



# Monitoring Revegetation Projects for Biodiversity in Rainforest Landscapes

Toolkit Version 1.

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Carla P. Catterall



# Rainforest CRC

Cooperative Research Centre for Tropical Rainforest Ecology and Management



# MONITORING REVEGETATION PROJECTS FOR BIODIVERSITY IN RAINFOREST LANDSCAPES TOOLKIT VERSION 1.

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# 1. INTRODUCTION

## 1.1 PURPOSE OF THE TOOLKIT

This toolkit was written to assist landholders, community groups and revegetation practitioners to monitor the outcomes of revegetation projects for biodiversity. Other objectives of revegetation, such as catchment protection or timber production, are not covered here. The toolkit was developed for rainforest revegetation projects in eastern Australia.

Researchers from the Rainforest CRC have developed the toolkit with the assistance of restoration practitioners. We have tried to make the toolkit 'as simple as possible while still being useful'. Feedback from users is welcome and will be used to improve future versions of the toolkit.

## 1.2 SCOPE OF TOOLKIT VERSION 1.

This version of the toolkit includes five sections that provide:

1. Background information on monitoring and revegetation;
2. Information on the design of monitoring programs;
3. Proformas for recording the on-ground works done in a revegetation project;
4. Protocols and proformas for monitoring 'basic indicators' of revegetation projects; and
5. Information on data management, analysis and evaluation.

Future versions of the toolkit will provide information, protocols and proformas for monitoring 'advanced indicators' (e.g. flora, fauna and ecological processes) in revegetated sites.

## 1.3 STAGES OF RAINFOREST REVEGETATION

Revegetated rainforest sites typically progress through two main stages: an initial 'establishment' phase and a longer-term 'building' phase. The 'establishment' phase is the period from when seeds or seedlings are planted until they have 'captured' the site, forming a relatively closed canopy and suppressing grasses and weeds. The establishment phase may last three to five years, depending on site conditions, planting design, maintenance, and so on.

In the 'building' phase, the planted trees mature, reproduce and eventually die, and other species of plants and animals are recruited to the site. In a restoration project, the aim of this phase is typically the development of a floristically and structurally diverse forest that provides habitat for native wildlife (Catterall *et al.* 2006). It may take decades or even centuries for a revegetated site to come to resemble mature rainforest.

The focus of the information obtained through monitoring will vary over the course of a revegetation project. During the 'establishment' phase, attributes such as the survival and growth of planted trees, grass cover and canopy closure are likely to be of interest to practitioners. Once 'site capture' has been achieved, the focus of attention may switch to the development of forest structure, plant recruitment, and the value of revegetated sites to wildlife.

## 1.4 REASONS FOR MONITORING REVEGETATION

The revegetation of cleared rainforest land is a recent activity in Australia. Individuals and community groups initiated a few projects in the 1970s, but most projects date from the 1990s as a result of government funded schemes such as the Wet Tropics Tree Planting Scheme and the Natural Heritage Trust. In total, these schemes have resulted in the reforestation of several thousand hectares of cleared land in rainforest landscapes, at a cost of some tens of million of dollars and many thousands of hours of volunteer effort (Catterall and Harrison 2006; Kanowski and Catterall 2006).

It is fair to say that most people involved in revegetation have focussed on 'getting trees in the ground', rather than on monitoring the outcomes of their work. Nevertheless, the design and management of revegetation projects has improved over time as practitioners have kept track of the survival and growth of planted trees, and how this has varied with site preparation, planting techniques, stocking rates, the matching of species to sites, and so on (Kooyman 1996; Florentine and Westbrooke 2004).

To date, only a few practitioners have attempted to monitor the value of their revegetation projects for biodiversity (e.g. Tucker and Murphy 1997; Grundon *et al.* 2002). One reason for this is that most revegetation projects are still young, while the use of revegetated sites by wildlife is typically a long-term goal. Another reason is that responsibility for revegetation projects has largely been devolved to landholders and community groups, many of who do not have the time, resources or expertise to design and conduct formal monitoring programs (Freeman 2004). The short-term and insecure funding available for revegetation projects has also made it difficult to develop long-term monitoring programs.

A third reason is that many people assume that revegetation projects will automatically be valuable for wildlife. Consequently, monitoring revegetation projects for biodiversity is sometimes considered a pointless task (Freeman 2004). However, it is becoming increasingly evident that revegetated sites can vary widely in their value to biodiversity, according to factors such as the number and types of tree species used in plantings, the structure of the vegetation, the availability of particular resources, and the proximity of sites to remnant forest (Catterall *et al.* 2004, 2006; Kanowski *et al.* 2005, 2006). These factors may interact in complex ways, making it difficult to predict the outcomes of revegetation for wildlife, at least from current knowledge.

Furthermore, even with the significant investment in reforestation that has occurred in recent decades in Australia, only a small proportion of the area of cleared land has been replanted (less than 1% in rainforest landscapes) (Catterall and Harrison 2006). Unless novel and cost-effective reforestation methods are developed, only small areas of degraded land are likely to be reforested (Lugo 1997; Lamb *et al.* 2005). However, without proper monitoring, it will not be known whether these novel and cost-effective approaches to reforestation will also be valuable for biodiversity.

For these reasons, we need to gain a much better understanding of the outcomes of revegetation projects for biodiversity. This will require both the improved documentation of work done in revegetation projects, and the routine monitoring of the outcomes of projects for biodiversity (Freudenberger and Harvey 2003a; Catterall and Harrison 2006). While this will demand considerable effort from reforestation practitioners, the pay-off will be a greatly improved knowledge of the factors affecting the biodiversity value of reforested sites, under a range of conditions. This knowledge will in turn increase the ability of reforestation practitioners to design plantings to meet particular objectives, including the restoration of biodiversity, and should increase the willingness of funding bodies to invest in reforestation projects.



### **Box 1. What is Rainforest Biodiversity?**

Biodiversity (or 'biological diversity') is a term used to describe the variety of life on the planet, in all its forms and levels of organisation. Rainforests support an exceptionally high proportion of Australia's biological diversity, despite occupying a small proportion (<1%) of the continent. This is because the present day rainforests of Australia are relicts of the ancient, diverse forests that once covered much of the continent. Over the past few million years, as Australia has become more arid, rainforests have contracted to moist refugia along the north and east margins of the continent. The main areas of rainforest in Australia today include the tropical rainforests of Cape York Peninsula, the Wet Tropics rainforests of northern Queensland, the subtropical rainforests of southeast Queensland and northern New South Wales, and the temperate rainforests of Tasmania.

Rainforests are characterised by a suite of physical, structural, and floristic attributes that set them apart from other Australian vegetation types. These generally include a high diversity of plant species from characteristic families (such as the Araucariaceae, Cunoniaceae, Elaeocarpaceae, Lauraceae, Meliaceae, Monimiaceae, Moraceae, Myrtaceae, Podocarpaceae, Proteaceae, Rutaceae, Sapindaceae, Sapotaceae and Sterculiaceae), a closed canopy, the presence of characteristic life forms such as vines, epiphytes, palms, strangler figs and trees with buttress roots (depending on the particular forest type), many plant species that bear fleshy fruit, and a humid microclimate without extreme temperatures.

In turn, the rainforest fauna includes many specialist animals that rely on the particular environments and resources of rainforests. The animals and plants interact to influence many aspects of rainforest dynamics. For example, most rainforest plants are pollinated by insects, birds, bats and other mammals, the seeds of most rainforest plants are dispersed by birds and mammals, and the recruitment of seedlings is strongly influenced by rodents and other seed predators, ground birds which turn over the leaf litter, and herbivores such as wallabies.

These complex interactions between animals and plants are one of the reasons why rainforests support such a rich biodiversity. Other reasons include the long history of rainforests in Australia, the relatively productive environments they tend to occupy, and the disturbance regimes to which they are exposed (frequent, but scattered small-scale disturbances from tree-falls; occasional large-scale disturbances, e.g. from cyclones).

Humans have had a profound effect on the distribution of rainforests in Australia. The use of fire by Aborigines may have reduced the overall extent of rainforest, but may also have protected particular rainforest patches. Since European settlement, the remaining rainforests have been extensively cleared for agriculture, especially lowland rainforests and forests on fertile soils. As a consequence, many rainforest plants and animals, and some rainforest types, are now considered threatened.

What is the future of rainforest biodiversity in Australia? While most of the remaining rainforests are in conservation reserves, many remnant forests are small, isolated by clearing and subject to a range of threats including the loss of key species, the disruption of important animal-plant interactions, competition from introduced species, and climate change.

There is a pressing need for reforestation of cleared rainforest landscapes. Reforestation can provide habitat for rainforest wildlife, increase the connectivity between remnant forests, increase the amount of forest cover, and help mitigate the impacts of climate change and other disturbances to biodiversity and ecosystem services. The rich biodiversity of rainforests provides both the impetus for restoration projects, and a real challenge to practitioners in terms of the complexity of the task.



## 2. DESIGN OF MONITORING PROGRAMS

### 2.1 ISSUES TO CONSIDER IN DESIGNING A MONITORING PROGRAM

Monitoring programs can range from surveys of simple variables such as plant survival and growth at a single site, through to detailed surveys of a range of organisms and ecological processes on replicated treatment, control and reference sites. These different approaches to monitoring will give information of different value and rigour, but will also require different amounts of effort and expertise. For these reasons, monitoring programs need to be designed to meet the objectives and constraints of a particular situation.

A major issue to consider in the design of a monitoring program is the purpose to which the monitoring results will be put. For example, a monitoring program designed to track the progress of revegetation at a single site and evaluate its outcomes may require repeated surveys of the revegetated site, as well as surveys of one or more forest reference sites. In contrast, a monitoring program designed to compare the performance of different revegetation methods would need a different design, e.g. one that involved surveys of replicate 'treatment' and 'control' sites, as well as (ideally) a number of reference sites.

A second issue to consider in the design of a monitoring program is the time, skills and resources of the individual or group responsible for the monitoring. Monitoring revegetation requires long-term commitment, good record-keeping and data management practices, and the use of well-documented and repeatable methodologies. This toolkit provides information and tools to assist in these tasks, but individuals and groups need to carefully assess their capacity to conduct a monitoring program. It would be a waste of time and money to embark on a monitoring program for which interest and funds could not be sustained over the long-term.

