examination of abundance in different tiers.

VEGETATION

Many definitions of different tiers have been used in various studies.The most commonly used is that described for 20m x 20m plots in Allen 1993.The following tier split is considered a good compromise for New Zealand forests and it still allows comparison with data collected by the widely used Allen 1993 method.

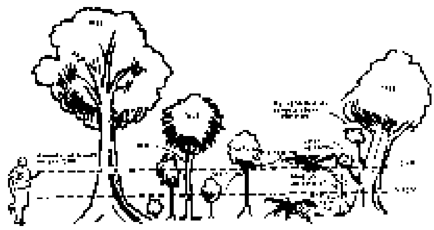
Tier	Height
Large seedling	0.45m – 1.35m
Sapling	Greater than 1.35m in height and less than 3cm DBH
Tree	Greater than 1.35m and greater than 3cm DBH

Seedlings below 0.45m are not examined under these tiers. Large short-term fluctuations in small seedling numbers can make their use as an indicator of forest condition difficult.

Epicormic shoots are also assessed within the understorey.These are shoots that form around the base of the stem of an existing tree.They are common on tree species such as pigeonwood, mahoe, broadleaf and kamahi. A common approach is to consider only epicormic shoots that form from the stem below 1.35m. Height to the tip of the shoot is then measured from the ground and the epicormic shoots placed into the large seedling or sapling tier as above (*see* 'Epicormic shoot counts', p.45). Figure 10 shows important aspects involved in assessment of forest understorey. Density of epicormic shoots can be a useful measure of understorey condition because they respond quickly to the removal of browsing animals.

Approaches to the assessment of abundance, which can be used to examine the understorey, are provided in 'Abundance of indicator species' p. 127.

Exclosures can be useful in examining this indicator. They provide an indication of condition of the understorey in absence of large browsing animals (sometimes also possums with certain types of exclosure). This can be compared with areas outside exclosures to examine differences, and identify the species that are being removed by browsing. It is not always necessary to establish your own exclosure, you may be able to examine a nearby exclosure in a similar vegetation type. Natural exclosures, such as steep cliffs or gorges where large browsing animals cannot get access, are often present in an area of forest.



See Figure 10, page 35 for a useful approach to classifying

Comments

- Definition of standard height tiers important for comparability
- Measurement of epicormic shoots important due to their potential quick response
- Examination of man-made and natural exclosures are useful to identify some of the differences in relation to browsing animals

References

Allen 1993

'Quick plot method for vegetation assessment', p.31

VERTICAL AND HORIZONTAL VEGETATION STRUCTURE

The indicator

What is it?

Vertical structure is the relative complexity of the forest in terms of number and cover of overlapping layers of vegetation. Similarly horizontal structure is the relative complexity, or patchiness in terms of the number of patches and area of different types of vegetation (*see* Figure 32, p.117).

Discussion

This is can be a complex indicator in New Zealand forests that needs to be considered carefully. It is suggested that users develop a good knowledge of this indicator before attempting to apply it. It is usually assessed in relation to a specific question, such as the quality of bird habitat, rather than in terms of any general surveillance of vegetation condition.

Complexity of vertical structure has been found in some situations to be linked to bird numbers (Ferris-Kaan & Patterson 1992, Clout & Gaze 1984). Greater complexity of vertical structure may also provide greater protection from erosion (Marden & Rowan 1988).

Complexity of horizontal vegetation structure is likely to influence the relative attractiveness of forest to different native and introduced vertebrates. Deer, for example, may be more abundant if a forest has a variety of patches of older forest, young regeneration and small clearings. Possums will be more abundant on forest/pasture margins. Horizontal structure may be useful in identifying changes in overall forest composition or regeneration pattern. Is there a trend toward the collapse of high forest areas toward predominantly tree fern areas, for example?

Forest remnants within a production farm/forest landscape present another example of horizontal vegetation structure. In this situation, studying this indicator can allow monitoring of the relative size and distance between remnants.

Some key issues

- This can be a complex indicator to measure in New Zealand forests.
- Changes can be difficult to interpret, and occur over a considerable time.

PHOTO: PETER HANDFORD

PHOTO: DOC

FIGURE 34: Horizontal structure of patches/fragmentation of vegetation (above). Complexity of vertical structure may influence attractiveness to birds (right).

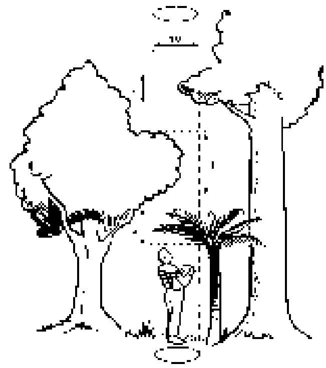
MEASUREMENT METHODS

Point intercept

Vertical vegetation structure can be assessed using this method by applying the same basic method as outlined on p.114 for canopy cover, but also recording the heights of various vegetation intercepts along a vertical line (Clout & Gaze 1984, Spurr & Warburton 1991, West 1986) or within pre-defined height classes. This allows graphical depiction and comparison of vegetation structure for different areas (for example, Clout and Gaze 1984). It also allows estimation of percentage cover within different layers, by recording the proportion of points that encounter vegetation in a certain height tier for example, 2m-5m. If required, this can be used to calculate an index of structural diversity 'foliar height diversity' for comparison between areas (*see* Table 4).

A useful simpler, coarser approach to defining vertical structure using a form of point intercept is to assess it visually using a vertical cylinder of a set diameter of 1m (*see* Cylinder intercept assessment …', p.49 Separate plants intercepting this cylinder are recorded along with an estimate of the height range of their intercept (*see* Figure 16). This allows approximations of the number of layers present, based on the average number of plants per point.

A point intercept approach can also be used to estimate horizontal structure by recording the structural type of vegetation present at a point, for example, low tree fern cover, mature canopy, emergent podocarp, etc. This information can then be used to calculate the percentage of the horizontal area covered by each of the types of vegetation. This gives a measure of the horizontal vegetation structure.



See Figure 15 page 54 for a simplified approach to assessment of forest structure using cylinder intercept.

Comments
- Can be time-consuming, depending on method
- Precise if carefully undertaken
- Suitable if good precision is required and conscientious, skilled field workers are available
- Can be difficult to assess when lower vegetation layers obscure upper vegetation

References

Ferris-Kaan & Patterson 1992
Clout & Gaze 1984
Spurr & Warburton 1991
West 1986
'Cylinder intercept assessment for forest structure', p.49

Visual assessment

Visual estimates of the percentage cover occurring in different height tiers or horizontal area cover in different structural vegetation classes can be undertaken. The same issues of large measurement error with such visual estimates, as identified under 'Canopy cover, p. 113 , apply. This approach is suitable for distinguishing between different forest community types and is used in the New Zealand RECCE plot method (Allen 1992).

Comments
- Relatively rapid and requires little equipment
- Large observer variation/measurement error
- Suitable if a low level of precision is required, such as in an early survey to determine forest types

References

Allen 1992

Line intercept

Discussion

This method can be used for examination of horizontal structure. The basic approach is as set out in 'Canopy cover' p.115, but the structural type of vegetation (*see* point intercept above) is also assessed. This allows percentage cover in different vegetation types to be estimated.

Comments

- Can be time consuming identifying boundaries, particularly in some vegetation types
- Can be precise if undertaken well
- Suitable if a good level of precision is required, and there is a simple forest structure with easily identified changes in structure, gaps, etc

References

Ferris-Kaan & Patterson 1992

Aerial photographs

Discussion

Horizontal structure/patchiness can be examined by identifying/marking areas of different structural type on aerial photographs (preferably viewed in stereo). Percentage areas, line or point intercept can be assessed directly from marked areas of the photograph (*see* Figure 32). Other possible measures from Table 4 may also be taken.

Comments

- Can cover large areas rapidly
- Photographic record available for re-observation, re-analysis
- Can be expensive
- Good if results are required relatively quickly over large and inaccessible areas

References

Pekelharing 1979

TABLE 4: Attributes of vegetation structure that influence diversity of animals (from Ferris-Kaan & Patterson 1992)

Type of Structural Feature	What to Measure	Notes
Vertical layering (stand structure)	a Number of layers b Cover of each layer c Calculate foliar height diversity (FHD) from a & b	Define layers to be assessed according to forest type and objectives
Horizontal patchiness	d Number of patches per unit area e Percentage area of each patch type f Number of patches of each type g Calculate mean patch size from d and e h Calculate patch size diversity from e and f	Define minimum patch diameter and patch/ vegetation types
Quantity of edge	i Edge:area ratio j Length of edge (total for each type of patch interface)	

SPECIES COMPOSITION AND DIVERSITY

The indicator

What is it?

The number of plant species and their relative abundance, often examined within a certain height tier.

Discussion

This can be an important indicator. The impacts of browsing animals will often reduce the diversity of native plant species by selectively removing the most palatable species. Reduction in the diversity of species or reduction in the composition of certain groups of species (such as fruiting large leaved coprosma species) can reduce the potential range of food supply for native birds. Individual plant species vary in their timing of flowering and fruiting, and in high or low flowering/fruiting years. Maintaining diversity to allow ongoing food supply for birds through these variations can be important.

Some key issues

- Important to ensure that the same areas/plots are assessed when examining change over time.

PHOTOS: PETER HANDFORD

FIGURE 35: Diversity of plant species present can be examined. Greater understorey diversity may be present where there are fewer browsing animals.

Measurement methods

Vegetation assessments almost invariably collect information on plant species and their abundance. This information can provide indications of species diversity and composition in a forest area. This can form a useful indicator in tracking change over time, or comparing one forest area to another, for example, comparing an area with high browsing animal numbers with one with low numbers.

% Composition

This involves a simple calculation of the percentage of the vegetation (for example, cover, number of stems, etc) for each species. In some situations it is useful to examine composition in relation to groups of species. For example, what are the percentages of high, and low deer-browse preferred species?

Comments

- Simple and useful presentation of results

Species lists – species richness

This is the total number of species present in an area. It can be presented as 'species richness', that is, the number of species per unit area (for example, /ha). Care has to be taken in using this measure and comparing it over time if different observers have been involved. Ability of different people to identify species accurately will impact on the results. For such comparisons over time, it is essential the same effort is expended in identifying species.

Comments

- A simple and easily understood measure
- Care required with measurement and comparison

Diversity indices

These indices take into account the relative abundance of species, as well as the total number. For example, an area of vegetation that has 20 species with five of them relatively abundant would have a higher diversity index than an area with 20 species, but only one that is abundant. One commonly used diversity index is the Shannon-Weaver Index.

$$H^1 = -\sum_{i=l}^{S} P_i \ln P_i$$

Where H^1 = diversity, Pi = proportion of the ith species, ln = natural logarithm,

and $\sum_{i=l}^{S}$ is the sum of the calculations made for all the S species present.

For example, 10 plots were measured in the understorey of two similar areas of forest, one had occasional browsing by domestic stock, while the other was securely fenced to exclude stock. These plots gave the following proportions of different species.

Area one (unfenced)				
Species	*Total number*	*Proportion of total (Pi)*	*Ln of proportion (In Pi)*	*-Pi x In Pi*
Urtica ferox	15	0.714	-0.337	0.241
Alectryon excelsus	2	0.095	-2.354	0.224
Dysoxylum spectabile	1	0.048	-3.037	0.146
Coprosma grandifolia	0	0	0	0
Coprosma foetidissma	3	0.143	-1.945	0.278
Total	**21**	**1**		**0.889**

Area two (fenced)				
Species	*Total number*	*Proportion of total (Pi)*	*Ln of proportion (In Pi)*	*-Pi x In Pi*
Urtica ferox	10	0.263	-1.336	0.351
Alectryon excelsus	8	0.211	-1.556	0.328
Dysoxylum spectabile	12	0.315	-1.155	0.364
Coprosma grandifolia	5	0.132	-2.025	0.267
Coprosma foetidissma	3	0.079	-2.538	.201
Total	**38**	**1**		**1.511**

Comments

- Important always to look at the species data and not just the index
- Quite different species mixes can give a similar diversity index

References

Ferris-Kaan & Patterson 1992

ABUNDANCE OF 'INDICATOR' SPECIES

The indicator

What is it?

The relative or absolute abundance of a particular 'indicator' species or group of species.

Discussion

There are many situations when the abundance of a particular species or group of species will be important as indicators. The abundance of seedlings and saplings of species that are highly palatable to introduced browsing animals may be assessed to indicate how successful animal control operations have been in improving understorey condition.

It is often useful to monitor species that are an important food source for birds or are important canopy species.

Species or groups of species that are selected as indicators will vary from site to site depending on the species present and management objectives. The key issues section below identifies some important considerations in selecting indicator species.

Some key issues

Selection of appropriate species is important. Some important features are:

- Relevant to the issue you are interested in – for example, are browsed by introduced animals, an important food source for birds, etc.
- Sufficiently common that you will be able to locate it readily.
- Has either a sufficient local seed source or source of vegetative propagation (for example, underground stem rhizomes, or stems for epicormic shoots). Without this, it may need to re-colonise the area, which can be very slow.
- Has a sufficient growth rate so changes will occur quickly.

Be careful using the same indicator species in different areas. Aspects such as browse preference for different species can vary greatly between areas.

PHOTOS: PETER HANDFORD

FIGURE 36: The abundance of particular species such as hen and chicken fern (*Asplenium bulbiferum*: right) can be examined.

Measurement methods

A variety of methods can be used to assess abundance.They are suitable for different situations of vegetation stature, abundance and management issues.Table 5 below shows how vegetation stature and abundance can affect the choice of method. An outline of the main methods of assessing abundance is also set out below.

Frequency – presence or absence

The presence or absence of a particular species within a bounded plot or at a given point is recorded, which allows frequency to be calculated as the percentage of plots/points at which the species occurs.

For example: Fifty 5m-radius plots are established along a transect to examine the frequency of kamahi seedlings between 0.5m and 1.35m in height, and kamahi epicormic shoots between 0.5m and 1.35m in height. Six of the plots contained kamahi seedlings and 15 contained epicormic shoots.This gave seedling frequency of 12 percent and shoot frequency of 30 percent.

