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).

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

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

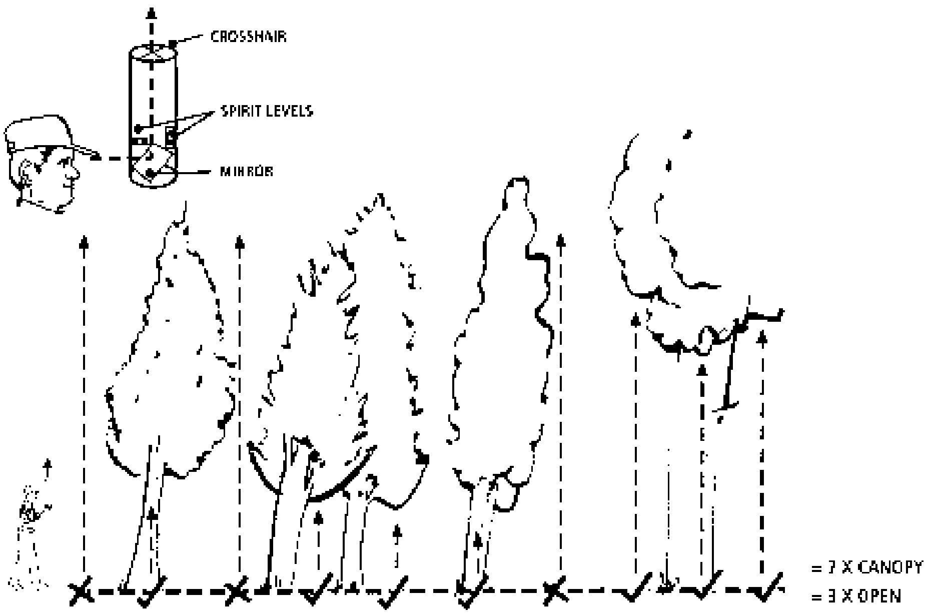
Dunn 1999

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

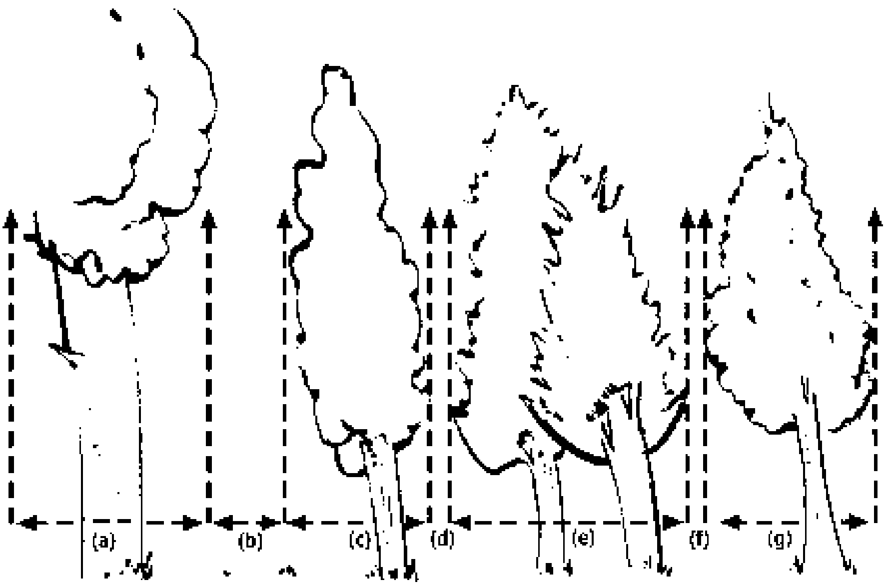
- Can be time consuming, depending on method
- Precise if carefully undertaken
- Suitable where good precision is required and conscientious, skilled field workers are available