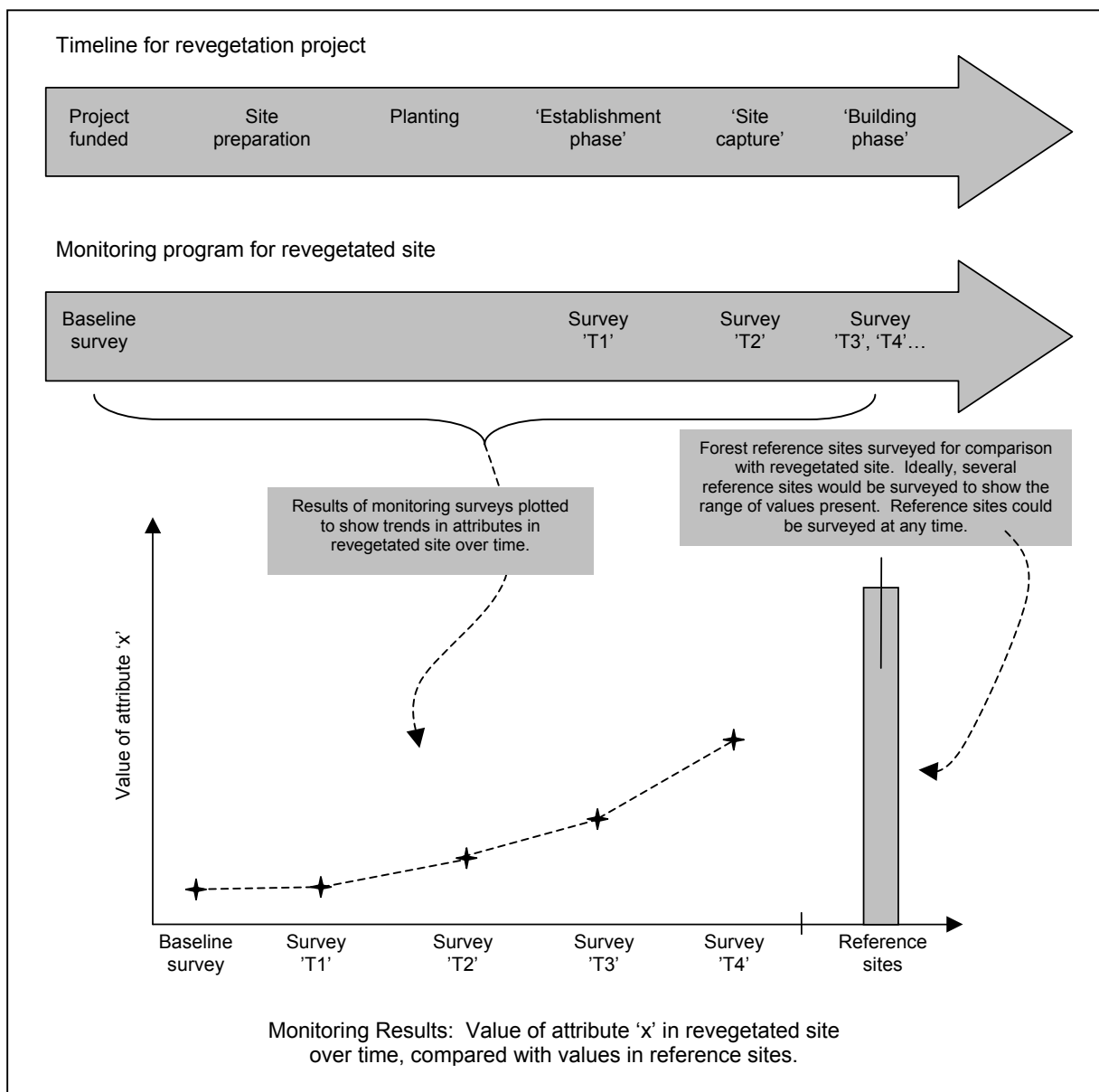
Other issues to consider include the type of attributes that will be surveyed, the methodologies used to conduct those surveys (e.g. the number and size of survey plots) and the survey regime (i.e. the number and frequency of monitoring surveys). Potentially, a wide range of attributes could be surveyed to provide information on the structure, composition and ecological function of a revegetated site (Society for Ecological Restoration 2004). Section 4 of this toolkit presents protocols for surveying 'basic indicators' in revegetated sites. These are aspects of forest structure that provide information on the development of a revegetated site (e.g. tree size, canopy cover, ground cover) and the habitat value of the revegetated site for wildlife (e.g. forest structure, woody debris). Protocols for surveying plants, animals and ecological processes in revegetated sites will be the subject of future versions of the toolkit. The question of when and how often to monitor ('survey regime') will be addressed at the end of this section.

### 2.2 TRACKING THE PROGRESS OF A REVEGETATION PROJECT

One reason to monitor a revegetation project would be to track the progress of the project over time and to evaluate its 'success'. A monitoring program designed to meet this objective would normally involve the repeated survey of a revegetated site, ideally from before the revegetation was established (i.e. a survey of baseline conditions), as well as surveys of one or more reference sites (i.e. forests representing the 'target condition', such as remnant forests of the type that may have occurred on a site prior to clearing). Comparison of the monitoring results with baseline data can show how much a site has changed following revegetation, while comparison with forest reference site(s) can show whether the revegetated site has achieved the target condition, and if not, what attributes need further development. In practice, both types of comparison are worthwhile. Illustrated in Figure 1,

below, are the steps involved in a monitoring program aimed at tracking the performance of a revegetated site and evaluating its progress.

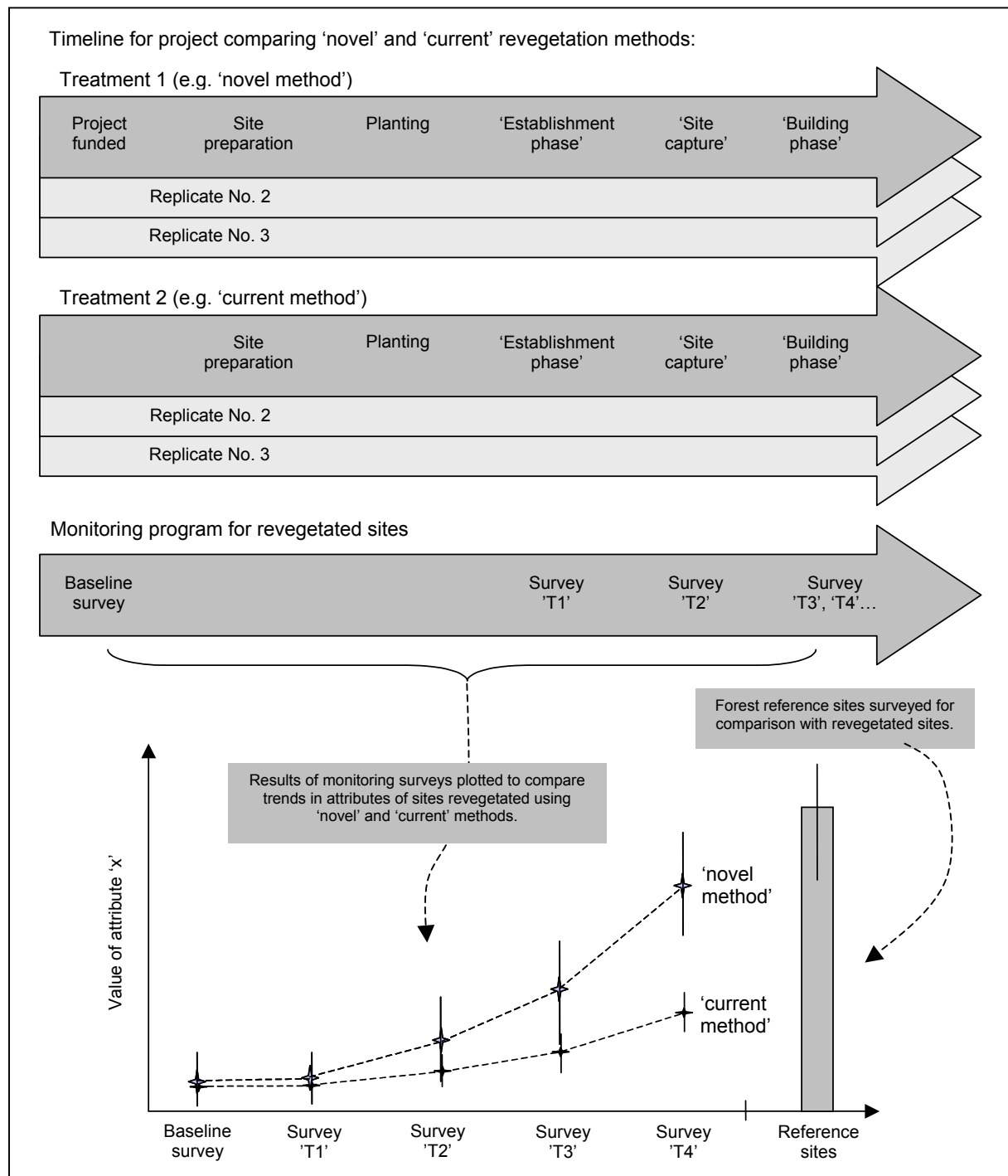
This type of monitoring was used by Jansen (2005) to evaluate the value of a revegetation project on the Atherton Tablelands, northern Queensland, for rainforest birds. In this study, several young replanted sites and several reference sites in rainforest were monitored annually for three years. Some of the replanted sites were monitored from before establishment to provide baseline data. The results of the study showed that, even when young, the plantings provided habitat for a number of rainforest birds (although these were mostly generalist or 'edge' species). Over time, the composition of the bird assemblage in the replanted sites tended to become more similar that found in rainforest. On the basis of this monitoring program, Jansen was able to conclude, "habitat restoration [at Donaghy's corridor] has good potential for success". Such statements would obviously be very useful in a funding application.



**Figure 1:** Illustration of the steps involved in monitoring the progress of a revegetated site and evaluating its performance against baseline data and forest reference sites.

## 2.3 COMPARING THE PERFORMANCE OF DIFFERENT METHODS

With a suitable design, the protocols and proformas presented in this toolkit could also be used to compare the performance of different revegetation methods (e.g. a 'novel' method with current practices). A monitoring program for this type of project would typically require the survey of replicate plots or sites; some planted using the novel method and others with current methods, as well as the survey of baseline conditions and reference sites (Figure 2). Replicate sites are important for controlling for the effects of site-specific factors in an experiment (e.g. site history, disturbance, landscape context). They increase effort but also the generality of results.



**Figure 2:** Illustration of the steps involved in monitoring the results of a project comparing the outcomes of different revegetation methods.

An example of this type of monitoring comes from northern New South Wales, where Harden *et al.* (2004) compared the costs and benefits of two different restoration methods, the 'Bradley' and the 'Wingham Brush' methods, at a particular remnant. They set up a series of paired plots in the remnant, where one plot in each pair was treated with the Bradley method, and the other with the Wingham Brush method. They then monitored the response of plant recruitment and growth to each method, and also kept records of the effort required for each method. They found that both methods actually produced very similar outcomes for rainforest regeneration. However, the Wingham Brush method required just one-tenth of the effort of the Bradley method at that site. The results of this study provided strong support for the use of the Wingham Brush method at the site, even though its use had initially been opposed by the organisation funding the restoration works. The Wingham Brush method has subsequently been adopted in other rainforest remnants in the region.

## 2.4 SURVEY REGIME: WHEN AND HOW OFTEN TO MONITOR

An important question to consider in the design of a monitoring program is, 'when and how often should monitoring surveys be conducted?' The answer to this question is, 'it depends', first, on the timescale over which changes in target variables are expected to occur (if, for example, to monitor plant recruitment, then annual surveys are probably sufficient); second, on the ecology of the target variables (e.g. to monitor birds, surveys may have to account for seasonal migration); third, on how much effort is needed to survey a variable with acceptable precision (e.g. 'one-off' surveys may be strongly affected by chance events, such as the weather); and fourth, on the time and resources available for conducting the surveys.

Fortunately, the attributes surveyed in this version of the monitoring toolkit comprise various aspects of forest structure, which in rainforest tend to change relatively slowly, can be surveyed at any time of year and in any (reasonable) weather, and with fair precision given a suitable protocol.

A possible survey regime for monitoring basic indicators in a revegetated site might include (i) a baseline survey, (ii) one or more annual surveys until 'site capture' (typically, three to five years after establishment), and (iii) less frequent surveys thereafter, perhaps every three to five years, depending on the interest and resources of those people conducting the surveys. Surveys of (iv) one or more reference sites would also generally be needed to evaluate the progress of the revegetated site towards target conditions. Note that if baseline data were not available (e.g. if an established site was being monitored), then 'control sites' could be surveyed to provide surrogate baseline data. Control sites are sites judged to be similar to the condition of the revegetated site prior to on-ground works (e.g. a pasture or regrowth site).