Plot size is important because it will directly affect frequency.The larger the plot size the more likely the species will be present. Plot size should be not so small that the species of interest is rarely present neither should they be so large that the species is almost always present because this will make any increase hard to detect. Ideally, plot size should be such

TABLE 5: Use of different methods for assessing plant abundance

Growth form	*Distribution*	*Density*			
		Very low	*Low*	*Medium*	*High - very dense clumps of individuals or patches – making counting difficult*
Distinguishable individual plants	**Scattered**	Map & total count of individuals – if practical	Frequency/ density	Density	% cover
	Clumped (discrete patches)	Map & total of count number of patches – if practical	Density of patches, and density within patches	Density of patches, and density within patches	% cover
Indistinguishable individual plants (for example, vines or rhizomes)	**Scattered**	Map & % cover in each area (average % cover) – if practical	% cover	% cover	% cover
	Clumped (discrete patches)	Map & count number of patches, area of patches – if practical	Density of patches and size of patches	Density of patches and size of patches	% cover

that a frequency of between about 10 percent and 60 percent is obtained. The same plot size must be used for any comparisons between areas or over time. Using the same permanently marked plots is also advised (*see* 'What is the advantage of re-measuring change …', p.97)

This is a relatively quick and easy method, generally involving a low level of measurement skill. However it does not involve assessing the 'amount' of a species at a sample plot/point so it can be less effective at picking up small changes than cover or density-based methods.

Comments

- Quick and simple to measure
- Selection of plot size is very important
- Can pick up large changes when densities are quite low
- Not as good at picking up small changes

Density

This is normally assessed using bounded plots. All individuals (for example, tree stems, or ground fern crowns etc) are counted within the plot area. Abundance is then described as individuals per square metre, or per hectare.

For example: A 20m X 4m (80m^2) plot was assessed to examine the abundance of pigeonwood seedlings and saplings. This formed part of a monitoring programme involving several plots through the forest area. A thorough search of the plot revealed 18 seedlings and eight saplings. This gave the following densities for this plot:

Per plot	Seedling		18
	Sapling		8
Per square metre	Seedling	18/80	0.23
	Sapling	8/80	0.1
Per hectare (1 hectare = 10,000 m^2)	Seedling	18x10,000/80	2250
	Sapling	8x10,000/80	1000

Comments

- Provides simple objective data
- Can be a time-consuming method
- Selection of plot size is important (*see* 'What plot size', p.99)

Biomass

This is the total weight or quantity of living material. It is not generally practical to measure this directly for plants so it is usually estimated indirectly through relationships to more easily measured parameters such as diameter of tree stems, crown diameter of shrubs or canopy cover (Spurr & Warburton 1991).

Biomass is not generally used in practical regular monitoring because of these complexities. It can be a useful measure for identifying primary production in scientific studies, or examining carbon storage. Such studies normally include forest floor material as well.

Comments

- Considerable effort required to obtain good accurate data
- Data useful for scientific studies

References

Spurr & Warburton 1991

Cover

Commonly this relates to the percentage of cover of an area of the forest canopy, forest floor, or of a specified height tier. Absolute area of cover, usually in square metres, may sometimes be measured if monitoring, for example, the spread of a particular patch of weeds.

Percentage cover can be measured by any of the methods described under 'Canopy Cover' p. 113-117 above. As discussed in that section, visual estimates of cover have a low level of precision and are only suitable for picking up large changes. Point intercept methods can provide greater precision.

For example: A point intercept method was used to assess percentage cover of different species in the canopy. This involved assessing 100 points at 2m spacing along a transect. At each point the species present in the canopy directly above that point was recorded. The results for each species and associated estimate of percentage of cover were as follows:

Kamahi	32 points	32 percent cover
Hinau	20 points	20 percent cover
Pigeonwood	30 points	30 percent cover
Tree fern species	18 points	18 percent cover

Comments

- Useful in areas of high density and indistinguishable plants

References

'Point intercept …' p.53

DISTRIBUTION OF KEY SPECIES/UNCOMMON SPECIES

The indicator

What is it?

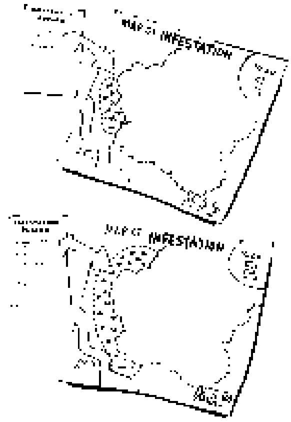
The distribution of important or rare plant species.

Discussion

This indicator becomes particularly important if a particular species is localised or present as small patches in particular locations (for example, New Zealand mistletoe). In these situations its presence at certain locations becomes more important because density across the whole area may be too low to measure.

Maintenance of the species at locations and increase or decrease in the number of locations where the species is present can be monitored as well as changing locations of a species.

This indicator can also be of particular importance with weed species that are new infestations, if their occurrence and spread are important.



see Figure 22, p.74

Some key issues

- Intensity (area covered and effort) of searching needs to be similar to make valid comparisons of changes in distribution over time, or between areas.
- What scale should distribution be assessed at? This needs to be determined depending on factors such as how large an area the species is spread over, and how precisely you need to know individual locations.

Measurement methods

Measuring changes in the distribution of a species will help identify changes in the size of the total population as well as its relative density or cover. For example, an examination using plots through a forest reserve where a species is present may show that the density of individuals remains constant. However, a wider examination of distribution throughout the whole region may show the species is declining. It may be disappearing from some areas while remaining unaffected at others.

If a species is uncommon, widespread random sampling to assess cover or density will be of little help because the species will seldom, if ever, be encountered (*see* also Table 5). In these situations mapping of scattered individuals or groups of the species may be more appropriate.

It is also important to identify if both adults and juveniles are present when assessing distribution (*see* also 'Population structure', p.136). This can give an indication of whether the population is increasing or declining.

Mapping

Thorough searching of an area is undertaken to identify locations of individuals or localised populations. These are then mapped at a scale sufficient to allow their easy relocation in the field. The suitability of different mapping scales will depend on what is being mapped. If a 50-hectare area of a rare canopy species is being identified, then mapping on 1:50,000 maps may be appropriate. If you are examining locations of individual rare plants or patches of plants aerial photographs of 1:5000 or larger scale may be appropriate.

Comments

- Choice of mapping scale is important
- If accurate coordinates are present (for example, from GPS), a smaller scale may be used
- When comparing distribution, intensity of searching must be similar

Total counts/absolute cover

Total known individuals over an area or within a localised population may be counted, or absolute cover determined (*see* 'Understorey abundance', p.128 and Table 5), where appropriate. Marking of individuals or small populations on the ground (for example, with marker pegs, or tags) may be necessary to ensure they can be relocated. Total numbers/cover can be monitored at regular intervals to identify changes.

For example, a manager wants to examine changes in mistletoe distribution between two areas, one with possum control, one without. Both areas are thoroughly searched for mistletoe before a possum control operation. Mistletoe locations are identified on 1:10,000 scale aerial photographs, and written notes are kept on how to locate each plant. One year after the control operation, the area is searched again to relocate the plants. In the control area, 24 of the original 26 plants were still present, and an additional three were found. In the no-control area, only 16 of the original 22 plants were still present, and no new plants were found.

Comments

- Thorough and consistent search effort required
- Very effective for rare species of well-known distribution

FLOWERING AND FRUITING OF KEY SPECIES

The indicator

What is it?

The amount of fruiting or flowering of key species, sometimes including other features such as damage to fruit or flowers.

Discussion

The amount of flowering and fruiting can be useful and important indicators for several reasons:

- Very important to examining the ongoing reproduction of the plant species involved.
- Important high quality food sources for birds which can affect their breeding success.
- Some (particularly certain larger fruits – eg, hinau) are important food sources for introduced vertebrates, particularly the possum, affecting their fat levels and condition (Cowan 1990).
- As it requires considerable resources for a plant to produce flowers and fruit, consequently, sustained improvements in the level of fruiting and flowering can sometimes indicate an improvement in overall plant health.

Individual New Zealand native plant species vary considerably from year to year in their level of flowering and fruiting, sometimes with higher fruiting levels every two to five years, with some years of nil or very low levels of flowering and fruiting (West 1986, Leathwick 1984, Dijkgraaf 1998). It is important that the impacts of these natural fluctuations are taken into account when using this indicator to look at changes in relation to management.

Some key issues

- It is necessary to develop knowledge of the phenology cycles of the species involved.
- Select species that are easier to assess – for example, have conspicuous fruits and flowers, and are significant to the ecosystem – for example, important food source for birds (*see* appendix 3) or introduced vertebrates or important canopy species.

Measurement methods

Flowering and fruiting can impinge on different parts of the forest ecosystem. Most New Zealand forest plant species fluctuate from year to year in the amount of fruiting and flowering (Leathwick 1984). Successful fruiting and flowering have an obvious relationship to regeneration for the species concerned. Several studies have shown important links between flowering and fruiting of some important forest species and increases in native and pest animals. For example, relationships exist between major seeding or 'mast years' in beech (*Nothofagus* species) and, mice, stoat, and bird abundance (Murphy et al 1995). Because of their very high nutritive value, flowers and




PHOTOS: DOC

FIGURE 37: Fruiting and flowering of different species forms an important resource to birds and other animals, as well as providing plant regeneration.

fruits are often targeted by introduced browsers such as possums. Measures of the level of impact on flowers and fruit are important to identify the damage caused by pests such as possums.

Several simple approaches to the assessment of flowering and fruiting are possible (*see* Figure 38).

Visual estimates

Regular visual assessment of flowering and fruiting of different plant species, and estimates of the percentage of the canopy with fruit or flowers, can provide valuable early information. Monthly records can be kept of a sample of individual trees, or through general assessment of an area of forest (*see* 'Flowering and fruiting observation record', p.57). As with most visual estimates, this will not provide sufficient precision to identify small changes. However, it can be sufficient to pick up major flowering or fruiting events of significance to management.

Comments

- Provides a general indication of timing, and peak years
- It is important to calibrate visual estimates year to year by taking photographs of fruiting and flowering

References

'Flowering and fruiting observation record', p.57
Leathwick 1984
Williams & Karl 1996
Clout & Gaze 1984

Seed-fall counts

Direct counts of seed-fall can provide precise estimates of its abundance. Such methods are generally easier for species with larger fruits. Two suitable ways of gathering this information are as follows:

Traps: Fixed litter fall traps can be constructed that collect fruit, flowers, leaves and other litter falling from above. These traps often involve some sort of large funnel on a stand above the ground that collects material and directs it into a removable 'jar'. Simple traps can be constructed by mounting a bucket on a stake under the tree. Measurement of the amount of material collecting in these traps, including a count of seeds/fruit is used to monitor changes.

Ground plots: A quicker, lower cost alternative is to establish small circular ground plots below trees that are permanently marked. This method is only suitable for species with relatively large conspicuous fruit such as tawa, hinau, taraire, karaka, etc. A list of species for which this approach could be considered is given in 'Ground plot monitoring of seed and fruit-fall', p.62. In the plot, the fruit on the ground surface and among recently fallen litter is counted.

Other ground plot methods involving randomly located plots can also be used, as long as only fresh fruit is counted.

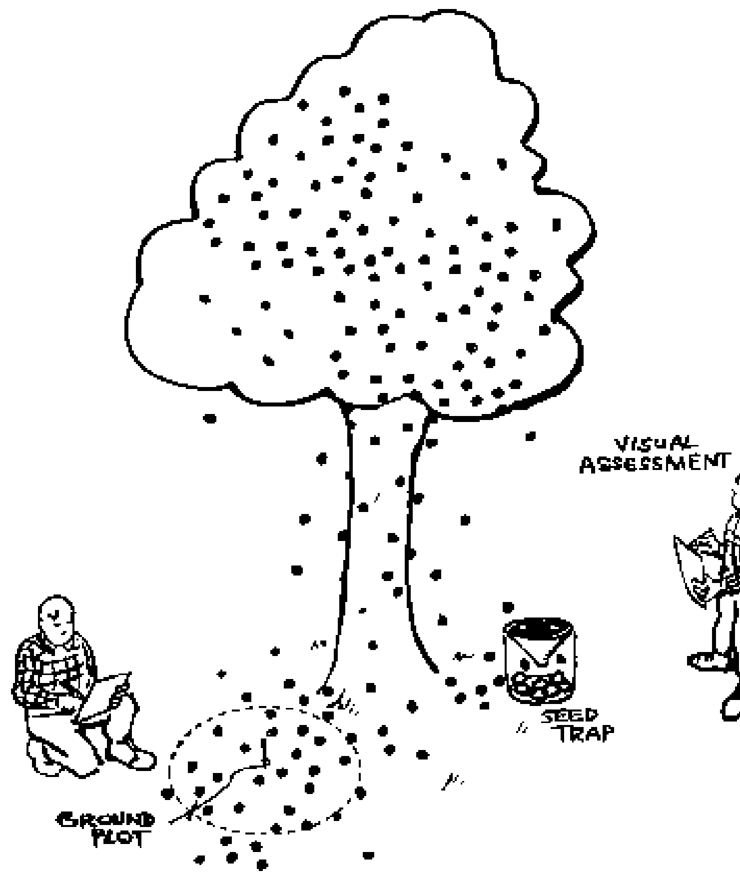
Comments

- Can provide a precise and objective measure
- Does not require much skill as long as only conspicuous, larger fruited species are examined

References

'Ground plot monitoring of seed and fruit-fall', p.62
West 1986
Cowan & Waddington 1990
Dijkgraaf 1998
Burrows 1994
Brockie 1992

FIGURE 38: Different methods of assessment of fruiting abundance.



POPULATION STRUCTURE

The indicator

What is it?

The relative numbers of plants of one species in different age/growth classes.

Discussion

Relative numbers of adult and juvenile plants can be a useful indicator to help determine if a species is increasing, stable or in decline. If no juvenile plants are present, then there may be some concern about the regeneration of the species. With ongoing monitoring, the progress of development from one age/growth/size class to the next can be examined to identify if normal regeneration is occurring or if it is being hindered by some impact such as browsing.

It is important to understand the species being examined, in terms of what is a usual population structure. Some light demanding species may have few seedlings present under a full canopy, but then have bursts of regeneration when the canopy opens after such events as damage by wind storms.

When using this indicator to compare areas, they need to be similar, ideally only differing in some major agent that is causing change, such as much greater browsing animal numbers in one area. Without this consideration, it can become difficult to interpret the reasons for differences between areas.

Some key issues

- Identify the best way to examine different age/growth classes for the species concerned. This may be by examining height classes, different growth phases (for example, juvenile and adult foliage), or diameter classes for woody species.
- Ensure age/growth/size classes being compared are the same.
- Understand the normal population structure of the species being examined.
- Only compare very similar forest areas.

Measurement methods

Obtaining information on the population structure (number of juveniles and adults) of a particular species provides indications of aspects such as regeneration and growth that identify if a species is increasing, stable or in decline.