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

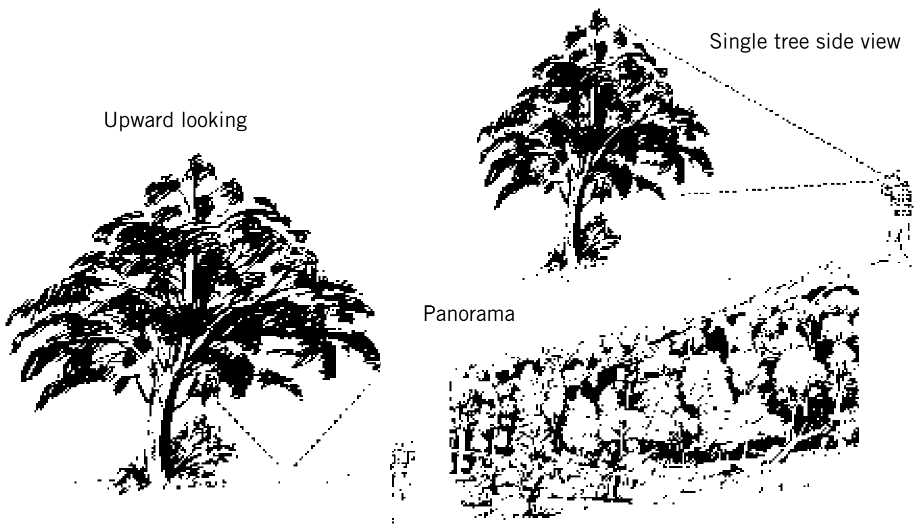
Photographic methods have several advantages, which include being relatively cheap and providing a permanent record that can be re-analysed in future. Photographs provide a good subjective demonstration of changes. With the advent of accessible digital image analysis technology, photography can also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

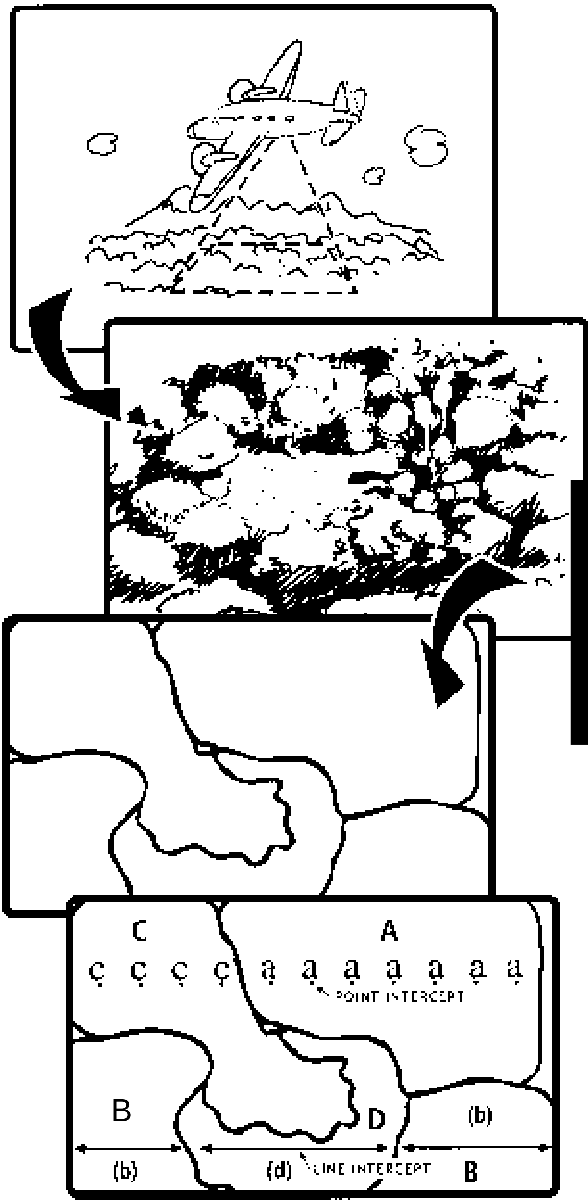


Figure 32: Aerial photographs can be used to assess changes in vegetation. As shown above, the area of different vegetation types on the photograph can be identified. Areas such as those shown as A, B, C and D can be measured approximately from the photograph using a planimeter. Point intercept and line 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.

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.

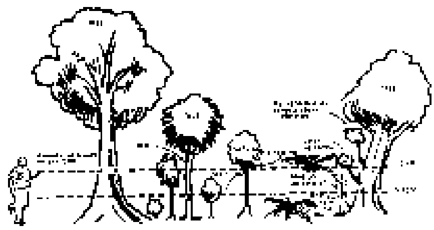
Tier	Height
Large seedling	0.45m – 1.35m
Sapling	Greater than 1.35m in height and less than 3cm DBH
Tree	Greater than 1.35m and greater than 3cm DBH

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).

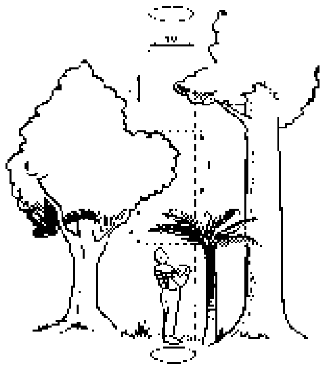
MEASUREMENT METHODS

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