A possible survey regime for monitoring the performance of different revegetation methods might include, for each of the replicate sites, (i) a baseline survey, (ii) one or more surveys until 'site capture', and (iii) at least one survey in the 'building phase' of revegetation, depending on the aims of the experiment. For example, if an experiment aimed to compare how quickly two different planting methods achieved canopy closure and suppressed grasses, then monitoring would not need to proceed much beyond 'site capture'. However, an experiment aimed at comparing the recruitment of special life forms to different planting methods might need to continue monitoring for a number of years or even decades after site capture. Again, (iv) surveys of one or more reference sites would also generally be needed to evaluate the performance of the revegetated sites against target conditions.

## 3. KEEPING RECORDS OF PROJECTS

### 3.1 WHY BOTHER?

Revegetation is inherently a long-term activity. The people monitoring a revegetated site may be doing so years or even decades after the site was established. In most cases, interpretation of the results of monitoring will be greatly assisted by records that describe the nature of the project, the on-ground works done in the project, and any subsequent maintenance activities. Unfortunately, good record-keeping practices have not been a feature of most revegetation projects in Australia to date. A review of approximately 13,000 revegetation projects funded by the Natural Heritage Trust (NHT) found that “very few” had adequately documented their on-ground works (Freudenberger and Harvey 2003a). In response to this situation, Freudenberger and Harvey (2003b) proposed a minimum set of records that should be recorded by revegetation projects in Australia, if the potential biodiversity benefits of those projects were to be assessed. We have drawn upon this list, as well as suggestions made by Kooyman (1996) and the Society for Ecological Restoration (2004), amongst others, to compile a list of attributes that we suggest should be documented by rainforest restoration and revegetation projects.

### 3.2 WHAT INFORMATION IS REQUIRED?

We suggest that three sets of information are recorded to provide sufficient background data to facilitate subsequent monitoring and reporting of the results of revegetation projects. These are:

- A description of the type of project and the site(s) on which the project occurs;
- A description of the on-ground works done in a project; and
- A record of subsequent maintenance activities.

Note that, where a project is conducted in stages, we recommend records be kept separately for each stage. This is because many factors that can affect the outcomes of a revegetation project, such as the prevailing weather conditions, weed control activities and perhaps planting methods will often vary between different stages of a project.

Most of the information sought in the record-keeping proformas is self-explanatory. More details are provided below.

### 3.3 PROJECT DESCRIPTION

An adequate description of a revegetation project should include the location of the site(s) on which the project occurs, a list of the project’s objectives, nomination of the reference condition and reference sites (if relevant), and details of some of the environmental factors that may affect the outcomes of the project. Some of the terms used in the proforma are defined below.

The **Project ID** is a unique code given to a project, for example by a funding body, to simplify the storage of information in a database. The **stage** of a project refers to a defined set of on-ground works, often commenced or conducted in a particular year. A project’s **objectives** refer to the main purposes of the project, in broad terms. Examples of objectives include improved biodiversity outcomes (e.g. conservation, restoration), timber production and catchment protection. The **reference forest condition** defines the type of forest that the project is trying to restore or create at a site. In many cases, this is the forest type that

occurred at a site prior to clearing. However, the pre-clearing forest type may not be known, or may no longer be an appropriate reference condition (e.g. if environmental conditions at the site have changed significantly since clearing). In these cases, another forest type may be chosen as the reference, or if none is suitable, the reference condition may need to be described from scratch. **Reference sites** are examples of the reference condition (should they exist). For example, a revegetation project on the Atherton Tablelands, north Queensland, may wish to recreate 'Mabi' forest (semi-deciduous complex notophyll vine forest on stony basalt). A possible reference site for Mabi forest would be the Curtain Fig National Park.

### 3.4 ESTABLISHMENT STATISTICS

The 'establishment statistics' comprise information about the on-ground works conducted in a project, including details of what, where, when and how much time, effort and money was expended on the project. This information is often very difficult to recover in later years if not recorded at the time the work was done. In many cases, keeping these records is usually just good 'housekeeping' on the part of a project. Nevertheless, it may not always be possible to record (or remember) this type of information in fine detail. In these cases, a 'ball park' figure will still be useful (e.g. were ten species planted, or fifty?).

For the purposes of this toolkit, we suggest that details of on-ground works be recorded separately for different types of activities, i.e. **remnant protection** (e.g. fencing a remnant, or placing a remnant under a formal conservation agreement), **remnant enhancement** (e.g. weed control in an existing remnant), and **revegetation** (planting of cleared or degraded land). This is because these activities require very different inputs (effort, materials, funding), and their outcomes may need to be monitored separately. For example, in an enhancement project which primarily involved weeding, it may be sufficient to record the weeds targeted, the control methods and the effort involved. In contrast, revegetation projects can vary in a range of details, including the numbers, life forms and origin of species planted, the stocking rate, the planting technique, and mix of species by successional stage. Sometimes, particular models of revegetation are used to guide activities (e.g. the 'maximum diversity' model of Goosem and Tucker 1995). Likewise, GPS coordinates of the areas subject to on-ground works should also be recorded separately for the main types of project activities. To help interpret these data, it is useful to provide a 'mud-map' sketch of the project, and to note whether particular areas contain one or more types of land-use (e.g. does an area mapped as 'revegetation' also include areas of remnant forest?).

### 3.5 MAINTENANCE RECORD

The third set of information required to document the work done in a revegetation project is a record of maintenance activities. This information is useful not only for interpreting the outcomes of a project (e.g. weed control may affect the success of a project), but also for documenting effort, both for reporting requirements or for planning future projects. The information we suggest be recorded includes the **date** of maintenance activities, a **description of those activities**, and the **inputs** (time, materials, costs) required for those activities.

### 3.6 PROFORMAS FOR RECORDING REVEGETATION PROJECTS

Proformas for project descriptions, establishment statistics and maintenance records are provided on the following pages.





<b>Project Name:</b>			
<b>Database Info:</b>	<b>Project ID:</b>	<b>Stage:</b>	<b>Year:</b>

**ENVIRONMENTAL DESCRIPTION OF PROJECT SITES**

<b>Landform</b> (circle the relevant term):	e.g. Plateau Crest Upper slope Lower slope Stream bank Flat Other (describe):
<b>Altitude:</b>	
<b>Geology / soils</b> (if known):	
<b>Existing vegetation on project site/s</b> (briefly describe):	
<b>Pre-European vegetation on project site/s</b> (if known):	
<b>Land-use history</b> (if known):	
<b>Landscape context</b> 1. Proximity to waterway and type of waterway:	1. Is this a riparian project (i.e. adjacent to a waterway)? Yes / No If <i>No</i> , how far is the project from a waterway (m or km)?  Describe the type/s of waterway nearby (circle most relevant term): Creek River Estuary Swamp Dam Lake Ocean
2. Proximity to remnant forest (if known):	2. How far is the project from remnant forest (m or km)? What is the type of forest?
3. Surrounding land uses (describe):	3.
<b>Disturbances</b> Is the site prone to flooding, frost, fire, cattle browsing, pig rooting, etc.? Describe.	

<b>Project Name:</b>			
<b>Database Info:</b>	<b>Project ID:</b>	<b>Stage:</b>	<b>Year:</b>

**OVERVIEW OF ON-GROUND WORKS**

What are the approximate dimensions of the project (this stage only)?			
<b>Length:</b>	m	<b>Width:</b>	m
		<b>Area:</b>	ha
Specifically, over what area/s were the following actions conducted (this stage only)?			
<b>Remnant protection:</b> (e.g. fencing, conservation agreement)	ha	<b>Remnant enhancement:</b> (e.g. weed control in remnants)	ha
<b>Revegetation:</b> (i.e. planting of cleared or degraded land)	ha	<b>Other (describe):</b>	ha

**MAP** In the box below, draw a 'mud-map' of the project site/s, showing:

- Areas of remnant protection, enhancement and revegetation covered by this stage of the project, and where they are located with respect to the entire project area;
- Location of other patches of remnant vegetation or revegetation on the site, and other relevant features of the site (e.g. property boundaries, roads, waterways, fences); and
- Approximate scale (include a scale bar, e.g. 0 \_\_\_\_\_ 100 m) and north arrow.





<b>Project Name:</b>			
Database Info:	Project ID:	Stage:	Year:

**REVEGETATION**

<b>Revegetation actions</b> Note: If some details are not known precisely, record 'best guess' and write 'approx.'. Record detailed planting information on following page.			
Details of site preparation (briefly describe):			
Number of species planted:		Number of stems planted:	
Planting stock (circle):	Seeds / Seedlings	What age / size?	
Stocking rate:	stems/ha	OR	Spacing of plants: m x m
What type of life forms were planted (circle all relevant categories)?			
Tree	Vine	Shrub	Groundcover
What was the biogeographical origin of the species planted (or provenances of spp. Planted, if relevant)? Circle all relevant categories:			
Local region	Australian, but outside region	Exotic	
Approximate mix of species by successional range (if known):			
Pioneers:	%	Secondary phase spp.	% Mature phase spp. %
Was a particular planting model used (e.g. 'framework species')? Name or describe the model, if relevant:			
Was fertilizer added to plants?		Yes / No	
If Yes, What product was used?		How much was used (approx.)?	
Was mulch added to plants?		Yes / No	
If Yes, what product was used?		How much was used (approx.)?	
Was the planting fenced?		Yes / No	
If Yes, what length of fencing?		m	
<b>Where was it done?</b>			
Provide a set of GPS coordinates that define where <b>revegetation</b> occurred during <i>this stage</i> of the project.		Datum:	
Does the area of <i>revegetation</i> (defined above) include any other land use?		Yes / No	
If Yes, what type of land use?			
What percentage of the area?			
<b>When was it done?</b>			
Date/s on-ground works took place:			
<b>How much did the on-ground works in <i>this stage</i> of the project cost (approximately)?</b>			
<b>Revegetation:</b>	Cash \$	In-kind \$	
What was the source of funds (e.g. Natural Heritage Trust)? If several sources, give a percentage from each source:			

<b>Project Name:</b>			
<b>Database Info:</b>	<b>Project ID:</b>	<b>Stage:</b>	<b>Year:</b>

**DETAILED PLANTING INFORMATION**

List of Species Used in Planting	Life form	Origin	Number of Stems
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
Note: If more than 30 species planted, tick here _____ and add extra page/s			

Notes: **Life form** = Tree / Vine / Shrub / Groundcover  
**Origin** = species or provenances from: Local region / Australian, but outside region / Exotic

Extract from: Kanowski, J. and Catterall, C. P. (2006) *Monitoring Revegetation Projects for Biodiversity in Rainforest Landscapes. Toolkit Version 1.* Cooperative Research Centre for Tropical Rainforest Ecology and Management. Rainforest CRC, Cairns (58pp.).





## 4. MONITORING ‘BASIC INDICATORS’

### 4.1 WHAT ARE BASIC INDICATORS?

This section of the toolkit presents information, protocols and proformas for monitoring ‘basic indicators’ at revegetated (and reference) sites. Basic indicators include various aspects of forest structure which have been selected for survey in this toolkit, because they:

- Provide information on important stages of development of a revegetation project;
- Can be measured relatively easily and rapidly, without specialist knowledge; and
- Are correlated with the use of sites by rainforest wildlife.

Protocols for monitoring advanced indicators (plants, animals and ecological processes of revegetated sites, whose survey may require specialist knowledge) will be presented in later versions of the toolkit.

The basic indicators used in this toolkit were identified from research conducted by the Rainforest CRC on the biodiversity values of reforested sites in tropical and subtropical Australia (see Table 1, below), and from other relevant work (e.g. Webb *et al.* 1976; McElhinny 2002; Big Scrub Rainforest Landcare Group and EnviTE 2006; Gibbons and Freudenberger 2006). Where possible, indicators were chosen to be consistent with state and national schemes (e.g. the ‘habitat hectares’ scheme developed by Parkes *et al.* 2003, now applied in some form in many states: see Eyre *et al.* 2006 for a scheme developed for Queensland), but the primary objective was relevance to monitoring revegetation in Australian rainforest landscapes.