This involves examining the relative abundance of juveniles and adults, and changes in proportions over time. With tree species, we commonly expect many more seedlings and saplings than adults, because many seedlings will die or are out-competed, leaving only a small number to eventually grow into mature trees. In situations where seedlings and saplings are present in relatively similar or lower numbers than adult trees, there may be some concern about maintenance of a forest canopy.

Care must be taken in interpreting the results from these sorts of considerations because some species may only regenerate occasionally following major events such as wind-throw. Long cycles over decades may be occurring that are not immediately obvious and are independent of current impacts. However, useful examinations of the same area over time or in relation to management changes, or between similar areas, can sometimes be made. If the impact of browsing ungulates is important, useful comparisons can often be made between the numbers of juveniles occurring in an exclosure, and the number outside. As discussed in 'Understorey abundance', p.119, both man-made and natural exclosures, such as cliffs or gorges, where browsing pressure is excluded can be examined.

Height/size classes

The simplest way to undertake this form of comparison is to collect abundance data, normally density, for different size classes of a species, or group of species. You cannot easily determine age of plants, so you have to assume their size is an indication of age. Suitable size classes for broad comparison with tree species are as follows (*see* Figure 10 p. 35).

Established seedling	Between 0.5m and 1.35m in height
Sapling	Over 1.35m in height, but less than 3cm in diameter at 1.35m
Tree	Over 1.35m in height, and over 3cm in diameter at 1.35m

More detailed size class comparisons are also commonly undertaken by examining the relative numbers of stems in different DBH (diameter at breast height) classes.

Comments

- Important to have consistent size classes between comparisons

References

'Quick plot', p.31

MORTALITY

The indicator

What is it?

The proportion of plants dying over a certain time period, within a certain age/size class.

Discussion

All plant stems have a certain life span and then eventually die. The annual rate of this mortality is an important indicator. An increase in the rate of mortality can indicate a decline in condition due to pests or diseases, or some other environmental factor. However it is essential to have some understanding of the population dynamics of the species involved, before attempting to use this indicator. For example, a long-lived species may have a low natural rate of mortality, whereas a short-lived species may have high levels of mortality. Some even aged stands may have occasional periods of high mortality associated with normal growth cycles.

Examining the size/age classes in which mortality is occurring is also important. An increase in mortality in immature stems can be particularly important – because such stems are clearly not dying from old age.

Some key issues

- Understand the population structure and dynamics for the species and area you are examining.
- Identify the size/age classes in which mortality is occurring.

Measurement methods

Some methods of examining mortality are as follows.

Death of marked trees

Live trees are tagged in plots in a forest area, and are reassessed at regular intervals to determine the number that are live and dead, allowing calculation of average annual levels of mortality. Large numbers of trees need to be tagged and monitored to get a reasonable assessment of mortality by this method (*see* Campbell 1990).

Direct assessment of the amount of dead standing stems at any one time is unreliable because of the difference in the durability of woods of different species. This results in the presence of potentially many more dead standing stems of durable species such as totara, compared to non-durable species such as kamahi.

Comments

- Requires considerable effort because large numbers of trees need to be marked
- Provides a robust measure of mortality

References

Campbell 1990

PHOTO: DOC

FIGURE 39: Dead tree

Change in total mortality over time

The proportion of total standing stems that are dead can be compared from assessment to assessment to identify if the relative amount of dead stems is changing. This relies on being able to identify the species of dead stems – this is not always easy.

Comments

- A less reliable measure than reassessing marked stems

LITTER-FALL

The indicator

What is it?

The total amount of annual litter-fall in an area of forest, often separated into twigs, leaf-fall, fruit and flowers.

Discussion

Litterfall provides an indication of total primary production or productivity of the forest. This varies greatly between different types of forest, and declines with increasing latitude and increasing altitude (Brockie 1992).

It may give some indication of the relative condition of similar areas of forest (Cowan & Waddington 1991), with more healthy areas producing a larger total amount of litter. Litter-fall also provides the food source for many invertebrates living on the forest floor, directly impacting these populations.

Litter accumulation on the forest floor is affected by the rate of decomposition, which is strongly influenced by climate. Warm, moist areas have much faster decomposition than cold, dry areas.

The use of this indicator may have some potential, but needs to be treated carefully due to the major variation naturally occurring between different forest areas in litter-fall and litter decomposition.

Green litter of some palatable species is commonly eaten from the ground by introduced browsing animals when animal numbers are high, and preferred food is in short supply.

Some key issues

- Understand the litter cycles of the species being studied, for example, when peak litter-fall occurs.
- Comparisons should only be undertaken with similar forests in a similar geographic and climatic location.

Measurement methods

Methods involve the collection of litter and usually assessment of oven dry weight. Other forms of field assessment, such as volume of loosely packed litter may be possible. Two possible methods of collecting leaf litter are identified below.

Litter trays

This is the same approach as identified with seed-fall traps. Collection cones or similar structures of a known collection area, into which litter can fall, are set up under the canopy. These are periodically cleared and the quantity of material collected is assessed.

Comments

- A quite widely used and reliable technique
- Considerable effort required to establish and maintain litter trays

References

Brockie 1992
Cowan & Waddington 1991
Cowan et al 1985.

Litter plots

In a similar way to that set out for seedfall plots, it may be possible to collect and assess litter from small plots on the forest floor, without the expense of establishing litter trays. Within small plots, intact litter is scraped up, to the level of the more decomposed humus layer. The quantity of this material can then be assessed. Care is required if ongoing monitoring is undertaken using the same marked plots, as fixed plots will always have less litter in subsequent measurements due to the accumulated litter sampled in the first measurement.

Comments

- This is a less proven technique than litter trays, and may have somewhat less reliable results
- Less effort will be involved in establishment and maintenance

WEED DISTRIBUTION

The indicator

What is it?

The distribution of particular weed species.

Discussion

The distribution of plant pests is often a very important indicator. Weeds may be new arrivals to an area and have potential to spread. Obtaining up to date information on distribution of weeds allows managers to identify new infestations, and identify sites where eradication may be possible.

Ongoing changes in the distribution of particular species, and their spread into new areas can be assessed.

Some key issues

- See 'Distribution of key species/uncommon species', p.131

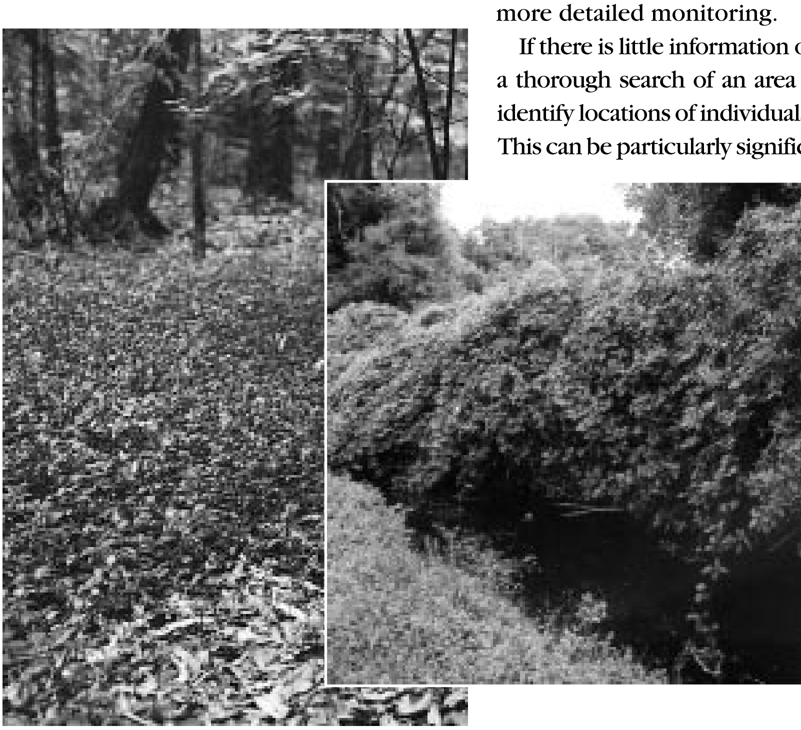
Measurement methods

The methods for assessing distribution are the same as those for examining the distribution of important or uncommon species (*see* 'Distribution of key species/uncommon species', p.131). Some particular points to consider about weed distribution are set out below. Useful information can also be found in the Department of Conservation's *Weed Surveillance Standard Operating Procedure* (DOC 1999)

It is necessary to obtain information about the presence and distribution of important weeds within an area under management. This initial work will be important to any decisions on more detailed monitoring.

If there is little information on the presence of weeds, a thorough search of an area should be undertaken to identify locations of individuals or localised populations. This can be particularly significant with new infestations of weeds because the weeds may be at a very low density and would not be picked up by abundance surveys.

When undertaking such searches, there are certain areas that are particularly vulnerable to the spread of weeds (DOC 1999), and these should form an important focus, particularly if resources to search the whole area are limited.



PHOTOS: PETER HANDFORD

FIGURE 40: Weed infestations of species such as *Tradescantia* (wandering jew) on the left or bindweed and blackberry on the right, can spread and smother regeneration.

Vulnerable areas include:

- Alongside roads and railways.
- Rubbish dumps.
- Places with low scrubby or disturbed vegetation.
- Beside streams, rivers, lakes or the coast.
- Places modified by human activity, for example, farms, cleared land, excavations.
- The edges of reserves, particularly close to settlements.

Mapping of the location of individual infestations should be undertaken for important uncommon species with only localised distribution (*see* 'Distribution of key species/ uncommon species', p.131). Mapping of specific locations of particular infestations enables their spread to be monitored. With localised infestations, it is sometimes possible to monitor the total cover or number of individuals.

For weeds that are more widely dispersed, the broad extent of distribution rather than individual infestations can be mapped. The suitability of different mapping scales will depend on what is being mapped. If a 50-hectare area of continuous evenly distributed weed infestation is being identified, then mapping on 1:50,000 maps may be appropriate. If you are examining locations of individual weed plants or patches of weeds over a small reserve, aerial photographs of 1:5000 or larger scale may be appropriate.

WEED ABUNDANCE

The indicator

What is it?

The relative or absolute abundance of a particular weed species or group of weed species (*see* 'Abundance of indicator species', p.127).

Discussion

The abundance of particular weed species can be important to managers of native forest. It can provide indications of whether the population is increasing or decreasing, and the impact of weed control or other management operations.

Including assessment of the abundance of both juvenile and adult plants is useful (*see* also 'Population structure', p.136) to identify if populations are increasing, with many juveniles, or are apparently fairly stable, with a few mature plants.

The Department of Conservation Standard Operating Procedure (DOC 2000) for monitoring weed control is a very useful reference for designing and undertaking weed abundance monitoring.

Some key issues

- See 'Abundance of indicator species', p.127.
- Select the important weed species to monitor. Look first at those species that have features such as high impact, potential for control, or are established throughout the area and spreading.
- If the species is new and only present as early introductions, a distribution survey (*see* 'Weed distribution', p.142) may be the best approach.

Measurement methods

As with vegetation in general, the approach to assessing the abundance of weeds will depend to a large extent on the growth form, distribution and relative density of the individual species.

Table 5 in 'Abundance of indicator species', p.131 identifies how these issues affect the method used. Methods available are also described in 'Abundance of indicator species'.

WEED POPULATION STRUCTURE

The indicator

What is it?

The relative numbers of plants of one weed species in different age/growth classes.

Discussion

This indicator can provide information on the trend in a weed population (*see* also 'Population structure, p. 136). Presence of mature adult plants that have been present for a long time, with no, or very few, juvenile plants, may suggest a fairly stable population. The presence of a few adult plants and many new juveniles suggests a potentially rapidly expanding population.

Examining the population structure can be important with species that take time to reach maturity and start producing seed. For example, introduced conifer species (pines, Douglas fir, etc) take years to reach a stage where they are producing seed. Identifying population structure when monitoring these species can help to identify which areas are priorities for control and which areas are not so urgent.

Some key issues

- See 'Population structure', p.136.
- Determine how you will clearly separate age/size/growth classes.

Measurement methods

See 'Population structure', p.136.

WEED MORTALITY

The indicator

What is it?

The proportion of plants dying over a certain time period, within a certain age/size class.

Discussion

As well as being a vital part of understanding general population dynamics of a weed species, assessing mortality can be particularly important when considering the effects of control operations such as herbicide application (DOC, 2000).

Some key issues

- See 'Mortality', p.138.

Measurement methods

Deaths of individually marked plants or the portion of stems or cover within marked plots can be assessed over time, including before and after a control operation. See 'Mortality', p.138 for an outline of measurement methods.

GROUND COVER

The indicator

What is it?

The proportion of the area of the forest floor in different classes of ground cover, such as bare soil, leaf litter, rock, moss, and live plants.

Discussion

Ground cover is an important indicator because it provides information on the likely stability of the forest floor and vulnerability to erosion. This can be important, for example, in examining the impacts of trampling by browsing animals. The amount of ground cover vegetation can provide information on the ability of seeds to germinate and survive as seedlings.

Some key issues

- Determine ground cover classes that will be used, and define them accurately to avoid confusion in the field.
- Ensure classes used are comparable with previous studies, or classes widely used in similar studies.

Measurement methods

Visual assessment

The percentage of ground cover in various categories, such as soil, rock, vegetation and litter, are visually estimated for a plot or the general area around a survey point. Normal difficulties with measurement variation for visual estimates occur.

