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

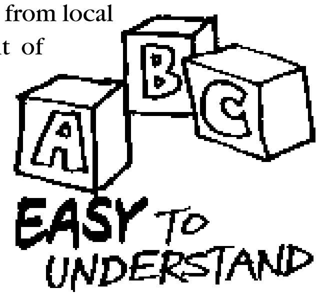
Introduction

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.

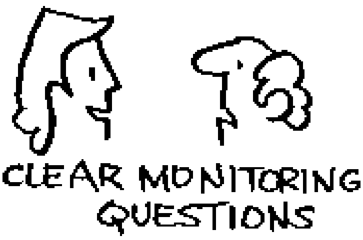
Examples

- 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?

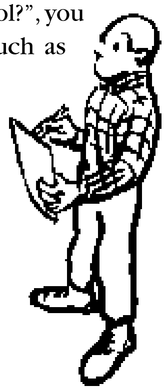
To design and set up useful monitoring, it is important to precisely define your monitoring question. For example, is the information you seek:

- 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.

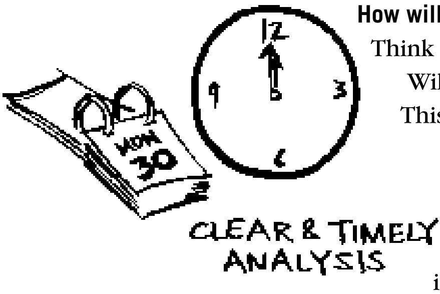
If you are not sure – do general surveillance first. If you don't have a specific monitoring question, such as: "How are seedling numbers changing following goat control?", you may be best to start with a general surveillance assessment of the area, such as outlined in the toolbox instruction – 'General 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.

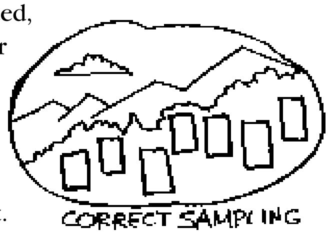
The group get together to look over the monitoring data to see what it shows. They have been working consistently on the possum control and feel there has been an improvement in the forest. When they look at the data, considerably less birds were recorded this year than last year, and more possums were 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?

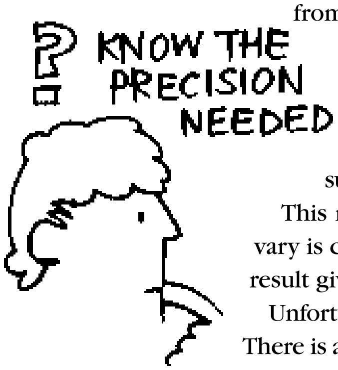
Bearing in mind the comments above, there are several ways of selecting samples. These methods and their merits are set out below.

- *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

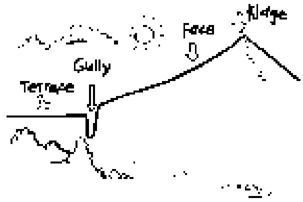
Data should always be collected in a way that allows later stratification if necessary. The most obvious and important way to do this is to ensure that all data always contains accurate information on its location so that it can be accurately plotted on a suitable scale map. This allows potential comparison 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:

  $$\textit{sample size} = \textit{variance} / (\textit{mean} \times \textit{precision} / t\ \textit{value})^2$$

  In our example:

  Sample size $= 21.27 / (10 \times 0.15 / 2)^2$
  $= 21.27 / (0.75)^2$
  $= 37.81$, 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.

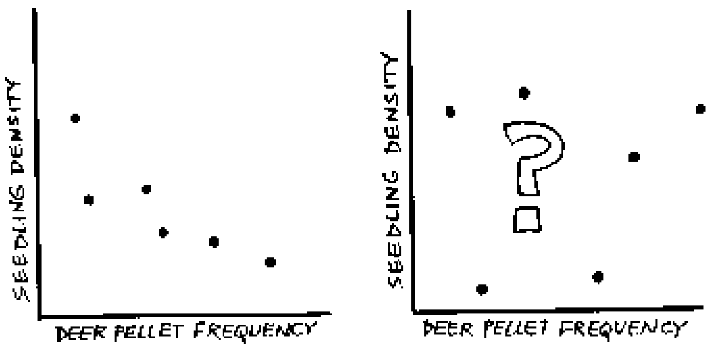
Remember a series of data points is much more powerful than just a couple of points. Keep on measuring even when you think things may have stopped changing. Fluctuations may occur, perhaps once in five years, and if measuring has ceased, they may be missed. If resources are limited, it is better to have 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.

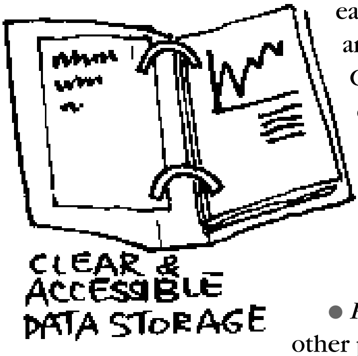
This also provides opportunities to undertake wider interpretation of data and examination of relationships between different indicators. Linking of data to Geographic Information Systems (GIS) provides opportunities to examine links between a large number of different 'layers'. For example, relationships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