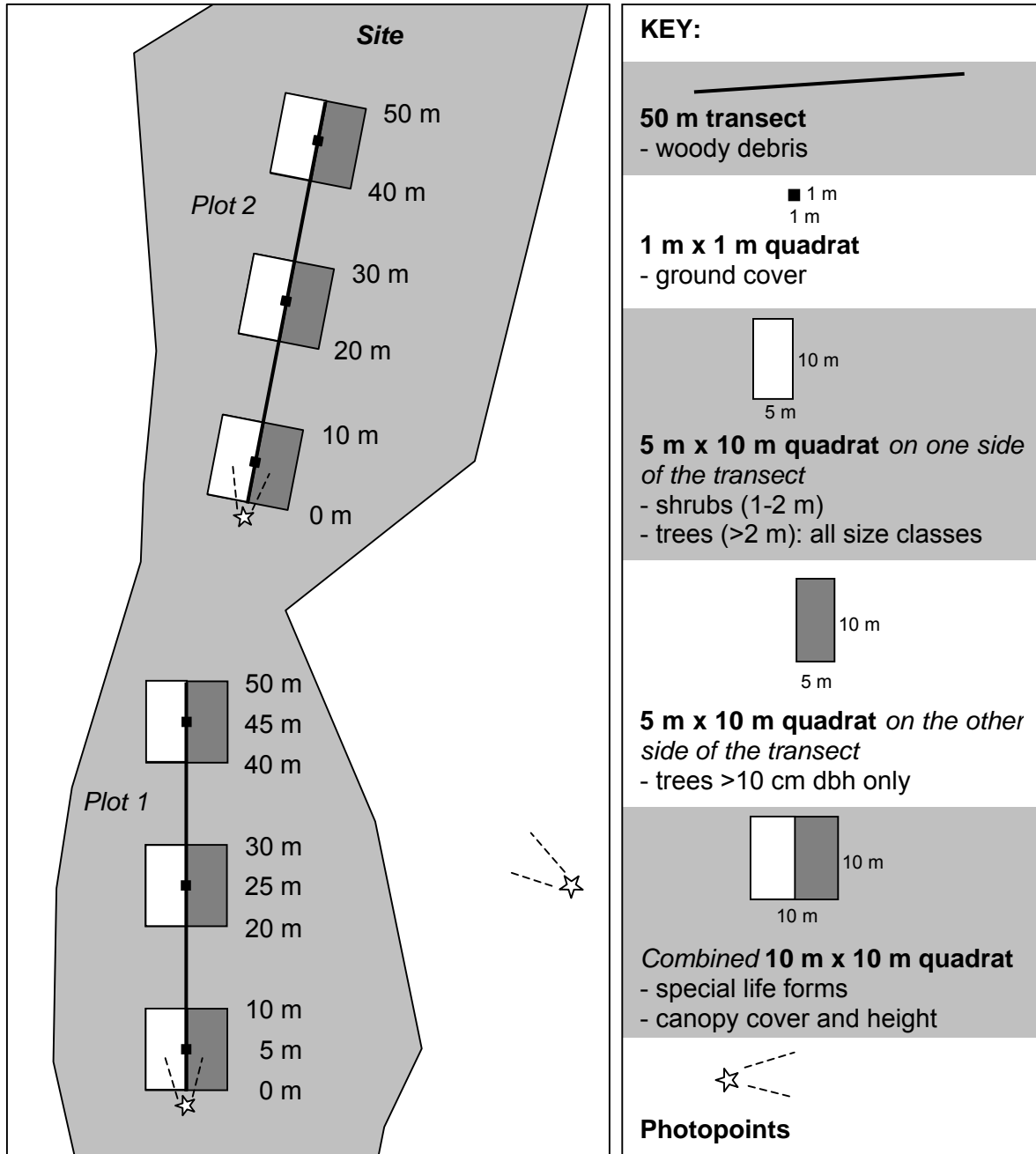
An important point to keep in mind when monitoring basic indicators is that the proforma is concerned with various aspects of vegetation structure, regardless of whether that structure is provided by native or exotic plants (weeds). The composition of the vegetation can be noted at the end of the proforma, and will be assessed in more detail when ‘advanced indicators’ are surveyed at a site.

**Table 1:** The relationship between forest structural attributes and rainforest wildlife in reforested sites in tropical and subtropical Australia. The number of ‘+’ symbols represents the number of analyses (out of four) where a significant positive correlation was found between structural attributes and wildlife. Analyses conducted for: (i) all reforested sites, and (ii) young replanted sites only, for each of the (iii) tropics and (iv) subtropics, from a total of 64 reforested sites, 5-70 years old (data from: Kanowski *et al.* 2003, 2006; Proctor *et al.* 2003; Catterall *et al.* 2004; Wardell-Johnson *et al.* 2005; Kanowski and Catterall 2006; P. Grimbacher, unpublished data).

Structural attribute	Correlation with rainforest wildlife:				
	Plants	Birds	Reptiles	Mites	Beetles
Canopy cover	++++	+++	+++	+	+++
Canopy height	+++	+++	+	++	++
Tree density	++++	++++	+	+	+++
Basal area of trees	++++	++++	++	++	++
Shrubs density	++++	++++	+	+	++
Stem diversity: tree dbh and shrubs	+++	++++	++		++++
Special life forms	++	+++	+	++	++
(Lack of) grass cover	+++	++++	+	+	+++
Leaf litter cover	++	+			+
Woody debris	+	+	+	+	+

## 4.2 MONITORING BASIC INDICATORS: BASIC SURVEY DESIGN

The monitoring of basic indicators involves the survey of various aspects of vegetation structure on defined transects and plots, using a standard design (Figure 3). The same design is used for surveys of revegetated sites (all ages, including baseline studies) and 'reference' sites.



**Figure 3:** Standard layout of survey plots for monitoring basic indicators. Two 50 m x 10 m plots are surveyed per site. Each plot comprises a 50 m transect with three sets of quadrats at the 5 m, 25 m and 45 m points. Note: It may be necessary to 'bend' or break the transects at one or more points in some circumstances. However, the total length of the transects, and the size and number of quadrats, should remain unaltered. Any variations on the standard layout should be clearly documented and depicted on a map of the site.

Ideally, the survey plots used to monitor basic indicators would be set up and permanently marked in a revegetated site prior to any on-ground works being conducted. The same plots would then be surveyed each time the site was monitored. Use a metal peg or star-picket to permanently mark the location of the 0 m point on each transect. Record the location of the 0 m point with a GPS, record the compass bearing of each transect and mark the location of the transect on a 'mud-map' of the site. Space for recording these details is provided in the proforma for monitoring basic indicators (Section 4.5).

### 4.3. LIST OF BASIC INDICATORS AND THEIR DEFINITIONS

The basic indicators surveyed in this toolkit are based on structural attributes as listed in Table 2, below.

**Table 2:** List of attributes to be surveyed for monitoring basic indicators.

Attributes	Definition
Canopy cover	Projective cover (%) of vegetation >2 m above ground (= shade cast by vegetation >2 m above ground, if sun was directly overhead).
Canopy height	Height attained by the crown of the tallest tree in the canopy. The canopy is the layer of foliage forming the 'roof' of the forest; it may be broken by gaps or incomplete. In some sites, it may be necessary to distinguish canopy trees from emergents (i.e. trees projecting above canopy with crowns exposed on all sides).
Ground cover	Proportion of ground (%) covered by (a) vegetation <1 m high (score for each of: grass, herbs, ferns, vines and scramblers, trees and shrubs, moss), (b) leaf litter and fine woody debris, (c) coarse woody debris, (d) rock, (e) soil, (f) other.
Trees	Live freestanding woody-stemmed plants >2 m high. Trees are assessed by dbh class (= stem diameter at 1.3 m above ground): <2.5 cm, 2.5-10 cm, 10-20 cm, 20-50 cm, 50-100 cm, >100 cm.
Structural damage to trees	Any significant structural damage to live trees from storms or cyclones is recorded as: 1 = defoliation and smaller branches broken; 2 = larger branches broken, 3 = trunk broken; 4 = tree pushed over at >45° angle or uprooted.
Standing dead trees (stags)	Dead freestanding woody-stemmed plants >2 m high, assessed by dbh class: <2.5 cm, 2.5-10 cm, 10-20 cm, 20-50 cm, 50-100 cm, >100 cm.
Shrubs	Live freestanding woody stemmed plants 1-2 m high.
Special life forms	Plant life forms characteristic of rainforest and/ or particular forest types. Includes: strangler figs, hemi-epiphytes, vines ('slender' <5 cm diameter, 'robust' >5 cm diameter), vine towers, vine tangles, thorny scramblers, clumping epiphytic ferns, other epiphytes, tree ferns, ground ferns, palm trees, understory palms, cordylines, herbs with long, wide leaves, herbs with strap leaves, cycads (with stems or on ground), other life forms characteristic of a site.
Coarse woody debris	Fallen logs and branches, lying on or within 2 m of the ground and >10 cm diameter. Where present, coarse woody debris usually comprises most of the volume of woody debris. Provides stable habitat for organisms dependent on rotting wood, as the core tends to remain moist.
Fine woody debris	Woody debris 2.5-10 cm diameter. Fine woody debris usually adds little to woody debris volume and can dry out, making it poor habitat for many organisms. However, it may be the only type of woody debris present on young sites. Note: Measurement of fine woody debris is OPTIONAL in this toolkit.

## 4.4 PROTOCOLS FOR MONITORING BASIC INDICATORS

### Equipment required:

50 m measuring tape, flagging tape, 2.5 m PVC pipe marked at 1 m and 2 m, ruler or dbh tape, four 1 m sticks, clipboard and proforma, compass, camera (useful: GPS, clinometer, binoculars).

### Step by step instructions:

Select the location of the two survey plots (each is 50 m x 10 m).  
Draw a map of the site, showing the location of each plot. *For each plot:*

- Step 1:** Briefly **describe the survey area:** location, landform, slope, aspect, soils, proximity to waterways and to other habitats/ land uses.
- Step 2:** **Lay out a 50 m transect.** Record the compass bearing of the transect.
- Step 3:** Progressively **set out and survey the sets of quadrats** centred on the 5 m, 25 m and 45 m points. Survey ground cover, forest structure, canopy cover and height, and special life forms in these quadrats (see Figure 3: further details below).
- Step 4:** **Survey coarse woody debris** (fallen logs and branches >10 cm diameter) by walking along the 50 m transect, and counting the number of times the transect crosses fallen logs (on or within 2 m of the ground). Logs are classified by diameter class at the point crossed by the transect. If a log crosses a transect more than once, it is counted each time it is >10 cm diameter at the point of intersection. *Optional: Also survey fine woody debris (logs, branches 2.5-10 cm diam.) on the 50 m transect, if desired.*
- Step 5:** **Take a photo** of each monitoring plot from the 0 m point, along the transect.
- Step 6:** **Make general comments** on the structure and composition of the vegetation, and any variation across the site, in the tree / canopy layer, the understorey/ ground layer, and the recruitment of species to the site. Note any weed or maintenance issues.

**Repeat Steps 1 to 6 for the second survey plot.**

- Step 7:** Before leaving, take a '**landscape photo**' of the site. Record its location and direction.  
**Check** that the proforma has been completed.