Comments

- Only provides very broad estimate
- Only suitable for examining very large changes

References

Allen 1992

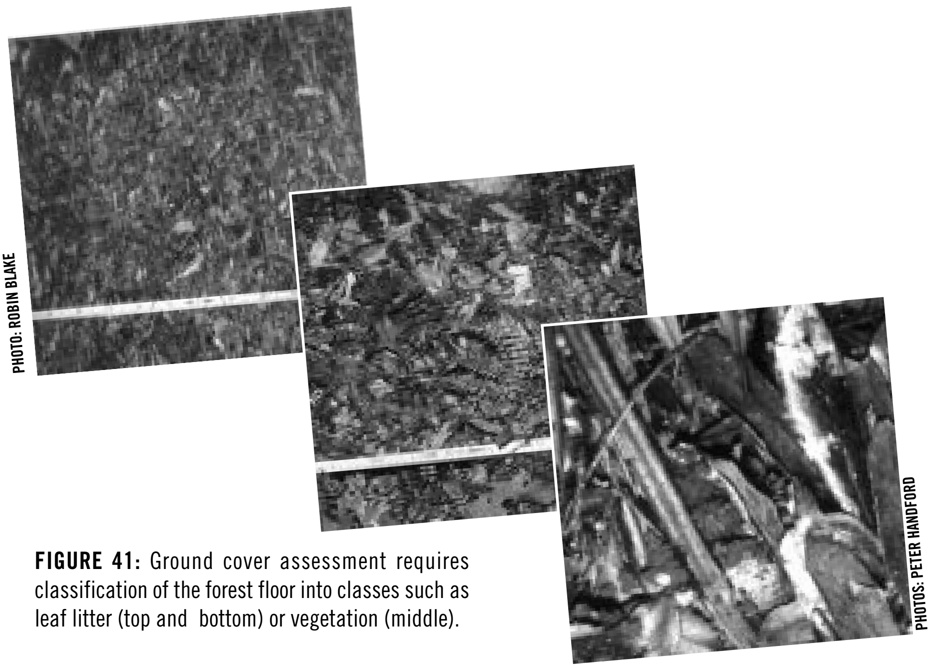
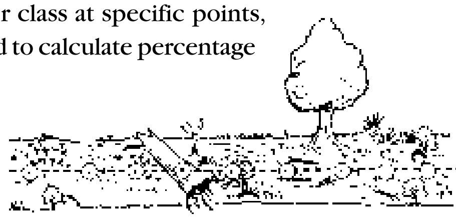


FIGURE 41: Ground cover assessment requires classification of the forest floor into classes such as leaf litter (top and bottom) or vegetation (middle).

Point intercept

An objective and commonly used method. Ground cover class at specific points, normally along a transect line, is recorded. This is then used to calculate percentage in different types of cover (for example, litter, vegetation, soil, rock, etc) from the total number of points assessed (*see* Figure 16, p.54).



For more details of 'point intercept' see Figure 16 p. 54.

Comments

Can provide a reliable, objective estimate

References

'Point intercept – for forest ground cover assessment', p.53

BIRD DISTRIBUTION

The indicator

What is it?

The distribution of important or rare bird species.

Discussion

As with the assessment of rare plant species, this indicator becomes important where a particular species is localised or present as small patches in particular locations (for example whio, blue duck). In these situations its presence at certain locations becomes more important because density across the whole area may be too low to measure.

Maintenance of the species at particular locations, and increases or decreases in the number of locations where the species is present can be monitored.

Some key issues

- Intensity (area covered and effort) of searching needs to be similar to make valid comparisons of changes in distribution over time, or between areas.
- What scale should distribution be assessed at? This needs to be determined depending on factors such as how large the area is where the species occurs, and how precisely you need to know individual locations.

Measurement methods

The issues with the use of bird indicators identified under 'Bird abundance' (p. 148) need to be taken into account when examining bird distributions. Some possible methods used in New Zealand are set out below.

Mapping locations of uncommon species

The locations of sightings of species of interest are recorded and mapped at suitable scale, such as on NZMS 260 series, 1:50,000 maps. 'Distribution of key species/uncommon species', p.131

FIGURE 42: Birds form an important part of the forest ecosystem and can perform roles such as seed dispersal.

PHOTOS: DOC

identifies some points to consider. Relevant information on individual sightings is recorded where possible, such as numbers of individuals seen, habitat, sex, juvenile or adult.

Comments	**References**
● Provides a useful first reference ● When comparing distribution, intensity of searching must be similar	Hay et al 1989

Mapping presence within grid squares

The area of a set map grid square is traversed, and the presence of species identified within the grid squares is recorded. During the 1970s this approach was undertaken across New Zealand using 10,000 yard grid squares. This culminated in the publication in 1985 of maps of the distribution of 118 land bird species (Bull et al 1985).

Comments	**References**
● Publication of historic national data mean subsequent comparisons are possible ● It is important that intensity of searching, and observer skill are similar when comparing distribution to look at change	Hay et al 1989 Bull et al 1985

BIRD ABUNDANCE

The indicator

What is it?

The relative or absolute abundance of a particular bird species or group of bird species.

Discussion

Information on birds can provide valuable indicators. Native bird species are consumers of various primary production from the forest, whether it is fruit and nectar bearing species (*see* Appendix 3) or invertebrates that in turn feed on the forest. Because of this the abundance of birds may provide an indication of the wider condition of the forest such as the maintenance of a diversity of fruiting and flowering species, and maintenance of abundant vegetative growth and litter fall for invertebrates.

However, as discussed below in 'Some key issues' there are considerable difficulties in getting reliable estimates of changes in bird abundance. Reliable estimates can be achieved, but they require careful design of monitoring and careful assessment in the field.

Some key issues

Monitoring of forest birds can be difficult. It requires good bird identification skills, both from sightings and calls, and these skills take time to develop. There can be considerable error introduced into bird monitoring from different observers having differing abilities in bird identification. Different bird species vary greatly in their habits, and in how conspicuous (lively and noisy) they are and, consequently, in how easy they are to count. Some bird species, move around during the year following seasonal food sources. Most birds are more active and vocal during breeding, and are quiet and reclusive during the post-breeding moult. Differences in activity also occur with changing weather and time of day. These factors need to be considered in any bird monitoring.

Some useful pointers when considering bird monitoring are:

- Learn or improve your bird identification. The best way to do this is to spend time in the forest with a pair of binoculars, trying to locate and identify all the birds you hear or see.
- Possibly concentrate on key species you know you can identify for example, kereru, tui/ bellbird.
- Collect data over a period, for example, one month, not just days, and measure at the same time each year.
- Collect data in the same weather conditions – ideally fine and still.
- Assess when birds are most conspicuous – usually in the breeding season between August and November.
- Use methods that minimise identification based on calls alone.

Measurement methods

Territory mapping

This involves intensive study of an area, sometimes including marking of individual birds to allow identification of territories for territorial species. Estimates of the density of birds can then be made, and presence or absence of known birds from territories monitored. This is a time consuming method that requires considerable skill. It is normally used for detailed scientific studies.

Comments
- Very time consuming if useful results are to be obtained

References
O'Donnell 1996

Capture rate in mist netting

Some studies (Brockie 1992) have used catch rates in mist nets to provide some indication of relative abundance. This method is limited to skilled individuals with approval for mist netting. It is time consuming to install and monitor nets, but it allows collection of other population data in detailed scientific studies.

Comments
- Requires specialist skills and is time consuming.
- Nets can catch selectively for example, those species low in the forest.

References
Brockie 1992

Five-minute count

This is the most widely used method in New Zealand. All birds seen or heard over a five-minute period at a fixed listening point are recorded. Big differences are likely with seasonal changes in 'conspicuousness' of different species. It does not assess a fixed area.

Comments
- Requires good birdcall identification skills
- Subject to all usual bird monitoring variation

References
Hay et al 1989
Elliott 1998
Dawson & Bull 1975
Cassey & Craig 1998

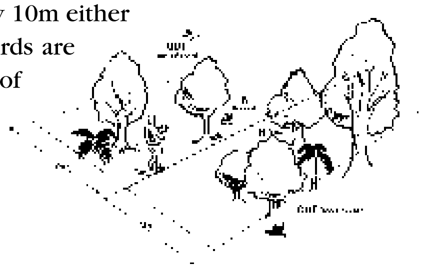
Distance sampling

This method involves assessing distance to each bird observed on a transect or at a point. This allows calculation of bird density, subject to various assumptions. This is potentially a useful technique but likely to involve considerable difficulty in estimating distances, particularly if there are many observations.

Comments	**References**
● Has advantage of providing a measure of actual density	Cassey & Craig 1998
● Estimation of distances to birds can be difficult	Cassey et al 1998
	Buckland et al 1993

Fixed area – 'slow walk' transects

This is something of a hybrid technique. It involves slowly walking along a transect and only recording birds that are present within a set distance, usually 10m either side of the transect (*see* Figure 21). Because only nearby birds are included, this technique results in a much higher proportion of birds identified by sight. It is probably less affected by changes in conspicuousness. It also provides some measure of density because counts are area related.



For more details of the 'slow walk' transect see Figure 20 p. 68-71.

Comments	**References**
● Greater proportion of birds identified by sight, so lower call identification skills may be required	'Forest bird slow walk transects', p.68
● Some indication of density provided	Lovegrove 1988
	O'Donnell 1996

BIRD SPECIES COMPOSITION AND DIVERSITY

The indicator

What is it?

Number of bird species and their relative abundance.

Discussion

This uses data gathered under the abundance methods. Species generally vary in their conspicuousness and likelihood of being sampled under these methods. Consequently, each species is effectively measured on its own scale (Dawson 1981). This means using data gathered when assessing abundance may give an incorrect indication of species diversity and composition. The more time and effort that has gone into abundance measurement, the less significant this problem will be because when large amounts of time and effort are expended, even relatively rare or inconspicuous species will be recorded.

Use of this indicator should be kept simple, used sparingly, and with the limitations discussed above well understood. With this in mind, consideration of the total number of species and the number of indigenous compared with exotic species can be useful.

Some key issues

- See general issues, above.

Measurement methods

Uses data gathered under assessment of abundance, and also possibly in distribution studies. Simple calculations can be undertaken to identify the total number of species, and the proportion of species in different groups (for example, exotic and indigenous species). Diversity indices, such as the Shannon-Weaver Index (*see* 'Species composition and diversity', p.124), can also be used.

BIRD POPULATION STRUCTURE

The indicator

What is it?

Various features associated with individual bird populations such as relative numbers of juveniles and adults, sex ratios and fledging rates.

Discussion

This indicator provides specific information about individual species in a certain area. It is normally used when examining specific issues for the management of rare or endangered species.

This approach involves monitoring individual birds to examine things such as movements, breeding success and mortality. Individual birds are identified by banding, tagging, attaching radio transmitters, or occasionally by distinctive natural markings.

Some key issues

- This indicator generally requires considerable skill and resources to measure.
- Avoiding disturbance to the species involved requires skilled and experienced fieldworkers.

Measurement methods

These methods are difficult and require a high level of skill. They are generally suited to detailed research studies involving skilled people.

Detailed population studies

Identification of breeding pairs, nests, and monitoring of reproductive success is a useful technique, but requires large amounts of time and skilled people (Powlesland 1997). It is suited to studies on key populations of important species, or where specific impacts are to be examined.

Comments	References
• Very time-consuming and requires skilled people.	Hay et al 1989 Powlesland 1997

Nesting success

Similar to the above method, this approach concentrates on the proportion of nests to successfully produce young, and the proportion of nests to fail. It requires locating nests, and then regularly observing it to identify if young are produced, or if the nest is preyed on. The Mayfield method (Mayfield 1961, Mayfield 1975) should be used.

Comments	References
• Time-consuming and requires skilled people to get good results and avoid disturbance of birds	Clout et al 1995 Mayfield 1961 Mayfield 1975 Johnson 1979

LARGE VERTEBRATE PEST DISTRIBUTION

The indicator

What is it?

The distribution of particular pest species, for example, deer, goats or pigs.

Discussion

As with plant pests, the distribution of animal pests is an important indicator. If animal pests are new arrivals to an area, they will potentially spread. Obtaining up-to-date information on distribution of animal pests allows managers to identify new introductions, and identify sites where eradication may be possible.

Ongoing changes in the distribution of an animal species, and their spread into new areas can be assessed.

Some key issues

The key issues are similar to those for other indicators involving assessment of distribution:

- Intensity (area covered and effort) of searching needs to be similar to make valid comparisons of changes in distribution over time, or between areas.
- What scale should distribution be assessed at? This needs to be determined depending on factors such as how large an area the species is spread over, and how precisely you need to know individual locations.
- If species are widespread throughout the area, examining distribution may be of little use.

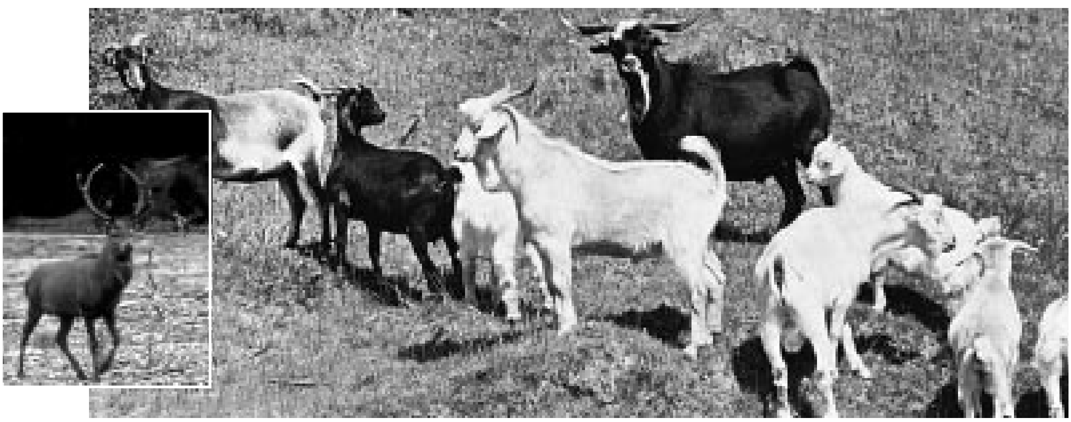
Measurement methods

As with monitoring the distribution of bird species, distribution can be identified by mapping individual records of animals, or by identifying if they are present in particular 'grid squares' following a traverse of the area.

Mapping of the distribution of populations is important for comparison with other ecological data. Standardisation of the scale of mapping is required. Mapping on 1:50,000 scale topographical maps is often the most appropriate.

In some situations, such as when the control is undertaken by forest managers or licensed commercial operators, records of the individual locations of hunting kills and observations can be maintained. This can provide indications of areas of animal activity and abundance.

Mapping data in an electronic GIS (Geographic Information System) format is useful for managers of large forest areas.



PHOTOS: DOC

FIGURE 43: Large vertebrate pests such as deer and goats can have major impact on forest ecosystems.

LARGE VERTEBRATE PEST ABUNDANCE

The indicator

What is it?

The relative, or absolute abundance of a particular animal pest species or group of pest species.

Discussion

Information on the abundance of animal pest species is important. Certain monitoring questions may mean you need to compare changes in browsing animal abundance to measures of vegetation condition, such as understorey density to examine how animal populations may be affecting vegetation.

The abundance of pest animals is important when examining the operational success of animal control operations.

Some key issues

- Make sure the pest species assessed is relevant to your monitoring question.
- If you are monitoring abundance, the animal needs to be common enough so you can readily locate it. Otherwise, it may be better to assess distribution.