### Detailed instructions for ground cover, forest structure, canopy cover and canopy height:

At each plot, set out quadrats centred on the 5 m, 25 m and 45 m points. *At each point:*

- Survey **ground cover** on a 1 x 1 m quadrat. Use four 1 m sticks to define the quadrat. Categories of ground cover include: (a) vegetation within 1 m of the ground, categorised by life form; (b) leaf litter and fine debris, (c) coarse woody debris; (d) rock, (e) bare soil; or (f) other.
- Survey **forest structure** on two adjacent 5 m x 10 m quadrats (see Figure 3). Use a 2.5 m length of pipe (flipped end-over-end) to locate the corners of the quadrats and mark with flagging tape.
- In one of the 5 m x 10 m quadrats, count all shrubs (1-2 m high) and trees (>2 m high), categorised by dbh class. If trees have multiple trunks, tally each trunk >2 m high.
- In the other 5 m x 10 m quadrat, count only larger trees (>10 cm dbh), by dbh class.
- Tally standing dead trees (**stags**) in the same way, but separately from live trees.
- Assign any living trees with **structural damage** (e.g. from cyclones) to a damage class: 1 = defoliation / minor damage, 2 = major branches broken, 3 = stem broken, 4 = stem pushed over.
- **Canopy cover** is assessed above the 10 m x 10 m quadrat. It can be estimated directly or calculated from a digital photo (see Appendices). We suggest using both methods.
- Assess **canopy height** above the 10 m x 10 m quadrat (the height of the tallest tree in the canopy). At some sites, it may be necessary to distinguish canopy trees from emergent trees (= trees projecting well above the canopy, with crowns exposed on all sides).
- **Special life forms** are recorded if present in the combined 10 m x 10 m quadrat. Note also if special life forms are present on the site, if not recorded on one of the plots.

*Remember: This proforma surveys vegetation structure, regardless of whether plants are native or exotic. The composition of the vegetation can be noted at the end of the proforma.*

## 4.5 PROFORMA FOR MONITORING BASIC INDICATORS

A proforma for monitoring basic indicators is provided on the following pages.

<b>Project Name:</b>			
Age of revegetation (if relevant):	yrs	Assessed by:	Date assessed:
Database Info:	Project ID:	Stage:	Year:

Description of Survey Plots	Plot 1	Plot 2
<b>Location</b> at 0 m point (map / GPS coordinates, and datum used)		
<b>Compass bearing</b> of transect (from 0 m mark)		
<b>Landform</b> (e.g. plateau, crest, upper slope, mid-slope, lower slope, stream bank, flat)		
<b>Slope</b> (°) or description		
<b>Aspect</b> (compass bearing)		
<b>Soil type / geology</b>		
How close is the plot to a <b>waterway</b> ? What type of waterway? (i.e. creek, river, lake, etc.)	m	m
How close is the plot to the edge of the site? What are the <b>adjacent land uses</b> ?	m	m

**MAP** To help relocate the monitoring plots in future surveys, draw a map showing:

- Major features of the site (relevant property boundaries, roads, waterways, fences, landmarks);
- Location of remnant vegetation and/or revegetated sites;
- Location of monitoring plots (mark 0 m points) and landscape photopoint(s); and/or
- Approximate scale (include a scale bar, e.g. 0 \_\_\_\_\_ 100 m) and north arrow.

**PROFORMA FOR MONITORING BASIC INDICATORS**

Project Name:	Assessed by:	Date assessed:	Page 2 of 6
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**GROUND COVER, CANOPY COVER and CANOPY HEIGHT**

For each survey plot, lay out a 50 m transect. Then, mark out and survey quadrats centred on the 5 m, 25 m and 45 m points (see Figure 3).

**Ground Cover** = proportion of the ground covered by (a) vegetation within 1 m of ground (various categories), (b) leaf litter and fine woody debris, (c) coarse woody debris, d) rock, (e) soil, or (f) other.  
 At the 5 m, 25 m and 45 m points, define a 1 m x 1 m quadrat, by using four 1 m sticks. Looking down on the plot, estimate the proportion of ground obscured by each category of cover, if present.

Ground Cover	Plot 1			Plot 2		
	5 m	25 m	45 m	5 m	25 m	45 m
Location of quadrat:						
<b>a) Vegetation within 1 m of the ground</b>						
<b>Grass</b> (and sedges)	%	%	%	%	%	%
<b>Herbs</b> (soft-stemmed plants)	%	%	%	%	%	%
<b>Ferns</b>	%	%	%	%	%	%
<b>Vines and scramblers</b> (inc. lantana)	%	%	%	%	%	%
<b>Tree seedlings, shrubs</b>	%	%	%	%	%	%
<b>Moss</b> (and liverworts and lichens)	%	%	%	%	%	%
<b>b) Leaf litter</b> and fine woody debris <10 cm diam.	%	%	%	%	%	%
<b>c) Coarse woody debris</b> >10 cm diameter	%	%	%	%	%	%
<b>d) Rock</b>	%	%	%	%	%	%
<b>e) Soil</b>	%	%	%	%	%	%
<b>f) Other</b> (including tree trunks, roots, etc.)	%	%	%	%	%	%
<b>TOTAL (Must add up to 100%)</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>

**Canopy Cover** = shade cast by vegetation >2 m above ground, if sun was overhead. It can be estimated by eye (although this can be very subjective) or calculated from a photo. We suggest using both methods. In both cases, determine canopy cover for a 10 m x 10 m quadrat around each point.

1. Estimate canopy cover visually, e.g. by reference to canopy photos (see Appendix 1).
2. Take a digital photo of the canopy (approx. 10 m x 10 m) above each point to calculate canopy cover (see Appendix 2). Record the number of each photo for later reference.

Canopy Cover	Plot 1			Plot 2		
	5 m	25 m	45 m	5 m	25 m	45 m
Location of quadrat:						
<b>Visual estimate of canopy cover</b>	%	%	%	%	%	%
<b>Canopy photograph</b> (record number for reference)						
<b>Canopy cover calculated from photograph</b>	%	%	%	%	%	%

**Canopy Height** = the height of the tallest canopy tree in a 10 m x 10 m quadrat around each point. The canopy is the layer of foliage forming the 'roof' of the forest. It may be broken by gaps or incomplete. In some sites, it may be necessary to distinguish canopy trees from emergent trees (i.e. trees projecting well above the canopy, with crowns exposed on all sides).

Note: Estimating height is difficult. Use a clinometer or range finder if available. Alternatively, place a 2.5 m length of pipe against a tree, and standing at a distance, estimate height in multiples of 2.5 m.

Canopy Height	Plot 1			Plot 2		
	5 m	25 m	45 m	5 m	25 m	45 m
Location of quadrat:						
<b>Height of tallest tree in canopy</b>	m	m	m	m	m	m
<b>Height of emergent trees</b> (if present)	m	m	m	m	m	m

**PROFORMA FOR MONITORING BASIC INDICATORS**

Project Name:	Assessed by:	Date assessed:	Page 3 of 6
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**FOREST STRUCTURE**

Trees and shrubs are counted on quadrats centred on the 5 m, 25m and 45 m points. At each point, set out a 10 m x 10 m quadrat (= two 5 m x 10 m quadrats, located either side of the transect: see Figure 3). Use a 2.5 m length of PVC pipe (flipped end-over-end) to locate the corners of the quadrats and mark with flagging tape.

**In one 5 m x 10 m quadrat**, count all shrubs (1-2 m high) and trees (>2 m high). Use the 2.5 m pipe (marked at 1 m and 2 m) to quickly assess whether plants are shrubs or trees (measure height to the base of the highest leaf). Trees are tallied by dbh class (= stem diameter 1.3 m above ground). If trees have multiple trunks, score each trunk >2 m high. Tally dead trees (stags) separately from live trees.

**In the other 5 m x 10 m quadrat**, count only larger (>10 cm dbh) trees and stags, by dbh class.

If living trees are damaged, also score each **damaged stem**: 1 = defoliation/ smaller branches broken; 2 = larger branches broken; 3 = trunk broken; 4 = tree pushed over >45° or uprooted.

PLOT 1 5 m	Shrubs (1-2 m high) Tally of stems	Trees (>2 m high) tally stems by dbh class					
		<2.5 cm dbh	2.5-10 cm dbh	10-20 cm dbh	20-50 cm dbh	50-100 cm dbh	>100 cm dbh
First 5 m x 10 m quadrat							
Second 5 m x 10 m quadrat	Larger trees (>10 cm dbh) only						
Structural damage: score for each damaged stem (1-4)							
Dead trees (stags): tally	First quadrat						
	Second quadrat (stags >10 cm dbh only)						

Note: Draw a line under the table when the plot has been completed.

PLOT 1 25 m	Shrubs (1-2 m high) Tally of stems	Trees (>2 m high) tall stems by dbh class					
		<2.5 cm dbh	2.5-10 cm dbh	10-20 cm dbh	20-50 cm dbh	50-100 cm dbh	>100 cm dbh
First 5 m x 10 m quadrat							
Second 5 m x 10 m quadrat	Larger trees (>10 cm dbh) only						
Structural damage: score for each damaged stem (1-4)							
Dead trees (stags): tally	First quadrat						
	Second quadrat (stags >10 cm dbh only)						

Note: Draw a line under the table when the plot has been completed.

PLOT 1 45 m	Shrubs (1-2 m high) Tally of stems	Trees (>2 m high) tall stems by dbh class					
		<2.5 cm dbh	2.5-10 cm dbh	10-20 cm dbh	20-50 cm dbh	50-100 cm dbh	>100 cm dbh
First 5 m x 10 m quadrat							
Second 5 m x 10 m quadrat	Larger trees (>10 cm dbh) only						
Structural damage: score for each damaged stem (1-4)							
Dead trees (stags): tally	First quadrat						
	Second quadrat (stags >10 cm dbh only)						



**PROFORMA FOR MONITORING BASIC INDICATORS**

Project Name:	Assessed by:	Date assessed:	Page 4 of 6
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**FOREST STRUCTURE**

Trees and shrubs are counted on quadrats centred on the 5 m, 25m and 45 m points. At each point, set out a 10 m x 10 m quadrat (= two 5 m x 10 m quadrats, located either side of the transect: see Figure 3). Use a 2.5 m length of PVC pipe (flipped end-over-end) to locate the corners of the quadrats and mark with flagging tape.

**In one 5 m x 10 m quadrat**, count all shrubs (1-2 m high) and trees (>2 m high). Use the 2.5 m pipe (marked at 1 m and 2 m) to quickly assess whether plants are shrubs or trees (measure height to the base of the highest leaf). Trees are tallied by dbh class (= stem diameter 1.3 m above ground). If trees have multiple trunks, score each trunk >2 m high. Tally dead trees (stags) separately from live trees.

**In the other 5 m x 10 m quadrat**, count only larger (>10 cm dbh) trees and stags, by dbh class.

If living trees are damaged, also score each **damaged stem**: 1 = defoliation/ smaller branches broken; 2 = larger branches broken; 3 = trunk broken; 4 = tree pushed over >45° or uprooted.

PLOT 2 5 m	Shrubs (1-2 m high) Tally of stems	Trees (>2 m high) tally stems by dbh class					
		<2.5 cm dbh	2.5-10 cm dbh	10-20 cm dbh	20-50 cm dbh	50-100 cm dbh	>100 cm dbh
First 5 m x 10 m quadrat							
Second 5 m x 10 m quadrat	Larger trees (>10 cm dbh) only						
Structural damage: score for each damaged stem (1-4)							
Dead trees (stags): tally	First quadrat						
	Second quadrat (stags >10 cm dbh only)						

Note: Draw a line under the table when the plot has been completed.

PLOT 2 25 m	Shrubs (1-2 m high) Tally of stems	Trees (>2 m high) tall stems by dbh class					
		<2.5 cm dbh	2.5-10 cm dbh	10-20 cm dbh	20-50 cm dbh	50-100 cm dbh	>100 cm dbh
First 5 m x 10 m quadrat							
Second 5 m x 10 m quadrat	Larger trees (>10 cm dbh) only						
Structural damage: score for each damaged stem (1-4)							
Dead trees (stags): tally	First quadrat						
	Second quadrat (stags >10 cm dbh only)						

Note: Draw a line under the table when the plot has been completed.