Measurement methods

Faecal pellet counts

This method has been widely used for some time in New Zealand, particularly in studying deer populations. The method basically relies on a relationship between the amount of faecal pellets in an area and the size of animal populations. However, the amount of faecal pellets present can also be affected by other factors, particularly weather. Wet weather results in the faster decay of pellets so fewer pellets would be present. Conversely, dry weather reduces the rate of decay so more pellets would be present. There are ways of adjusting for these (Baddeley 1985), but they mean this method can be unreliable if you are trying to accurately examine change over time.

The assessment and results presented generally have two forms, which are often undertaken together.

- *Density:* The number of faecal pellet groups in small plots along a transect are counted. This is used to calculate the density (pellet groups per hectare) of pellet groups. As discussed above, the method can be affected by weather by increasing or decreasing the decay rates of pellets. To get useful estimates of pellet density, considerable effort can be required. Animal density estimates can be calculated, but rely on broad assumptions on defecation rate.
- *Frequency:* A simplified and commonly used method is to record just the presence of faecal pellet groups within a plot. Percentage frequency is then calculated for the survey to provide a measure of relative abundance that can be monitored over time. This has the same drawbacks as other frequency-based measures which are not very effective at picking up small changes in abundance.

Comments

- Needs to be treated with care, can produce unreliable results

References

Baddeley 1985

Hunter effort

This generally involves recording the number of animals killed per hunting day as a measure of relative abundance. It can be a useful method for monitoring of deer, goat and pig numbers. It can be enhanced to record animals seen and also hours hunted per day to increase reliability and information.

Records of helicopter hunting and animals killed per machine hour also provide valuable hunter effort information. Records of numbers seen can be recorded in situations where kills are not appropriate. These hunter effort methods provide an index of abundance. They can be affected by hunter skill and exposure of animals to hunting pressure.

Recreational hunter returns can be used to provide this information. There is often considerable concern about the accuracy of such returns because they rely on hunter honesty. Improvements to such systems can be achieved by concentrating record keeping on known reputable hunters, and phone and mail follow-up surveys.

Comments

- Can provide useful indications of abundance
- Difficult to pick up small changes
- Impacted by differences in hunter skill, and exposure of animals to hunting pressure

References

Henderson & Nugent 1989

Handford 1992

Hunted density

This method has been used particularly on goats. It involves setting up small hunting plots of perhaps 10-20ha and then carefully and thoroughly hunting the animals to extinction, over a short period, in this area. An estimate of density is obtained from the number of animals killed and the size of the area hunted.

Comments

- Requires careful planning and supervision to get meaningful results
- Potentially simple and useful method if undertaken carefully

Population model estimates

If there is some information on the trend in population density and the number of animals that are being shot from an area, crude estimates of total population and average population density can be made. This method requires access to information from other studies on the likely rate of population increase for the species.

As an example, if a deer population over an area of 10,000ha of forest has been shown from pellet surveys to have remained fairly stable, and about 150 deer have been shot in the area per annum, then all of the population's natural increase is being removed by hunting. If you assume a natural rate of increase of 30 percent per annum, then the total population would be around 150 x 1/0.3= 500, and the density would be 500/10 = 5 / km^2.

Comments

- Provides a check on the reasonableness of estimates produced from other measures
- Can be refined over time as more information is collected

LARGE VERTEBRATE PEST POPULATION STRUCTURE

The indicator

What is it?

Various features associated with individual animal pest species populations such as relative numbers of juveniles and adults, sex ratios, animal weight and condition.

Discussion

Information on aspects of individual animal pest population structure can provide indications of trends in these populations, and sometimes the relationship of the population with its habitat. For example, the presence of large numbers of juveniles may suggest the population is increasing. An increase in animal body weight may suggest an increase in the amount of food available from the understorey. A decline in bodyweight may suggest increasing competition within a larger population.

Trends within populations can often be complicated by many different factors. Specialist knowledge is often required in interpreting the changes.

Some key issues

- Make sure the feature of the population you are assessing is relevant to your monitoring question.
- Check you have some knowledge or experience of the population features being examined, so you will be able to draw some useful conclusions.

Measurement methods

Key information is usually:

- *Sex.*
- *Age:* on both deer and goats, age can be determined by counting annual rings on a cross section through the incisor teeth.
- *Condition:* where carcasses are extracted, such as in helicopter venison recovery, condition can be determined from carcass weight. The jawbone length in deer has also been used as an index of body size (Henderson & Nugent 1989).

Relationships between age and body size can identify the relative condition of a population.

POSSUM DISTRIBUTION

The indicator

What is it?

The distribution of possum populations within an area.

Discussion

Possums are present in most areas of mainland New Zealand. However, there are areas, particularly in the far north and far south where possums are not yet present or are just entering. Identifying and monitoring this distribution can be important to management. As with large animal pests, obtaining up-to-date information on the distribution of possums in new areas may allow identification of sites where eradication may be possible.

Abundance of possum populations may vary considerably between areas. Monitoring of the distribution of different abundance levels can provide useful information for management and allow comparison with other indicators providing information, such as, impacts on native vegetation.

Some key issues

The key issues are similar to those for other indicators involving assessment of distribution:

- Intensity (area covered and effort) of searching needs to be similar to make valid comparisons of changes in distribution over time, or between areas.
- What scale should distribution be assessed at?
- If possums are very widespread throughout the area, examining distribution may be of little use.

FIGURE 44: The possum is one of the most widespread and destructive forest pests in New Zealand.

PHOTO: DOC

Measurement methods

Distribution can be identified by mapping individual records of animals from trapping or poisoning, or through identifying if they are present in particular 'grid squares' following a traverse or other assessment of the area.

As with other indicators examining distribution, mapping of the distribution is important for comparison with other ecological data. Standardisation of the scale of mapping is required. Mapping on 1:50,000 scale topographical maps is often the most appropriate.

POSSUM ABUNDANCE

The indicator

What is it?

The relative, or absolute abundance of a possums.

Discussion

As a pest that has a great impact on native forests, and on agricultural production through the spread of tuberculosis, information on the abundance of possums in forest ecosystems is crucial.

Monitoring questions often require impacts on native forests, such as changes in canopy condition, to be compared with changes in possum abundance, to examine how possum populations may be affecting vegetation.

Some key issues

- In any areas that possums have recently colonised, or where densities are extremely low, measurement of abundance may be more difficult.

Measurement methods

Faecal pellet counts

This method has been less commonly used in recent times for assessing trends in possum populations. The presence of faecal pellets in small plots along a transect is recorded. This allows a percentage frequency to be calculated for the survey.

As with all pellet survey methods (*see* 'Large vertebrate pest abundance', p.153), this method can be affected by the impacts of weather in increasing or decreasing the decay rates of pellets. To get useful estimates of pellet density, considerable effort can be required. This method provides an index of abundance, not a direct measure.

Comments

- May be an option in some areas, for example, if trap catch cannot be used
- Usual variations associated with pellet counting methods need to be considered

References

Baddeley 1985

Morgan 1990

Trap catch

This method is the main method for assessing the relative density of possums in New Zealand, and it has also been widely used for the assessment of other small mammals such as rats and mice. Trap lines are set in accordance with a protocol (NPCA 2000) and the number of animals caught per 100 trap nights is used to assess relative population density. Traps are operated for three consecutive fine nights.

Comments

- The most widely used method in New Zealand
- Established measurement protocols

References

NPCA 2000

Trap to extinction

All the possums within a known area are trapped, and killed or removed over a short period (so no replacement breeding or immigration occurs). This allows estimation of density from the number of possums killed divided by the area trapped. Care must be taken to ensure all possums have actually been removed, and you are not just dealing with a 'trap-shy' population.

Comments

- Only practical over small areas because considerable effort is required
- Simple, and it provides control

References

Cowan & Waddington 1990

Bait take

This method involves assessment of interference with non-poisoned baits, or monitoring the removal of poisoned baits if control involving fixed bait stations is being undertaken. Records of bait taken from stations can give some indications of changes in possum populations. If high populations are present, a large proportion of bait will be taken, with lower populations a smaller proportion of bait will be taken. This method has been shown to be open to biases (Spurr 1995) when it is run over consecutive nights because the level of interference can increase from night to night as possums remember the location of baits. Adjustments can be made for this (Spurr 1995). It is not suitable when possums are at high numbers because all bait will be removed, making it difficult to compare populations above a certain level. However, it can potentially allow indicative monitoring of change over time on a site, at lower possum numbers. Having baits well spaced and using different random locations on each night may reduce bias.

Comments

- Care required to avoid bias
- Not effective with very high possum numbers

References

Spurr 1995

Waikato Conservation Board 1997

Damage and sign indices

Possums can produce conspicuous signs with bite marks and scratching on tree trunks, browsing of favoured canopy species, taking of fruit, etc. Visual assessment of this can be used to provide a qualitative index of possum numbers. Quantitative measurement of damage on vegetation or larger fruits of species such as tawa is possible and it can provide an index of populations.

However, these assessments can be misleading as indices of possum abundance because they are measuring the impacts rather than the actual population. For example, a large amount of possum browsing in an area may reflect the presence of larger numbers of favoured plant species that possums have travelled to from a considerable distance. It may not necessarily mean there are high possum numbers throughout the area. A change in the amount of damage on fruit may be affected by the amount of fruit produced in a year as well as possum abundance. If these interactions are taken into account, useful indications of changes in abundance can still be obtained.

Whenever examining changes in impacts on leaves or fruit, take care to separate possum damage from that caused by rodents or insects.

Comments	**References**
● Care required interpreting the results because this is an indirect measure of abundance which measures impact rather than populations	Payton et al 1999

POSSUM POPULATION STRUCTURE

The indicator

What is it?

Various features associated with individual possum populations such as relative numbers of juveniles and adults, sex ratios, possum weight and condition.

Discussion

As with large pest animals, information on possum population structure can be useful to provide indications of trends in the populations, and sometimes the relationship of the population with its habitat. For example, an increase in animal body fat may suggest an increase in a certain food source such as fruits (Cowan 1990), and a possible subsequent increase in population (Handford 1992). A decline in bodyweight may suggest increasing competition within a larger population.

Again, trends within populations can often be complicated by a influences from many different factors. Specialist knowledge is often required in interpreting the changes.

Some key issues

- Make sure the feature of the population you are assessing is relevant to your monitoring question.
- Check you have some knowledge or experience of the population features being examined so you will be able to draw some useful conclusions.

Measurement methods

Key information obtained is usually a combination of the following:

- *Sex.*
- *Age:* This can be determined on dead animals from counting the annual layers of cementum on a molar extracted from the lower jaw.
- *Body weight:* Possums can be easily weighed using a spring balance.
- *Presence of pouch young.*
- *Kidney fat levels* (in some scientific studies): On rare occasions this has been used as an index of condition. It involves removing kidneys from the body, dissecting and weighing the fat around the kidneys.

This information can be useful in identifying population trend. For example, identification of many small male possums in a population that has recently been reduced may indicate immigration from adjacent areas where possums are still common.

RODENT ABUNDANCE

The indicator

What is it?

The relative, or absolute abundance of a rodent species, for example, ship rat (*Rattus rattus*), Norway rat (*Rattus norvegicus*) and house mouse (*Mus musculus*).

Discussion

Rodents, particularly rats, have been shown to have great impacts on both vegetation, particularly through damage to flowers and fruit, and native wildlife, as predators and competitors.

Rodent populations undergo large fluctuations both seasonally, peaking in autumn and declining through winter, and between years (Innes 1990). Populations can decline by 90 percent between summer and winter (Warburton 1989). Fluctuation between years appears to be linked to available food source, fluctuations in predator numbers (for example, stoats and cats), and extremes of weather (Innes 1990 and also Brockie 1992). Presence of a high seed production can apparently influence breeding and survival resulting in peaks in populations. This is apparent for mice populations in relation to beech mast years and for rat populations in relation to high seedfalls of hinau and pigeonwood (Innes 1990, Murphy & Dowding 1995).

The presence of these large natural fluctuations can make using this indicator difficult. The usefulness of monitoring rodent populations and whether it will provide meaningful results needs to be carefully considered.

Some key issues

- Understand the large natural fluctuations that occur and how these may affect your monitoring.

FIGURE 45: Ship rat (*Rattus rattus*).

PHOTO : DOC

Measurement methods

Tracking tunnels

Involves setting up a small tunnel with an inkpad in the middle and paper at each end so the animal leaves its prints (*see* Figure 46). Each end of the tunnel is baited – usually with peanut butter. Species are identified by their tracks. The tracking frequency is then calculated from the percentage of tunnels tracked by different species.

PHOTO: DOC

FIGURE 46: Tracking tunnel

Comments

- Identification of tracks of different rodents requires care
- Tracking papers can be filed for subsequent re-analysis

References

King & Edgar 1977
Brown et al 1996
'Tracking tunnels for rodents and stoats', p. 79.

Trap catch

Similar method to that for possums, trap rate per 100 trap nights is used as an index of rodent numbers. Traps are set at a regular spacing through a forest area and baited with a mix of peanut butter and rolled oats. Traps are set for three consecutive fine nights, checked and reset each day. Half a trap night is subtracted for sprung but empty traps.

Comments

- Widely used method, considerable comparative data available

References

Cunningham & Moors 1983
Brockie 1992
Fitzgerald 1978
Innes 1990
Warburton 1989

Bait interference

Waxed baits are set and teethmarks recorded. The number of baits chewed is used to calculate a percentage of frequency of bait interference. It may sometimes be possible to identify general differences between mouse and rat teethmarks, but this can be difficult. This method has some limitations in very high rodent densities because all baits may be interfered with, making it is difficult to gain an idea of relative abundance. Individual animals may interfere with more than one bait (particularly if they are not sufficiently spaced), and may return to baits on subsequent nights.

Comments

- Care required to avoid bias
- Not effective at very high numbers
- Experience required to separate species teethmarks

References

'Rodent 'gnaw stick' bait interference', p.83.
Waikato Conservation Board 1997
Warburton 1989
Spurr 1995

STOAT ABUNDANCE

The indicator

What is it?

The relative, or absolute abundance of stoats.

Discussion

Stoats are a significant predator of native wildlife, particularly birds. They are present throughout mainland New Zealand, and can range widely, with home ranges of perhaps 100-200 hectares or more (King 1990). Stoats have been recorded as moving more than 20km in a period of a few weeks.

Abundance varies seasonally with lowest densities in winter and spring, and highest during summer. It also varies greatly with food supply in spring (King 1990). This has been shown in beech forests where higher mouse populations are sustained in the winter following a mast seedfall, which results in much higher stoat reproduction the following spring and high stoat numbers over that summer. Abundance then falls away to more usual densities by the following winter

Stoats are generally present at relatively low densities. Trap catch indices of <1 / 100 trap nights are common, with occasional peaks up to 5 / 100 trap nights. Tracking frequencies may be in the 1-5 % range. This means that large samples and considerable effort may be required to provide useful information on relative abundance, and changes following control operations (Brown & Miller 1998).

The presence of large natural fluctuations, large home ranges, and high mobility mean stoats can quickly re-enter areas where they are not currently present, making the use of this indicator difficult. As with rodents, the usefulness of monitoring stoat populations and whether it will provide meaningful results needs to be carefully considered.

Some key issues

- Low population densities means considerable work is required to monitor abundance.
- It is important to understand the large natural fluctuations that are likely to occur and how these will affect your monitoring.

FIGURE 47: Stoat (*Mustela erminea*).

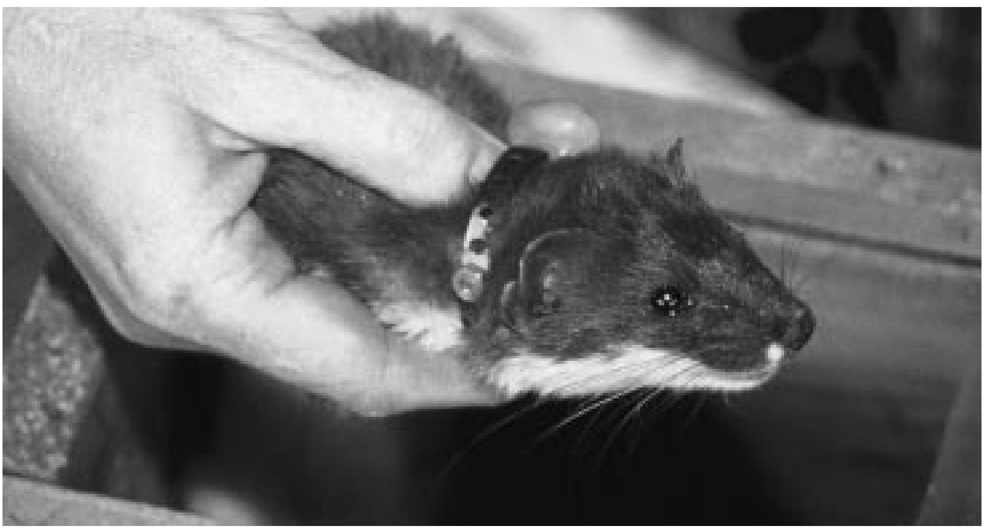


PHOTO: DOC

Measurement methods

Tracking tunnels

As described for rodents, baited tracking tunnels are established containing a central inkpad and tracking papers at each end. The number of tunnels containing stoat tracks is used to calculate a percentage of tracking frequency. Methodology for establishing these tracking tunnels is described in 'Tracking tunnels for rodents and stoats', p.79-82, and can also be found in King & Edgar (1977). Brown & Miller (1998), examine sampling requirements.

Comments

- Identification of tracks requires care
- Care required to standardise approach to handling and setting tunnels to allow valid comparison
- Tracking papers can be filed for subsequent re-analysis.

References

'Tracking tunnels for rodents and stoats', p.79
King & Edgar 1977
Brown et al 1996
Brown & Miller 1998

Trap catch

This involves a similar approach to that described for rodents and possums, with traps normally set out at a regular spacing along transects and the catch rate recorded. Because of the relatively low densities of stoats, traps need to be operated for a considerable period, for example, 40-50 traps for 7-14 days. Details on trap catch monitoring of stoats can be found in King & Edgar 1977.

Comments

- Widely used method, some comparative data available

References

King & Edgar 1977
King 1990

CAT ABUNDANCE

The indicator

What is it?

The relative, or absolute abundance of cats.

Discussion

- Cats can be important in forest ecosystems through their impacts on rodents, birds, and invertebrates (Brockie 1992).
- Relatively low population density, and evasive nature of cats, means use of this indicator is usually only suited to scientific research.

Measurement methods

The relatively low density of cats within native forest means that direct measure from, for example, trap catch indices is not generally suitable. Abundance is normally monitored in a generalised way from records of sightings and accidental trapping of cats in possum traps (Brockie 1992). Methods involving the use of 'chalk boards' to obtain foot prints in a similar way to tracking tunnels are currently being examined.

FIGURE 48: Feral cats can be important predators of birds, invertebrates and rodents.

PHOTO: DOC

ALL VERTEBRATE PESTS – GENERAL COMMENTS

General records on the presence of pest animals sighted in a forest area, and observations on their activity can be useful, and important background to other monitoring. Two broad approaches to this are briefly described below.

Observation records

Ongoing records of the numbers of animals seen as people work in or visit the forest can be useful. Also recording the time spent in the forest is important to identify increased sightings caused by a greater number of observers in the forest. Often animals such as goats or cats may have distinctive markings that can be recognised. These can be recorded to allow information to build up about the movement of a particular individual.

Visual assessments

From a combination of the amount of distinctive sign seen such as footprints, faeces, territorial marking, predation and approximate frequency of sightings, a broad assessment of abundance can be gained. An example of such a system that includes some more common animal pests is attached in 'General surveillance checklist for forest ecosystems', p.21.

INVERTEBRATES

The indicator

What is it?

The abundance of particular groups of invertebrates.A variety of other indicators for features such as invertebrate species diversity are possible.

Discussion

Invertebrate monitoring is potentially important and useful because invertebrates far outweigh all other terrestrial species in number with an estimated 20,000 to 30,000 species in New Zealand. Invertebrates carry out a wide range of roles in New Zealand ecosystems such as indigenous forests (Hutcheson et al 1999). Studies also indicate close relationships between insect communities and their habitat (Hutcheson et al 1999). Close relationships between invertebrate populations, birds and introduced predator populations have been suggested (Murphy and Dowding 1995) in some forests.

The key issue with the use of invertebrates as an indicator is their complexity and the large requirement for improved knowledge. In New Zealand it is thought that only about half the 20,000 to 30,000 species have been named and described. Monitoring of beetle species has been suggested as the most attractive invertebrate indicator for New Zealand (Hutcheson et al 1999). In most cases, monitoring of invertebrates is more in the realm of detailed scientific study, though this is likely to change in future as more information becomes available.

Some key issues

- Lack of identification skills.
- Lack of knowledge of New Zealand invertebrate fauna.

PHOTOS: DOC

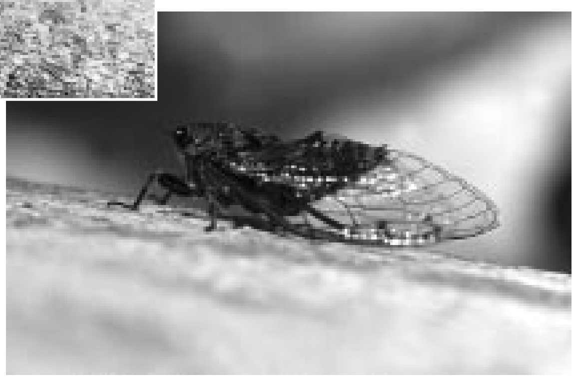


FIGURE 49: Tree weta (above) and cicada. There are an estimated 20,000-30,000 invertebrate species in New Zealand.

Measurement methods

A variety of methods have been used to trap invertebrates at various levels in the forest, search leaf litter layers, and trap invertebrates travelling up and down tree stems (Brockie 1992, Hutcheson et al 1999).

Sampling for invertebrates should occur during the period when they are most prevalent – between spring and autumn. Samples should be restricted to a shorter period within this, for example, four weeks in December (Hutcheson et al 1999).

Two of the most commonly used sampling methods for assessing invertebrates are:

Pit fall traps

Small containers are dug into the forest floor so invertebrates fall into them for later collection, identification and counting. Containers are shielded from the rain so they do not fill with water, and have some form of preservative solution in the bottom of the container to preserve insects when traps are left for an extended period. A plastic dinner plate supported above the ground on wire pegs can be used to keep rain out of traps, and a saturated sodium chloride (common salt) solution used as the preservative (Hunt et al 1998). Small 'fences' running out from the trap may be used to guide invertebrates and increase the catch.

There is concern from some studies (Hutcheson et al 1999) that this method does not always give reliable and useful results, and samples a relatively small part of the insect fauna. However, it is generally easier to establish this type of study than to use malaise traps.

Comments	References
• Likely to be easier to use than malaise traps, but only samples ground dwelling invertebrates	Brockie 1992 Hunt et al 1998
• Lack of identification knowledge is a problem	Hutcheson et al 1999

Malaise traps

These are designed to capture low level flying and hatching invertebrates, which are herded into a container for identification and counting. A small tent-like structure is erected to trap invertebrates emerging from the ground as well as those flying within about a metre of the ground. Studies suggest the majority of invertebrate biodiversity is in this zone (Hutcheson et al 1999).

Comments	References
• May be more effort than pit fall traps, but samples a greater range of invertebrates	Hutcheson et al 1999
• Lack of identification knowledge is a problem	

CLIMATE

The indicator

What is it?

Records of important climate measures that may affect forest ecosystems such as monthly maximum and minimum temperatures, monthly rainfall, salt laden storms, and major windstorm events.

Discussion

Climate can have important impacts on forest condition, through damage caused by salt laden storms 'burning' foliage, drought stress, or damage from windstorms. There also appear to be relationships between climate and fruiting and flowering intensity for some species. For example, hinau fruiting intensity appears to be linked to temperature in the previous summer (Cowan & Waddington 1990).

Obtaining basic climate information relevant to the forest area being monitored can be important in interpreting monitoring results.

Some key issues

- Identify existing sources of climate data relevant to your site. There is often good data being recorded, you may just need to get occasional access to this information.

Measurement methods

Organisations such as National Institute of Water and Atmospheric Research (NIWA) should be consulted for availability of data. Useful information includes monthly information on:

- Maximum and minimum temperatures
- Total wind run
- Wind directions
- Rainfall

Make simple observations of climatic events in your area, for example, a period of strong salt laden winds which occurred between certain dates, or that the area is very dry, and certain tree species are wilting.

When dealing with small forest remnants, changes in microclimate can be important. The most common change that can occur is an increase or decrease in exposure to wind because of a change in shelter. A common example is where plantation forest is harvested from around a small native remnant, which is then more exposed to the extremes of climate.

FIGURE 50: Climate has major impact on forest ecosystems.

PHOTO: DOC

HYDROLOGICAL/DRAINAGE CONDITIONS

The indicator

What is it?

Drainage conditions including aspects such as height of the water table, and presence of any surface water.

Discussion

Drainage conditions are important in determining which type of forest vegetation occurs on a particular site. Subsequent changes in drainage conditions have an important impact on vegetation condition. For example, a small remnant of kahikatea swamp forest may decline in condition if adjacent agricultural drainage lowers the water table. Alternatively, a change in drainage patterns that results in more surface water being present in an area of forest reserve may kill species requiring good drainage.

Some key issues

- Drainage is only likely to be an issue in flatter terrace or plain areas.

Measurement methods

If detailed information on water table level is required, holes can be dug in the area to form small wells. The water level within these wells can then be monitored. It is important to obtain information on the period for which the water table is at a certain level. The water table may fluctuate in height, but it is longer term changes that are likely to be most significant.

Records of observations can be kept on the presence of surface water or flooding in the area, and how long this surface water stays. This can provide an indication of the frequency of flooding.

Observations on changes in drainage patterns are useful, such as a changing stream course affecting the area, or development of a drainage system in association with agricultural or urban development.

FIGURE 51: Changes in drainage patterns, due to natural causes or human development, can have important impacts on vegetation.