PLOT 2 45 m	Shrubs (1-2 m high) Tally of stems	Trees (>2 m high) tall stems by dbh class					
		<2.5 cm dbh	2.5-10 cm dbh	10-20 cm dbh	20-50 cm dbh	50-100 cm dbh	>100 cm dbh
First 5 m x 10 m quadrat							
Second 5 m x 10 m quadrat	Larger trees (>10 cm dbh) only						
Structural damage: score for each damaged stem (1-4)							
Dead trees (stags): tally	First quadrat						
	Second quadrat (stags >10 cm dbh only)						

**PROFORMA FOR MONITORING BASIC INDICATORS**

Project Name:	Assessed by:	Date assessed:	Page 5 of 6
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**SPECIAL LIFE FORMS** Survey the presence of each life form in 10 m x 10 m quadrats centred on the 5 m, 25 m and 45 m points (see Figure 3). Note if a special life forms is present on site, if not in plots.

Special Life Forms	Plot 1			Plot 2			Onsite
	5 m	25 m	45 m	5 m	25 m	45 m	
Location of quadrat:							
<b>Strangler figs</b> Figs with network of roots around stem of host tree, rooted in ground							
<b>Hemi-epiphytes</b> Climbing plants adhering to tree trunks, rooted in ground, e.g. <i>Pothos</i>							
<b>Vines</b> Climbing woody-stemmed plants dependent on trees, etc. for support, and rooted in the ground	<b>Slender</b> (stem <5 cm diam.)						
	<b>Robust</b> (stem >5 cm diam.)						
<b>Vine towers</b> Dense columns of vines growing over and smothering tree crowns and stems							
<b>Vine tangles</b> Dense masses of interwoven vine stems in understorey or midstorey							
<b>Thorny scramblers</b> Thicket-forming spiny vines or shrubs, e.g. <i>Calamus</i> , lantana, cocksbur, raspberry	<b>Individual plants</b> present						
	<b>Thickets</b> present						
<b>Palm trees</b> Palms with stems >2 m high							
<b>Understorey palms</b> with stems <2 m high, e.g. walking stick palms, juvenile palm trees							
<b>Tree ferns</b> Ferns with stems usually >0.5 m high							
<b>Ground ferns</b> Ferns or fern-like plants without stems, growing on the ground							
<b>Clumping epiphytic ferns</b> Growing on trees, e.g. staghorns, elkhorns, basket ferns							
<b>Other epiphytes</b> Growing on trees not rooted on ground, e.g. trailing ferns, orchids							
<b>Cordylines</b> 'Palm-lilies': shrubs to 5 m high, occasionally branched, with long leaves							
<b>Herbs with long wide leaves</b> e.g. gingers, cunjevoi, bananas							
<b>Herbs with long strap-like leaves</b> e.g. lilies, mat-rush ( <i>Lomandra</i> )							
<b>Cycads</b> Plants with leathery palm-like foliage borne on stout stems or growing on ground (subterranean stems)	Stout stems, e.g. <i>Lepidozamia</i>						
	Ground cycads, e.g. <i>Bowenia</i>						
<b>Other</b> (describe)							

**Coarse woody debris\*** = fallen logs and branches >10 cm diameter, lying on or within 2 m of the ground. Count the number of logs intersected by each 50 m transect by diameter class, measured where crossed by the transect. If a log crosses the transect more than once, it is counted each time it is >10 cm diam.

Number of times logs intercepted on:	Coarse woody debris					Fine woody debris	
	10-25 cm	25-50 cm	50-75 cm	75-100 cm	>100 cm	2.5-5 cm	5-10 cm
50 m transect Plot 1							
50 m transect Plot 2							

\* OPTIONAL: Also survey fine woody debris (logs 2.5-10 cm diam.) on the 50 m transects, if desired.

**PROFORMA FOR MONITORING BASIC INDICATORS**

Project Name:	Assessed by:	Date assessed:	Page 6 of 6
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**GENERAL COMMENTS** *on structure and composition of vegetation, and variation across site.*

**Tree and canopy layer:**

**Understorey and ground layer:**

**Recruitment:**

*What type of plants are recruiting to the site (e.g. natives, weeds)?*

**Weed and maintenance issues:**

**Photopoint information** *(Note: mark locations of photopoints on 'mud-map', page 1 of proforma)*

Landscape photopoint location:	Direction of photo:
Map / GPS reference: Datum:	
Have photos been taken of <b>Plot 1?</b> Yes / No <b>Plot 2?</b> Yes / No	
If <i>not</i> at 0 m marks, note location and direction of photos:	

**Any other comments on the site?** If more space needed, tick here \_\_\_\_\_ and add extra page.



## 5. DATA MANAGEMENT, ANALYSIS AND EVALUATION

This section of the toolkit provides information on the storage and analysis of data from surveys of revegetated sites, and discusses ways in which that data from monitoring surveys might be used to evaluate the 'success' of a revegetation project, or to compare the performance of different revegetation techniques. Because we realise that data analysis can sometimes be daunting to people without scientific training, we have designed a simple Microsoft Excel spreadsheet ('Basic Indicator data file.xls') to store and automatically calculate the value of basic indicators from data recorded in the monitoring proforma, and to plot trends in the data over time. However, we also realise that there may be some situations where formal statistical analysis cannot be avoided (e.g. where there is a legal requirement to restore a site to a particular condition). We briefly discuss some of the approaches that might be used to analyse monitoring data in these situations, but assume that people needing to conduct formal analyses will seek out competent advice.

### 5.1 DATA MANAGEMENT

A revegetated site may take years to achieve 'site capture', decades to recruit a diverse range of native plants and wildlife, and centuries to approach the condition of remnant forest. Over that time, memories will fade, computers and software become obsolete, and volunteers come and go. Tracking changes in a revegetation project therefore requires good data management. While the details will vary, some of the key elements of good data management include data integrity (checking and correcting errors), data security (storing data in a secure and accessible file system, making and storing backup copies, keeping original field sheets), and maintaining metadata (keeping a record of what the data are about, the methodology used to collect the data, where the data are stored and in what format, the names of relevant computer files, etc.). A suggested approach to data management for information collected with this toolkit is as follows:

#### ***Data integrity***

The data in the proformas should be given a quick check while still in the field. Enter the data from the field proformas into a computer file as soon as possible after collection (same day or week, preferably), while the information is still fresh. A Microsoft Excel spreadsheet has been designed to store data from the monitoring proformas provided in this toolkit (see Section 5.2). The data entered into spreadsheets should be checked for errors by comparison with the proformas.

#### ***Data security***

Make at least one backup copy of the data on a suitable long-lasting medium (e.g. CD). The original field proformas and a backup copy of the data should be stored in a secure and well-maintained filing system. For additional security, a second back-up copy of the data could be stored at another location.

#### ***Maintaining metadata***

Keep a description of the data and the methodology used to collect the data (e.g. a copy of the toolkit or relevant pages from it), with the field proformas and the backup data. Keep a written record of where the data are stored and in what format, and the names of relevant computer files, with the field proformas and backup data. An example of the type of metadata that might be stored with the results of a monitoring survey is given in Table 3.

**Table 3:** Example of metadata associated with monitoring basic indicators at a revegetated site.

<b>Project Name:</b>	<i>Victoria Park restoration: site north of remnant</i>		
<b>Age of revegetation (if relevant):</b>	26 yrs	<b>Assessed by:</b> <i>John Kanowski</i>	<b>Date assessed:</b> <i>7 June 2006</i>
<b>Database Info:</b>	<b>Project ID:</b> <i>QBVR SE7</i>	<b>Stage:</b> <i>n/a</i>	<b>Year:</b> <i>1979</i>
<b>Data Description:</b>	<i>Results of survey of 'basic indicators' (vegetation structural attributes) on a revegetated ex-rainforest site</i>		
<b>Data Type:</b>	<i>Spreadsheet in Excel 2000 format</i>		
<b>Methodology:</b>	<i>Protocol for monitoring 'basic indicators' as per the 'Monitoring revegetation projects for biodiversity in rainforest landscapes: Toolkit version 1' (copy kept with this file).</i>		
<b>Location of Files:</b>	<i>The data are stored on the computer server at Griffith University at H:/RCRCR/monitoring/Basic Indicator data file Vic_Park_Reveg.xls; A copy is on the CD stored with this file. A second copy of the data is held by John Kanowski.</i>		

## 5.2 DATA ENTRY AND ANALYSIS

An Excel spreadsheet ('Basic Indicator data file.xls') has been written to accompany this toolkit, to help store, analyse and summarise the data collected from monitoring revegetated sites. The spreadsheet includes:

- A page of explanatory notes;
- Pages to record data from a number of monitoring surveys of a revegetated site, including a baseline survey;
- Pages to record surveys of reference sites; and
- A page that automatically creates summaries and graphs of trends in the data over time, and compares the trends with reference sites.

The data entry pages have the same format as the survey proformas. One page of the spreadsheet is associated with the data from one monitoring survey. Note that the file is in 'read-only' format, and needs to be saved under a different name (e.g. the name of the site being monitored) when first used to record data.

The spreadsheet automatically calculates the values of basic indicators from the monitoring data entered into it, using the calculations listed in Table 4. In most cases, these calculations are simply the average values of attributes from replicate plots, quadrats or transects in a monitoring survey, although some calculations are more complex.

The spreadsheet automatically creates graphs of trends in basic indicators at a revegetated site over time. These graphs include data from a baseline survey, if available, and show how much a site has changed following revegetation. The spreadsheet also creates graphs of the values of basic indicators in reference sites (if surveyed), to allow evaluation of the 'success' of the revegetation project when compared with the reference sites.

Examples of the spreadsheets and the graphs it produces are presented in Figures 4 and 5.

Copies of the spreadsheet ('Basic Indicator data file.xls') will be posted on the websites of the Rainforest CRC and / or the Griffith University Centre for Innovative Conservation Strategies (CICS). Questions or comments on the spreadsheet should be addressed to the authors of this toolkit.

**Table 4:** Derivation of basic indicators from data collected using the monitoring protocols presented in this toolkit. The indicators are calculated automatically when data are entered in the 'Basic Indicator data file.xls'.