PHOTO: DOC

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APPENDICES

1. PLANT NAMES USED IN THE TEXT Scientific names, six letter codes & common names

SCIENTIFIC NAME	6-LETTER CODE	MAORI NAME	OTHER COMMON NAME
Agathis australis	AGAAUS	kauri	
Alectryon excelsus	ALEEXC	titoki	
Alepis flavida	ALEFLA		mistletoe
Alseuosmia species	ALSEUO		
Aristotelia serrata	ARISER	makomako	wineberry
Ascarina lucida	ASCLUC	hutu	
Asplenium bulbiferum	ASPBUL	mauku	hen & chickens fern
Asplenium flaccidum	ASPFLA	raukatauri	drooping spleenwort
Asplenium oblongifolium	ASBOBL		shining spleenwort
Astelia species	ASTELI		
Beilschmiedia species			
Beilschmiedia tarairi	BEITAR	taraire	
Beilschmiedia tawa	BEITAW	tawa	
Blechnum fluviatile	BLEFLU	kiwakiwa	ray water fern
Blechnum chambersii	BLECHA		lance fern
Brachyglottis repanda	BRAREP	rangiora	bushmans friend
Carpodetus seratus	CARSER	putaputaweta	marble leaf
Cassinia leptophylla	CASLEP	tauhinu	cottonwood
Clematis paniculata	CLEPAN	puawananga	white clematis
Clianthus species			kaka beak
Coprosma ciliata	COPCIL		
Coprosma foetidissma	COPFOE	hupiro	stinkwood
Coprosma grandifolia	COPGRA	kanono	
Coprosma lucida	COPLUC	karamu	
Coprosma pseudocuneata	COPPSE		
Coprosma repens	COPREP	taupata	
Coprosma rhamnoides	COPRHA		
Coprosma robusta	COPROB	karamu	
Coprosma rotundifolia	COPROT		round leaved coprosma
Coprosma species	COPROS		
Coprosma tenuifolia	COPTEN		
Cordyline species	CORDYL		cabbage tree
Coriaria aborea	CORARB	tutu	
Corynocarpus laevigatus	CORLAE	karaka	
Cyathea dealbata	CYADEA	ponga	silver tree fern
Cyathea medullaris	CYAMED	mamaku	
Cyathea smithii	CYASMI	katote	soft tree fern
Dacrycarpus dacrydioides	DACDAC	kahikatea	white pine
Dacrydium cupressinum	DACCUP	rimu	red pine
Dicksonia fibrosa	DICFIB	wheki ponga	
Dicksonia squarrosa	DICSQU	wheki	rough tree fern
Dysoxylum spectabile	DYSSPE	kohekohe	
Earina autumnalis	EARAUT	raupeka	easter orchid
Elaeocarpus dentatus	ELADEN	hinau	
Elaeocarpus hookerianus	ELAHOO	pokaka	
Elaeocarpus species			
Fuchsia excorticata	FUCEXC	kotukutuku	tree fuchsia
Fuchsia species			
Geniostoma rupestre	GENRUP	hangehange	
Griselinia littoralis	GRILIT	papauma	broadleaf
Griselinia species			
Hebe stricta	HEBSTR		
Hedycarya arborea	HEDARB	porokaiwhiri	pigeonwood
Histiopteris incisa	HISINC	mata	water fern
Hoheria species			lacebark, ribbonwood
Ileostylus micranthus	ILEMIC		small flowered mistletoe
Knightia excelsa	KNIEXC	rewarewa	
Kunzea ericoides	KUNERI	kanuka	
Laurelia novae-zelandiae	LAUNOV	pukatea	
Leucopogon fasciculatus	LEUFAS	mingmingi	
Libocedrus bidwillii	LIBBID	kaikawaka	
Litsea calicaris	LITCAL	mangeao	
Lophomyrtus bullata	LOPBUL	ramarama	
Macropiper excelsum	MACEXC	kawakawa	
Melicope ternata	MELTER	wharangi	
Melicytus ramiflorus	MELRAM	mahoe	
Metrosideros diffusa	METDIF	akatea	white climbing rata
Metrosideros excelsa	METEXC	pohutukawa	
Metrosideros fulgens	METFUL		scarlet climbing rata
Metrosideros robusta	METROB	rata	northern rata
Metrosideros species	METROS		
Metrosideros umbellata	METUMB		southern rata
Microlaena avenacea	MICAVE		bush rice grass
Muehlenbeckia australis	MUEAUS	pohuehue	
Myoporum species			
Myrsine australis	MYRAUS	mapou	red matipo
Myrsine divaricata	MYRDIV		weeping matipo
Myrsine salicina	MYRSAL	toro	
Neomyrtus pedunculata	NEOPED	rohutu	
Nestegis cunninghamii	NESCUN	maire	black maire
Nestegis lanceolata	NESLAN		white maire
Nothofagus menziesii	NOTMEN	tawhai	silver beech
Nothofagus solandri var cliffortioides	NOTCLI	tawhairauriki	mountain beech
Nothofagus species			beech
Olearia rani	OLERAN	heketara	
Pennantia corymbosa	PENCOR	kaikomako	
Peraxilla colensoi	PERCOL	korukoru	mistletoe
Peraxilla species			mistletoe
Peraxilla tetrapetala	PERTET	pirirangi	mistletoe
Phormium species			flax
Phyllocladus spp			
Pittosporum crassifolum	PITCRA	karo	
Pittosporum eugenoides	PITEUG	tarata	lemonwood
Pittosporum species	PITTOS		
Pittosporum tenufolium	PITTEN		
Pittosporum umbellatum	PITUMB	haekaro	
Planchonella costata	PLACOS	tawapou	
Podocarpus hallii	PODHAL		halls totara
Podocarpus totara	PODTOT	totara	lowland totara
Polystichum vestitum	POLVES		prickly shield fern
Prumnopitys ferruginea	PRUFER	miro	brown pine
Prumnopitys taxifolia	PRUTAX	matai	black pine
Pseudopanax arboreus	PSEARB		five finger
Pseudopanax colensoi	NEOCOL		mountain five finger
Pseudopanax crassifolius	PSECRA		lancewood
Pseudopanax edgerleyi	PSEEDG	raukawa	
Pseudopanax simplex	PSESIM	haumakaroa	seven finger
Pseudowintera axillaris	PSEAXI	horopito	lowland pepper tree
Pseudowintera colorata	PSECOL	horopito	alpine pepper tree
Quintinia serrata	QUISER	tawherowhero	
Rhopalostylis sapida	RHOSAP	nikau	
Ripogonum scandens	RIPSCA		supplejack
Rubus cissoides	RUBCIS		bush lawyer
Rubus species	RUBUS		bush lawyer
Schefflera digitata	SCHDIG	pate	
Sophoroa species		kowhai	
Syzygium maire	SYZMAI		swamp maire
Tradescantia fluminencis			wandering jew/willie
Uncinia species	UNCINI		hook grass
Vitex lucens	VITLUC	puriri	
Weinmannia racemosa	WEIRAC	kamahi	
Weinmannia silvicola	WEISIL	towai	

2. PLANT SPECIES BROWSED BY ANIMAL PESTS

The following lists are not exhaustive, but are based on information in the references listed.

The browse preference given below is indicative only as preference will vary with location & other species available.

Plants identified as palatable to possums

SCIENTIFIC NAME	COMMON NAME	BROWSE PREFERENCE	REFERENCE
Alectryon excelsum	titoki	High	(2), (4),(7)
Aristotelia serrata	wineberry	Med – High	(5), (12), (11)
Asplenium bulbiferum	hen & chicken fern	Low	(12)
Beilschmiedia tawa	tawa	Med – High	(2), (4), (3), (7),(8)
Blechnum fluviatile		Low	(12)
Blechnum chambersii		Low	(12)
Brachyglottis repanda	rangiora	Med	(7)
Carpodetus seratus	putaputaweta	Low	(12), (11)
Clematis paniculata		Low	(12)
Coprosma foetidissma		High	(9)
Coprosma lucida	karamu	Low – High	(5), (12)
Coprosma repens	taupata	High	(4), (5)
Coprosma species	large leaved coprosma	High	(11)
Coriaria aborea	tutu	Med	(7), (4)
Cyathea medullaris	mamaku	High	(3), (5), (8)
Dacrydium cupressinum	rimu	Low	(12)
Dicksonia squarrosa		Low	(12)
Dysoxylum spectabile	kohekohe		(3), (4), (5)
Elaeocarpus dentata	hinau	low	(7), (4)
Elaeocarpus hookerianus	pokaka	Med – High	(3), (5), (12),(11)
Fuchsia excorticata	tree fuchsia	High	(2), (4), (3), (5), (12), (7), (9),(11)
Griselinia littoralis	broadleaf	Low	(12)
Hoheria species	ribbonwood	High	(5)
Libocedrus bidwillii	kaikawaka	Low – High	(5), (12)
Melicope ternata	wharangi	High	(5)
Melicytus ramiflorus	mahoe	Med	(2), (5), (7), (9), (11)
Metrosideros diffusa	pohutukawa	Low	(12)
Metrosideros excelsa	pohutukawa	High	(4), (5)
Metrosideros fulgens	scarlet rata vine	Med	(2), (7)
Metrosideros robusta	northern rata	High	(2), (8), (4), (7), (3)
Metrosideros umbellata	southern rata		(4), (5), (12), (9)
Muehlenbeckia australis			(7)
Myrsine australis		Low	(12)
Myrsine salicina	toro	High	(2)
Nestegis cunninghamii	black maire	Low	(11)
Nestegis lanceolata	white maire		(4)
Nothofagus species		Low	(5), (12)
Peraxilla species	mistletoe	High	(5)
Pittosporum umbellatum		High	(5)
Podocarpus hallii	Hall's totara	High	(4), (5), (12), (9), (11)
Polystichum vestitum	prickly shield fern	Low	(12)
Pseudopanax arboreus	five finger	High	(4), (5), (12), (7), (2)
Pseudopanax colensoi	mountain five finger	Med	(12)
Pseudopanax crassifolius	lancewood	Med	(12)
Pseudopanax edgerleyi	raukawa	High	(5)
Pseudopanax simplex	haumakaroa, seven finger	High	(9), (12), (11)
Pseudopanax species		High	(9)
Ripogonum scandens	supplejack	Med	(2)
Rubus cissoides	bush lawyer	Med	(12)
Rubus species	bush lawyer	Med – High	(7), (9), (11)
Schefflera digitata	pate	Med – High	(5), (12)
Syzygium maire	swamp maire		(4)
Uncinia species	hook grass	Low	(12)
Weinmannia racemosa	kamahi	High	(2), (4), (5), (12), (7), (8), (9), (11)

Plants identified as unpalatable to possums

SCIENTIFIC NAME	COMMON NAME	REFERENCE
Agathis australis	kauri	(5)
Beilschmiedia tarairi	taraire	(5)
Cyathea dealbata	silver tree fern	(8)
Cyathea smithii	smiths tree fern	(8)
Dacrydium cupressinum	rimu	(11)
Griselinia littoralis	broadleaf	(11)
Hedycarya arborea	pigeonwood	(8)
Laurelia novae-zelandiae	pukatea	Brockie 1993, (8)
Phyllocladus spp		(11)
Pseudowintera colorata	pepper tree	(11)
Quintinia serrata		(11)
Prumnopitys taxifolia	matai	(11)

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3 Atkinson 1992
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6 Blaschke 1992
7 Brockie 1992
8 Campbell 1990
9 Coleman et al 1985
10 Mitchell et al 1987
11 Nugent et al 1997
12 Wardle 1984

Plants identified as palatable to deer and goats

SCIENTIFIC NAME	COMMON NAME	PALATABLE TO	BROWSE PREFERENCE	REFERENCE
Alseuomia macrophylla		Goat		(6)
Aristotelia serrata	wineberry	Deer	Med	(11)
Asplenium bulbiferum	hen & chicken fern	Deer & Goat	High	(1), (12), (7), (10)
Astelia species		Deer	Med	(12)
Beilschmiedia tawa	tawa	Deer	Med	(1)
Carpodetus seratus	putaputaweta	Deer & Goat	Med-High	(1), (7), (11)
Coprosma ciliata		Deer	Med	(12)
Coprosma foetidissma		Deer	Med	(12)
Coprosma grandifolia		Deer & Goat	High	(1), (6), (10)
Coprosma lucida	karamu	Deer & Goat	High	(12), (6)
Coprosma pseumdocuneata		Deer	Med	(12)
Coprosma rhamnoides		Deer	Med	(12)
Coprosma robusta		Goat	High	(6)
Coprosma species	large leaved coprosma species	Deer & Goat	High	(12), (7), (11)
Coprosma tenuifolia		Goat	High	(10)
Dicksonia squarrosa		Goat	High	(10)
Elaeocarpus dentata	hinau	Goat	Med	(6)
Elaeocarpus hookerianus	pokaka	Deer	Med	(11)
Fuchsia excorticata	tree fuchsia	Deer & Goat	High	(12), (6), (11)
Geniostoma rupestre	hangehange	Deer & Goat	High	(1), (6)
Griselinia littoralis	broadleaf	Deer & Goat	High	(7),(10), (11), (12)
Hebe stricta		Goat	Med	(6)
Hedycarya arborea	pigeonwood	Goat	High	(6)
Hoheria	ribbonwood	Goat	High	(7)
Macropiper excelsum	kawakawa	Goat	High	(7)
Melicytus ramiflorus	mahoe	Deer & Goat	High	(1), (6), (7), (10), (11)
Metrosideros fulgens	scarlet rata vine	Goat	High	(7)
Myrsine australis		Deer & Goat	Med	(12), (6)
Myrsine divaricata		Deer	High	(12)
Nestegis cunninghamii	black maire	Deer	Low	(11)
Nothofagus menziesii	silver beech	Deer	Med	(12)
Nothofagus solandri var cliffortioides	mountain beech	Deer	Med	(12)
Nothofagus species		Deer	Low	(1)
Pittosporum tenufolium		Deer	Med	(1)
Polystichum vestitum	prickly shield fern	Deer & Goat	Med - High	(12), (7)
Prumnopitys ferruginea	miro	Deer	low	(11)
Prumnopitys taxifolia	matai	Deer	low	(11)
Pseudopanax arboreus	five finger	Deer	High	(1), (12), (7), (11)
Pseudopanax colensoi	mountain five finger	Deer	High	(12)
Pseudopanax crassifolius	lancewood	Deer	Med-High	(12), (11)
Pseudopanax edgerleyi	raukawa	Goat	High	(7)
Pseudopanax simplex	haumakaroa, seven finger	Deer & Goat	High	(1), (7), (11)
Pseudopanax species		Deer	High	(12)
Quintinia serrata		Deer	low	(11)
Ripogonum scandens	supplejack	Deer & Goat	High	(1), (10)
Rubus species	bush lawyer	Deer	Med	(11)
Schefflera digitata	pate	Deer & Goat	Med-High	(12), (7), (10)
Weinmannia racemosa	kamahi	Deer & Goat	High	(12), (6), (7), (10), (11)
	drooping & shining spleenworts	Goat	High	(7)

Plants identified as unpalatable to deer or goats

SCIENTIFIC NAME	COMMON NAME	UNPALATABLE TO	REFERENCE
Blechnum fluviatile		Goat	(10)
Cassinia leptophylla	tauhinu	Goat	(7)
Cyathea dealbata	silver tree fern	Goat	(7)
Cyathea smithii	Smith's tree fern	Goat	(7), (10)
Cyathodes fasciculata		Deer	(1)
Dacrydium cupressinum	rimu	Deer	(11)
Dicksonia fibrosa	wheki tree fern	Goat	(7)
Histiopteris incisa		Goat	(7)
Kunzea ericoides	kanuka	Goat	(7)
Microlaena avenacea	bush rice grass	Goat	(10)
Phyllocladus spp		Deer	(11)
Podocarpus hallii	Hall's totara	Deer	(11)
Pseudowintera axillaris	horopito	Goat	(7)
Pseudowintera colorata	pepperwood, horopito	Deer & Goat	(1), (7), (11)
Uncinia species	hook grass	Deer & Goat	(1), (10)

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3 Atkinson 1992
4 Atkinson et al 1995
5 Batcheler & Cowan 1988
6 Blaschke 1992
7 Brockie 1992
8 Campbell 1990
9 Coleman et al 1985
10 Mitchell et al 1987
11 Nugent et al 1997
12 Wardle 1984