Attribute	Definition / Derivation
Canopy cover	Average of cover estimates (either visual estimates, or calculated from photos).
Canopy height	Average of height estimates.
Tree density	Number of tree stems per ha, calculated for all stems, and for stems in each dbh class separately.
Shrub density	Number of shrub stems per ha.
Stem diversity	Shannon-Wiener (H) index of the proportion of stems in each size class, calculated from counts of trees in each dbh class and counts of shrubs: $H = -\sum p_i * \ln(p_i)$ , where $p_i$ is the proportion of stems in the $i^{th}$ size class.
Tree basal area	Cross-sectional area of trees, calculated from dbh classes: $BA (m^2 \text{ per ha}) = \sum n_i \pi (dbh_i)^2 / 40000$ , where $n_i$ is the number of stems in the $i^{th}$ size class/ ha, and $dbh_i$ is the notional diameter (cm) of the $i^{th}$ size class (= lower limit of class + 1/3 the class range, to account for the right-skewed distribution of stem sizes).
Stag basal area	Cross-sectional area of dead trees, calculated from dbh classes, as above.
Woody debris volume	Volume of woody debris calculated from the line intercept method (Van Wagner 1968): $V (m^3 \text{ per ha}) = (\pi^2 / 8 L) \sum n_i d_i^2$ where $L$ = transect length (m), $n_i$ = number of logs in the $i^{th}$ diameter class, and $d_i$ is the notional diameter (cm) of the $i^{th}$ size class (= lower limit of class + 1/3 the class range, to account for the right-skewed distribution of log sizes).
Ground cover	Average of cover estimates for each category.
Ground cover index	Index of the similarity of ground cover in revegetated sites compared with forest reference sites, where cover types are weighted by their average value in reference sites. $\text{Index} = \sum p_i * u_i$ , where $p_i$ is the value of the $i^{th}$ ground cover as a proportion of the average of the $i^{th}$ ground cover in forest reference site(s), and $u_i$ is the average of the $i^{th}$ ground cover in forest reference site(s). Note: the index does not include grass cover or rock cover. $p_i$ is capped at 1. The index ranges from 0-100 %.
Special life form frequency index	For each life form, the proportion of quadrats where each life form was recorded (index ranges from 0-1). If a life form was recorded on site, but not on any quadrats, it is given the value of 0.1.
Special life form index	The frequency of special life forms relative to their occurrence in forest reference site(s). $\text{Index} = \sum p_i / n * 100$ , where $p_i$ is the frequency of the $i^{th}$ life form, as a proportion of its average frequency in forest reference site(s), and $n$ is the number of life forms encountered in forest reference site(s). Note: $p_i$ is capped at 1. The index ranges from 0-100%. Life forms recorded in the revegetated site but not the reference site neither add to, nor detract from, the index score.
Site 'structural condition index'	The average value of selected structural attributes relative to forest reference sites (attributes are: canopy cover, canopy height, ground cover index, forest structure (shrub density, tree density in each size class, total tree density, tree basal area, stag basal area, stem diversity index), special life form index, coarse woody debris). $\text{Index} = \text{average } p_i * 100$ , where $p_i$ is the value of the $i^{th}$ attribute, as a proportion of its average value in forest reference site(s). Note: $p_i$ is capped at 1. The index ranges from 0-100%. This index provides a measure of the average development of structural attributes relative to forest reference sites: e.g. a score of 40% would indicate that, on average, the value of selected attributes at a site were at least 40% of values recorded in reference sites.
<i>Note, for all indices, 0 = unlike reference sites; 1 or 100 = similar to reference sites</i>	

Enter data from field proforma into cells in tables below						
Site name	Victoria Park					
Age of revegetation (yrs)	26					
Assessed by:	J. Kanowski					
Date of assessment:	7/06/2006					

Ground cover	Plot 1			Plot 2		
	5 m	25 m	45 m	5 m	25 m	45 m
Enter % cover for cover types present						
<b>a) Vegetation within 1m of ground</b>						
Grass and sedges		5	10	30		5
Herbs = soft-stemmed plants		60		10		10
Ferns						10
Vines & scramblers inc. lantana					25	
Trees, shrubs, seedlings	1		1		10	15
Moss and other cryptogams (liverworts etc)						
<b>b) Leaf litter</b> and fine woody debris <10 cm diam	80	15	79	20	35	50
<b>c) Coarse woody debris</b> >10 cm diam					10	
<b>d) Rock</b>	1			10		
<b>e) Soil</b>	18	20	10	30	20	10
<b>f) Other</b> inc. tree trunks, roots						
<b>TOTAL</b> (note: must add up to 100%)	100	100	100	100	100	100

Canopy cover	Plot 1			Plot 2		
	5 m	25 m	45 m	5 m	25 m	45 m
Enter % cover.						
<b>Visual estimate</b>	95	82	70	65	70	90
<b>Canopy cover calculated from photo</b>	91	76	65	60	65	82

Canopy height	Plot 1			Plot 2		
	5 m	25 m	45 m	5 m	25 m	45 m
Enter height in metres						
<b>Height of tallest tree in canopy (m)</b>	12	15	17	11	9	18
<b>Height of emergent trees</b> (if present) (m)						

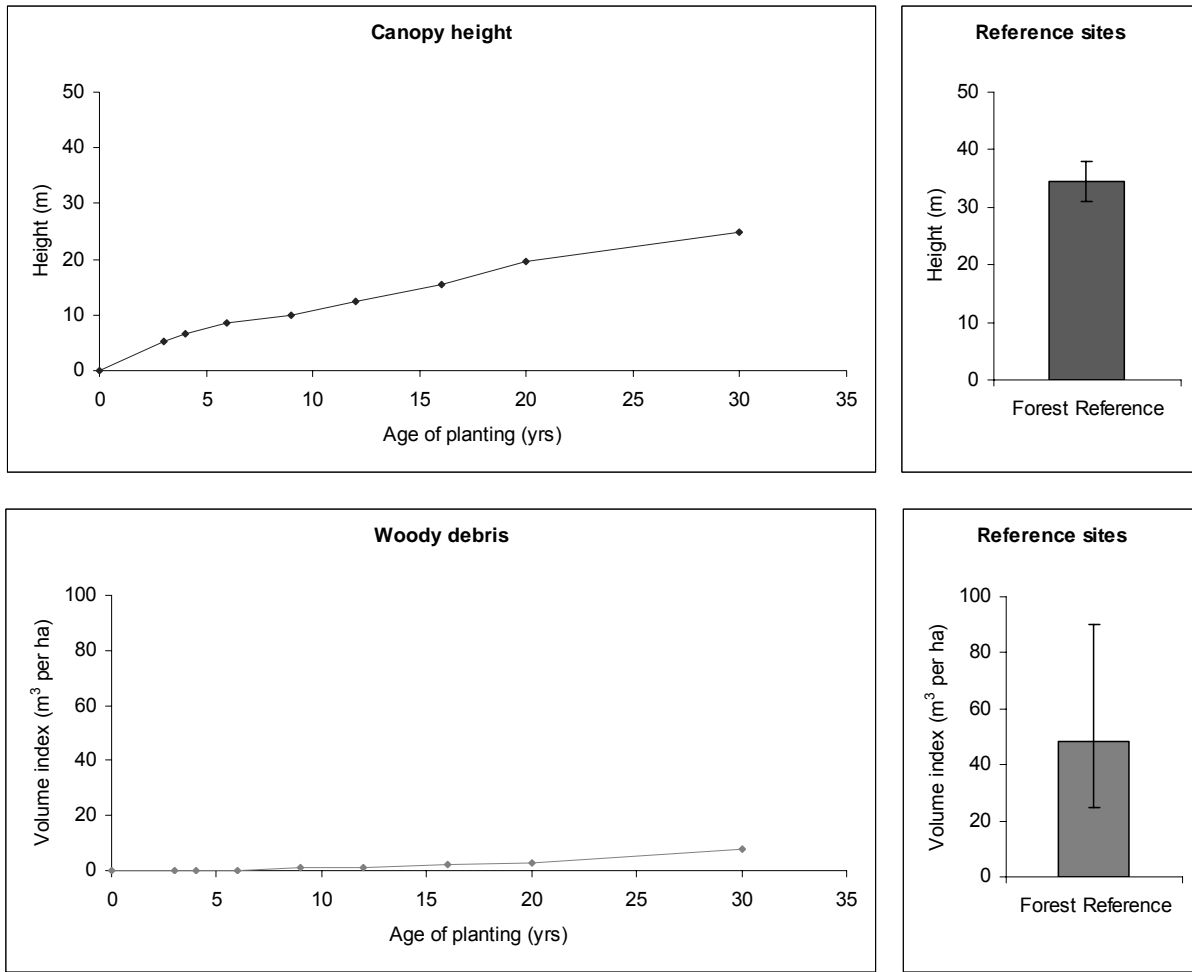
  

Summary data for 'basic indicators'		NOTE: DO NOT ENTER DATA INTO THE SUMMARY CELLS Values are calculated automatically	
Number of plots surveyed	2	The monitoring proforma is set up to accept data from 2 plots per site.	
Number of quadrats surveyed	6	However, calculations will still be correct, even if only 1 plot was surveyed at a site Note: calculations assume that ground cover was assessed on all 3 quadrats in each plot survey	
<b>ATTRIBUTE</b>	<b>Result</b>	<b>Units</b>	
<b>GROUND COVER</b>			
<b>a) Vegetation &lt; 1m of ground</b>			
Grass and sedges	8.3	%	
Herbs	13.3	%	
Ferns	1.7	%	
Vines & scramblers	4.2	%	
Trees, shrubs, seedlings	4.5	%	
Moss and other cryptogams	0.0	%	
<b>b) Leaf litter &amp; fine woody debris</b>	46.5	%	
<b>c) Coarse woody debris</b>	1.7	%	
<b>d) Rock</b>	1.8	%	
<b>e) Soil</b>	18.0	%	
<b>f) Other</b>	0.0	%	
<b>CANOPY COVER</b>			
Visual estimate	78.7	%	
Canopy cover calc. from photo	73.2	%	
<b>CANOPY HEIGHT</b>			
Height of tallest tree in canopy	13.7	m	
Height of emergent trees (if present)		m	

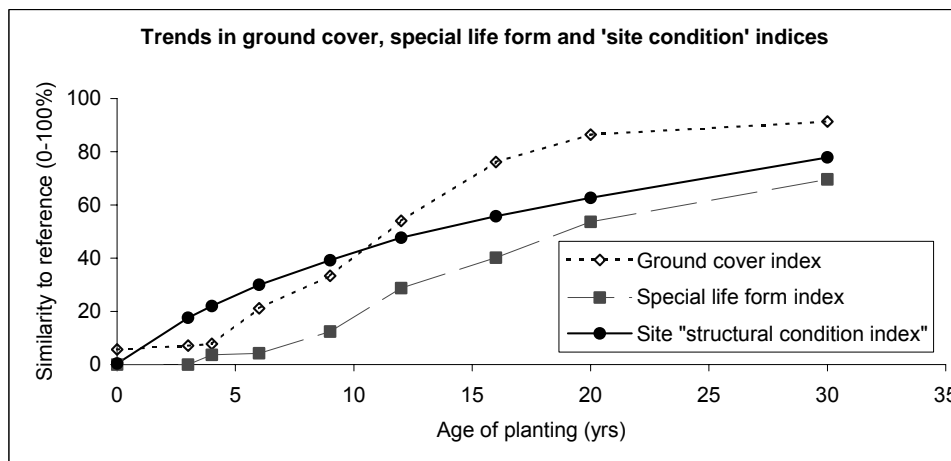
Figure 4: Example of part of a worksheet from the 'Basic Indicator data file.xls'. The worksheet is used to enter data from monitoring basic indicators at revegetated sites (top panel), and automatically calculates the values of basic indicators from these data (lower panel).



(a) Comparison of values in a revegetated site with mean (and range) of values in reference sites.



(b) Trends in indices of ground cover, special life forms, and structural condition in a revegetated site.



**Figure 5:** Comparison of trends in basic indicators in a revegetated site with reference sites: (a) comparison of canopy height and woody debris with values (mean + range) in reference sites; (b) trends in indices of ground cover, special life forms and 'site structural condition' in revegetated sites. The indices internalise a comparison with reference sites. The 'site structural condition' is simply the average of a number of structural attributes in revegetated sites, expressed as a proportion of corresponding values in reference sites (see Table 4). The example is from the summary worksheet in the 'Basic Indicator data file.xls', which automatically creates these graphs, given sufficient data.

## 5.3. EVALUATING REVEGETATION PROJECTS

### 5.3.1. Tracking the Progress of a Revegetation Project and Evaluating its 'Success'

When a revegetated site has been monitored on several occasions, the results of monitoring surveys can be graphed to show changes in the attributes of that site over time. Examination of trends in these attributes can show whether, and how fast, a site is developing towards target conditions. If a project is not progressing as swiftly as planned, or in the intended direction, changes can be made to the management of the project, or the design of future projects.