3. FRUITING AND FLOWERING NATIVE PLANT SPECIES USED BY NATIVE BIRDS

Flowers

PLANT SPECIES	bellbird	brown creeper	brown kiwi	fantail	grey warbler	kaka	kea	kereru	kokako	rifleman	silvereye	tomtit	tui	weka	yellow crowned parakeet	yellowhead	REFERENCE
Alseuosmia species	x												x				(3)
Aristotelia serrata								x									(4)
Beilschmiedia species	x												x				(3)
Clianthus species	x												x				(3)
Coprosma foetidissma								x			x						(5)
Coprosma rotundifolia				x													(5)
Cordyline species	x												x				(3)
Dysoxylum spectabile	x												x				(1), (3)
Earina autumnalis						x											(5)
Elaeocarpus dentatus	x												x				(1), (3)
Fuchsia excorticata	x					x	x	x			x		x				(1),(3), (5), (4)
Geniostoma rupestre	x												x				(1)
Knightia excelsa	x												x				(1), (3)
Kunzea ericoides	x																(1)
Metrosideros excelsa	x												x				(1)
Metrosideros fulgens	x												x				(1)
Metrosideros robusta	x												x				(1)
Metrosideros species	x												x				(3)
Metrosideros umbellata	x					x	x				x		x				(5)
Myoporum species	x												x				(3)
Nothofagus menziesii						x					x						(5)
Peraxilla species	x					x		x			x		x				(5), (3)
Phormium species	x												x				(1), (3)
Pittosporum crassifolum	x												x				(1)
Pittosporum eugenoides	x												x				(1)
Pittosporum species	x												x				(3)
Pittosporum tenufolium	x												x				(1)
Pseudopanax arboreus	x												x				(1)
Pseudopanax species	x												x				(3)
Sophoroa species	x												x				(1), (3)
Vitex lucens	x												x				(1), (3)
Weinmannia racemosa	x					x					x		x				(1), (5)

Fruit

Alectryon excelsus								x	x				x				(6), (2), (4)
Aristotellia fruticosa	x												x				(6)
Aristotellia serrata	x							x			x						(5), (4)
Ascarina lucida	x			x							x	x					(5)
Beilschmiedia tarairi								x									(2), (4)
Beilschmiedia tawa								x									(2), (4)

Fruit

PLANT SPECIES	bellbird	brown creeper	brown kiwi	fantail	grey warbler	kaka	kea	kereru	kokako	rifleman	silvereye	tomtit	tui	weka	yellow crowned parakeet	yellowhead	REFERENCE
Carpodetus serratus	x					x					x		x				(5)
Coprosma foetidissma	x			x		x		x			x				x		(5)
Coprosma grandifolia	x							x					x				(6), (4)
Coprosma lucida	x							x					x				(5), (4)
Coprosma robusta	x							x					x				(6), (4)
Coprosma rotundifolia											x						(6), (5)
Coprosma species	x	x						x			x	x					(5), (4)
Coriaria aborea	x							x			x						(6), (5)
Corynocarpus laevigatus								x									(2), (4)
Dacrycarpus dacrydioides	x							x			x		x				(6), (5), (4)
Dacrydium cupressinum	x					x		x		x	x	x			x		(5), (4)
Dysoxylum spectabile								x	x								(2), (4)
Elaeocarpus dentatus			x					x	x					x			(2), (4)
Elaeocarpus hookerianus	x							x									(4), (5)
Fuchsia excorticata	x			x				x			x						(6), (5), (4)
Geniostoma rupestre								x									(4)
Griselinia littoralis					x			x								x	(5)
Griselinia species								x									(4)
Hedycarya arborea	x					x		x	x				x	x			(5), (2), (4)
Ileostylus micranthus	x												x				(6)
Litsea calicaris								x	x								(2), (4)
Lophomyrtus bullata								x									(4)
Macropiper excelsum	x							x					x				(6), (4)
Melicytus ramiflorus	x							x					x				(6), (4)
Muehlenbeckia australis	x												x				(6)
Myrsine australis	x							x			x						(5)
Myrsine divaricata	x										x						(5)
Neomyrtus pedunculata	x										x						(5)
Nestegis cunninghamii								x	x				x				(2)
Pennantia corymbosa								x									(5)
Peraxilla species	x					x					x						(5)
Planchonella costata								x									(2)
Podocarpus hallii	x					x					x		x		x		(6), (5)
Prumnopitys ferruginea	x					x		x	x				x	x			(5), (2), (4)
Prumnopitys taxifolia								x	x				x	x			(6), (2)
Pseudopanax arboreus	x												x				(6)
Pseudopanax colensoi											x						(5)
Pseudopanax crassifolius	x	x			x	x		x			x	x					(5)
Pseudopanax edgerleyi	x			x		x				x	x	x	x				(5)
Pseudopanax simplex	x	x			x			x		x	x	x					(5)
Pseudowintera colorata	x							x			x						(5)
Rhopalostylis sapida			x					x	x								(2)
Ripogonum scandens	x					x		x	x		x		x				(6), (5), (2)
Schefflera digitata								x			x		x				(5)
Syzygium maire								x									(2)
Vitex lucens								x									(2)

REFERENCES
1 Castro & Robertson 1997
2 Clout & Hay 1989
3 Craig et al 1981
4 McEwen 1978
5 O'Donnell & Dilks 1994
6 Williams & Karl 1996

4. FLOWERING & FRUITING PERIODS FOR SOME PLANT SPECIES

from Payton et al 1999

SPECIES		AREA & INFORMATION SOURCE								
		(a)	NZ 1	NZ 3,(b)	North-land 4	Central North Island 5	Welling-ton 6	Canter-bury 7	West-land 8	Stewart Island 9
EMERGENT TREES										
Metrosideros robusta	Northern rata	Fl Fr	Nov-Jan Dec-Jan	Nov-Jan	Dec-Feb Jan-Apr	Dec-Jan	 May			
Podocarpus totara & P. hallii	Lowland totara & Hall's totara	(c) (d)		Sep-Oct Apr-May	 Jan-Dec	Dec Jan-Dec	Oct-Dec Feb-May	 Jan-Jun	 Feb-Aug	
CANOPY TREES										
Alectro excelsus	Titoki	Fl Fr	Oct-Dec Oct-Dec	Oct-Nov						
Beilschmiedia tawa	Tawa	Fl Fr	Sep-Dec Oct-Feb	Sep-Nov	Nov-Dec Jan-Dec	Dec-Feb Dec-May				
Dysoxylum spectabile	Kohekohe	Fl Fr	Mar-Jun Apr-Aug	Apr-May Jul-Aug	May-Jul Jan-Dec	Apr-Jul Aug-Feb				
Elaeocarpus dentatus	Hinau	Fl Fr	Oct-Feb Dec-May	Oct-Feb	Nov-Dec Jan-Jul	Oct-Jan Dec-Jun	Nov-Apr Mar-Aug			
Elaeocarpus hookerianus	Pokaka	Fl Fr	Oct-Jan Nov-Mar						 Feb-Jun	Jan Mar
Melicytus ramiflorus	Mahoe	Fl Fr	Nov-Feb Nov-Mar	Sep-Apr Feb-Jun	Oct-Mar	Oct-Mar Nov-Jun	Oct-Apr Nov-Jul	Dec-Jan Jan-Jul	 Feb-Aug	
Metrosideros excelsa	Pohutukawa	Fl Fr	Dec-Jan Jan-Feb	Dec-Jan						
Metrosideros umbellata	Southern rata	Fl Fr	Nov-Mar Dec-Apr	Nov-Jan					Oct-Feb	Nov-Feb Mar-May
Weinmannia racemosa	Kamahi	Fl Fr	Dec-Jan Jan-Apr	Nov-Jan		Oct-Jan Dec-Mar	Sep-May		Sep-Feb	Oct-Dec Jan-Apr
Weinmannia silvicola	Towai	Fl Fr	Sep-Dec Nov-Feb	Sep-Dec	Jan-Aug Dec-Oct					
SUBCANOPY TREES & SHRUBS										
Aristotelia serrata	Wineberry	Fl Fr	Sep-Dec Nov-Jan	Sep-Dec Jan-Feb	Oct-Nov Nov-Mar	Oct-Dec Nov-May	Oct-Nov	Nov-Dec Dec-Mar	Sep-Dec Jan-Apr	Nov Jan-Mar
Fuchsia excorticata	Fuchsia	Fl Fr	Aug-Dec Sep-Feb	Aug-Dec Dec-Mar	Jun-Nov Jul-Feb	Sep-Apr Oct-May		Sep-Jan Dec-Aug	Jul-Dec Dec-Feb	Jul-Dec Dec-Apr
Myrsine salicina	Toro	Fl Fr	Aug-Jan Sep-May		Jul-Sept Oct					
Olearia rani	Heketara	Fl Fr	Aug-Nov Nov-Jan	Sep-Oct	Sep-Nov Nov-Dec	Nov-Dec Jan-Feb	Oct-Apr Jan			
Pennantia corymbosa	Kaikomako	Fl Fr	Nov-Feb Jan-May	Sep-Oct Feb-May		Nov-Feb Jan-May	Nov-Dec Mar	Dec-Jan Jan-Apr	Nov-Dec Feb-Apr	Dec-Jan
Pseudopanax aboreus	Five finger	Fl Fr	Jun-Aug Aug-Feb	Jun-Aug	Feb-Sep Jan-Dec	Jul-Dec Jan-Dec	Dec-Feb	Jul-Nov Jan-Dec		
Pseudopanax colensoi	Mountain five finger	Fl Fr	Jun-Mar Jun-Mar						Sep-Dec Dec-Oct	Jan-Dec Jan-Dec
Pseudopanax crassifolius	Lancewood	Fl Fr	Jan-Apr Jan-Apr	Jan-Apr	Mar-May Mar-Oct	Mar Mar-Jan		Dec-Feb Jan-Oct	Jan-Feb Apr-Oct	Feb Jan-Dec

SPECIES		**AREA & INFORMATION SOURCE**								
		(a)	NZ 1	NZ 3,(b)	North-land 4	Central North Island 5	Welling-ton 6	Canter-bury 7	West-land 8	Stewart Island 9
Pseudopanax edgerleyi	Raukawa	Fl Fr	Nov-Mar Nov-Mar		Nov-Dec Jan-Mar	Dec-Feb Jan-Dec			 Feb-Oct	Nov-Feb Feb-Mar
Pseudopanax simplex	Haumakaroa	Fl Fr	Jun-Mar Jun-Mar						Dec-Feb Apr-Dec	Dec-Feb Jan-Dec
Schefflera digitata	Pate	Fl Fr	Feb-Mar Feb-Mar	Jan-Mar	Mar-Apr Mar-Aug	Dec-Mar Jan-Oct	 Mar-Aug	Dec-Jan Jan-Sep	 Jan-Dec	Feb-Mar Mar
LIANES (VINES)										
Metrosideros fulgens	Scarlet climbing rata	Fl Fr	Feb-Jun Oct-Dec	Feb-Jun	Mar-Aug Mar-Feb		Jan-Dec Jan-Oct		Jan-Dec	
Ripogonum scandens	Supplejack	Fl Fr	Dec-Jan (2) Jan-Dec (2)	Oct-Nov Jan-Dec	Oct-Dec Jan-Dec	Nov-Feb Jan-Dec	Dec-Apr Jan-Dec		 Jan-Dec	Dec-Feb Jan-Dec
EPIPHYTES										
Alepis flavida	Mistletoe	Fl Fr	Dec-Feb Jan-Jun							
Peraxilla colensoi	Mistletoe/ korukoru	Fl Fr	Nov-Feb Dec-Mar	Oct-Jan					Nov-Mar Feb-Aug	
Peraxilla tetrapetala	Mistletoe/ pirirangi	Fl Fr	Oct-Jan Dec-Feb	Oct-Jan					Nov-Feb Feb-Jun	

Fl = flowers
Fr = Fruit (unripe & ripe)
b ripe fruit only
c male cones
d female cones
1 Allan 1961
2 Moore & Edgar 1970
3 Salmon 1967
4 Best & Bellingham 1991
5 Leathwick 1984
6 Brockie 1992
7 Burrows 1994
8 O'Donnell & Dilks 1994
9 Wilson 1982.

5. EXPECTED VALUES FOR SOME INDICATOR MEASUREMENTS

The following table provides a general guide on the levels of measurement that may be provided by some indicators in forest ecosystems. Actual measurements can vary widely in relation to the features of a particular forest ecosystem.

These figures must not be used to imply what are appropriate levels for a particular forest area. That is something that will depend on factors such as conservation values, carrying capacity and management objectives.

VARIABLE	LOW	MODERATE	HIGH	MEASUREMENT METHOD
Possum trap catch (% trap catch)	5	10-15	30 –50	NPCA trap catch protocol
Possum density (no / ha)	1	4-6	8-12	Trap to extinction
Deer density (no / km^2)	2	5	15	Population estimates from pellet survey and population modelling.
Goat kill / man day	0.5	1	4-5	Professional hunter results.
Mouse tracking frequency (%)	5	25	40	Tracking tunnel lines
Rat tracking frequency (%)	30	60	90	Tracking tunnel lines
Stoat tracking frequency (%)	0	5-10	15	Tracking tunnel lines
Bird density (number of individuals/ha – all species)	1	5-10	20-40	From slow walk transects and territory mapping studies.

6. RANDOM NUMBERS

91	30	23	34	33	02	13	62	28	14	64	25	40	41	55	99	63	79
50	19	30	38	66	05	91	92	69	66	91	61	45	97	29	86	61	89
76	22	73	86	70	40	48	41	16	72	54	68	60	88	60	07	47	13
68	73	47	88	35	94	12	49	88	44	47	59	56	52	39	89	30	02
30	02	29	95	13	68	94	34	51	12	08	99	44	79	85	83	91	04
28	05	96	40	36	78	82	95	78	77	23	46	39	70	78	79	55	42
85	23	22	91	40	60	30	08	36	44	60	83	74	94	86	77	06	55
27	89	45	44	99	44	24	67	05	16	59	74	58	03	04	21	41	50
91	23	91	98	68	39	27	79	77	27	36	83	82	25	92	33	06	13
49	03	19	87	98	06	24	46	98	81	49	55	79	11	29	39	58	28
04	07	34	24	80	82	42	56	99	94	87	12	24	41	82	06	88	04
60	04	47	80	40	19	91	39	27	97	42	51	07	13	77	55	68	38
83	38	93	07	01	22	80	36	25	79	30	77	72	88	75	77	59	39
50	54	04	54	02	94	52	03	84	58	32	91	41	70	15	11	02	05
67	49	39	71	53	74	07	38	01	64	32	27	46	41	18	64	73	28
49	56	66	62	47	08	43	58	19	10	89	43	90	15	64	98	33	59
31	58	39	43	67	47	70	73	01	28	11	55	00	87	35	77	01	36
63	14	85	71	76	32	99	69	04	14	03	74	29	54	24	58	92	20
43	20	73	35	84	94	46	69	84	42	70	39	42	21	54	60	36	58
12	89	93	45	49	34	56	41	94	97	14	50	51	46	14	44	53	25
43	50	13	00	81	09	95	28	39	31	66	46	95	08	55	91	52	84
71	72	38	05	54	29	37	19	04	49	50	94	47	51	32	40	39	48
19	70	39	73	31	79	78	98	89	57	57	02	68	81				

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