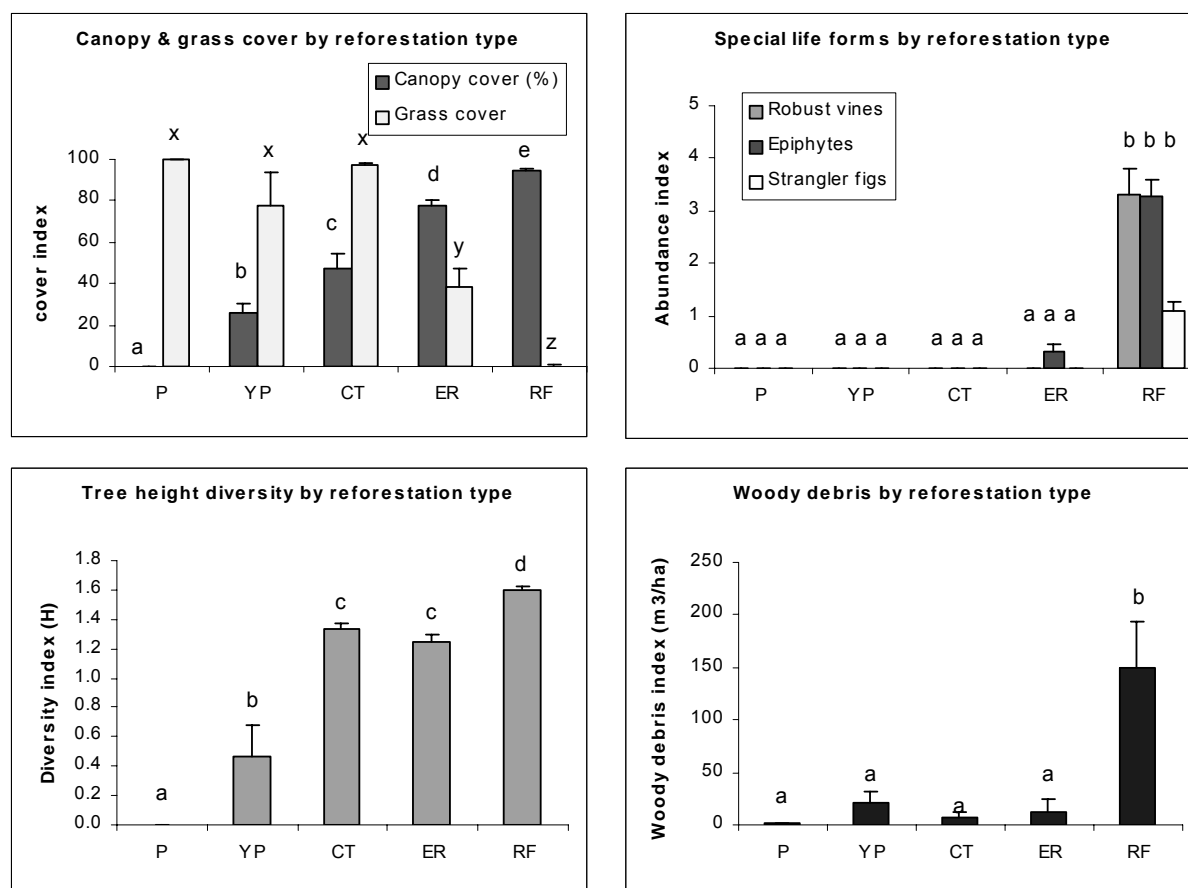
A useful way of evaluating the progress of a revegetated site is to compare the monitoring results with (i) baseline data (describing the condition of a site before the revegetation was established) and (ii) with data from surveys of one or more reference sites (i.e. forests representing the 'target condition', such as remnant forests of the type that may have occurred on a site prior to clearing). Comparison with baseline data will show how much a site has changed following revegetation, while comparison with forest reference site(s) can show whether the revegetated site has achieved the target condition, and if not, what attributes need further development. Comparisons with reference sites are particularly useful because many structural attributes vary between different forest types and regions (Webb *et al.* 1976).

Figure 5 shows an example of how trends in monitoring results can be compared with baseline data and reference sites. Trends can be examined for individual attributes (see, for example, trends for canopy height and woody debris, shown in panel (a) of Figure 5), or trends can be plotted for indices calculated across a range of attributes (e.g. panel (b) in Figure 5). The 'Basic Indicator data file.xls' associated with this toolkit calculates indices for ground cover, special life forms and an overall index of 'site structural condition' (see definitions in Table 4). These indices incorporate a comparison with reference sites in their calculation, and range from 0 (unlike reference conditions) to 100 (resembling reference conditions). While indices can greatly simplify the presentation of data from monitoring surveys, it is important not to lose sight of the underlying trends. For example, an index may fail to reveal changes in a monitored site, if an increasing trend in one attribute is cancelled out by a decreasing trend in another.

### 5.3.2. Evaluating the Performance of Different Revegetation Methods or Techniques

Monitoring programs aimed at comparing the performance of different revegetation methods require a suitable experimental design, typically the survey of different 'treatments' on replicate plots or sites over time (see Section 2). This type of monitoring is essentially ecological research and the results would need to be analysed by appropriate statistical methods. A detailed discussion of this topic is beyond the scope of this toolkit, and practitioners wanting to conduct this type of monitoring program should seek competent ecological and statistical advice.

An example of this type of analysis is presented in Figure 6, concerning the development of structural attributes in different types of reforestation in northern Queensland. The reforested sites were compared with control sites (pasture) and reference sites (rainforest). Five to ten replicate sites were selected in each 'treatment'. The results were analysed using ANOVA. The results show that restoration plantings had a more 'rainforest-like' structure than timber plantations, and there were some differences in structure between monoculture and mixed species plantations. While all reforested sites had acquired some forest attributes, all lacked some characteristic structural features of rainforest, particularly special life forms and woody debris.



**Figure 6:** Example of the use of monitoring results to compare the performance of different types of reforestation. Site types: P = pasture; YP = monoculture plantations; CT = mixed species cabinet timber plantations; ER = ecological restoration plantings; RF = rainforest. Site types with different letters have significantly different values for each attribute. The data are from surveys of sites on the Atherton Tableland, northern Queensland (Kanowski *et al.* 2003; Catterall *et al.* 2004).

## 5.4 OTHER ISSUES TO CONSIDER IN EVALUATING THE 'SUCCESS' OF REVEGETATION PROJECTS

### 5.4.1 Rigorous Assessments of the 'Success' of Revegetation Projects

The comparison of monitoring results from revegetated sites with baseline data and reference sites, as discussed above, will provide useful information on the progress of a site towards target conditions. However, in some cases, a more rigorous assessment of 'success' may be required: for example, when a restoration project has to meet legal or contractual obligations. One of the main features of a robust design would be the survey of replicate plots within the revegetated site, to properly account for the variability in a site and to facilitate statistical analysis of the results. Again, a detailed discussion of these matters is beyond the scope of this toolkit.

### 5.4.2 Assessing Whether a Revegetated Site is on a 'Recovery Trajectory'

The comparison of revegetated sites with reference sites might be considered an interesting but largely academic exercise, given that most revegetation projects are still relatively young and would not be expected to resemble mature rainforest for many decades, perhaps centuries. In these circumstances, it may be more useful to determine whether trends in the

attributes of a young revegetated site are tending to converge on the attributes of reference site(s), and whether the rate of convergence is acceptable. This approach has been termed 'trajectory analysis' by the Society for Restoration Ecology (2004). When combined with ecological knowledge, this approach may be useful in identifying which attributes need intervention to 'move' them towards target conditions, and which can be left to develop by natural processes. The graphs produced by the 'Basic Indicator data file.xls' (see Figure 5) are an informal kind of 'trajectory analysis' for basic indicators in revegetated sites.

Again, a robust formal assessment of the trajectory of a revegetated site would require the survey of replicate plots or sites, and suitable statistical analyses. Several authors have used multivariate analysis to argue that restoration is (Jansen 2005) or is not (Wilkins *et al.* 2003) progressing towards reference conditions. The Society for Restoration Ecology (2004) considers that trajectory analysis is "still under development". A proper assessment of whether a revegetated site is trending towards target conditions will probably require long-term data on the developmental trajectories of many sites, representing a range of ecological conditions, and we are still a long way off having such data for rainforest. For example, an analysis of successional trajectories in jarrah (*Eucalyptus marginata*) forests rehabilitated after bauxite mining required data from several hundred plots, some of which had been monitored for decades (Grant 2006). It is hoped that the production of this toolkit will facilitate the collection of data to advance our knowledge of the ecological development of revegetated sites in rainforest landscapes.

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## GLOSSARY

Term	Definition
Actions	The on-ground activities undertaken to achieve the project objectives, in broad terms. For the purpose of this toolkit, these actions are likely to include remnant protection, remnant enhancement and revegetation.
Advanced indicators	Measures of plant and animal composition or ecological processes of a site, which may require specialist knowledge and training. Protocols for monitoring advanced indicators will be presented in later versions of the toolkit.
Aspect	The compass direction you face when you stand on a slope and look in the direction of the steepest fall of land
Basal area	Cross-sectional area of trees, calculated from counts of stems in dbh classes.
Baseline data	Information on the condition of a site prior to revegetation. The comparison of monitoring results with baseline data can show how much a site has changed following revegetation. Where baseline data are not collected, it is difficult to make strong claims about the effects of revegetation on target variables.
Basic indicators	Aspects of forest structure that reflect the development of a revegetation project, can be measured easily and rapidly in the field, without specialist knowledge, and are correlated with the use of sites by rainforest wildlife.
Building phase of revegetation	The stage of revegetation after 'site capture', during which the planted trees mature, reproduce and die, and other species of plants and animals are recruited to the site. In a restoration project, the aim of this phase is typically the development of a floristically and structurally diverse forest that provides habitat for native wildlife. It may take decades or even centuries for a revegetated site to come to resemble mature rainforest.
Canopy cover	Projective cover (percentage) of vegetation >2 m above ground (= shade cast by vegetation >2 m above ground, if sun was directly overhead).
Canopy height	Height attained by the crown of the tallest tree in the canopy. The canopy is the layer of foliage forming the 'roof' of the forest; it may be broken by gaps or incomplete. In some sites, it may be necessary to distinguish canopy trees from emergent trees.
Coarse woody debris	Fallen logs and branches >10 cm diameter, lying on or within 2 m of the ground. Where present, coarse woody debris usually comprises most of the volume of woody debris. Provides habitat for organisms dependent on rotting wood, as the core remains moist.
Control sites	Sites not revegetated but included in the monitoring program to represent examples of the 'do nothing' option. Monitoring control sites can help to identify what outcomes were due to revegetation and what to other factors (e.g. natural regrowth). Control sites can also be used to provide surrogate baseline data, if baseline data were not collected from sites prior to revegetation.
Correlation	A term describing the statistical relationship between two variables. Two variables can be positively correlated if their trends run in the same direction (e.g. tree height and dbh), or negatively correlated if their trends run in opposite directions (e.g. canopy cover and grass cover). When variables are correlated, one can be used as a surrogate for the other in monitoring surveys.
Datum	The horizontal reference system used to draw up a map grid (e.g. WGS84, GDA94). For any set of GPS or map coordinates, the datum should be specified; both the coordinates and datum are needed to specify a location.
Dbh (diameter at breast height)	The diameter of a tree, measured at 1.3 m above the ground, or above the buttress (if present).
Emergent trees	Trees projecting well above canopy, with crowns exposed on all sides.
Establishment phase of revegetation	The period from when seeds or seedlings are planted until they have 'captured' the site, forming a relatively closed canopy and suppressing competing grasses and other weeds. The establishment phase may last three to five years, depending on site conditions, planting design, maintenance, etc.

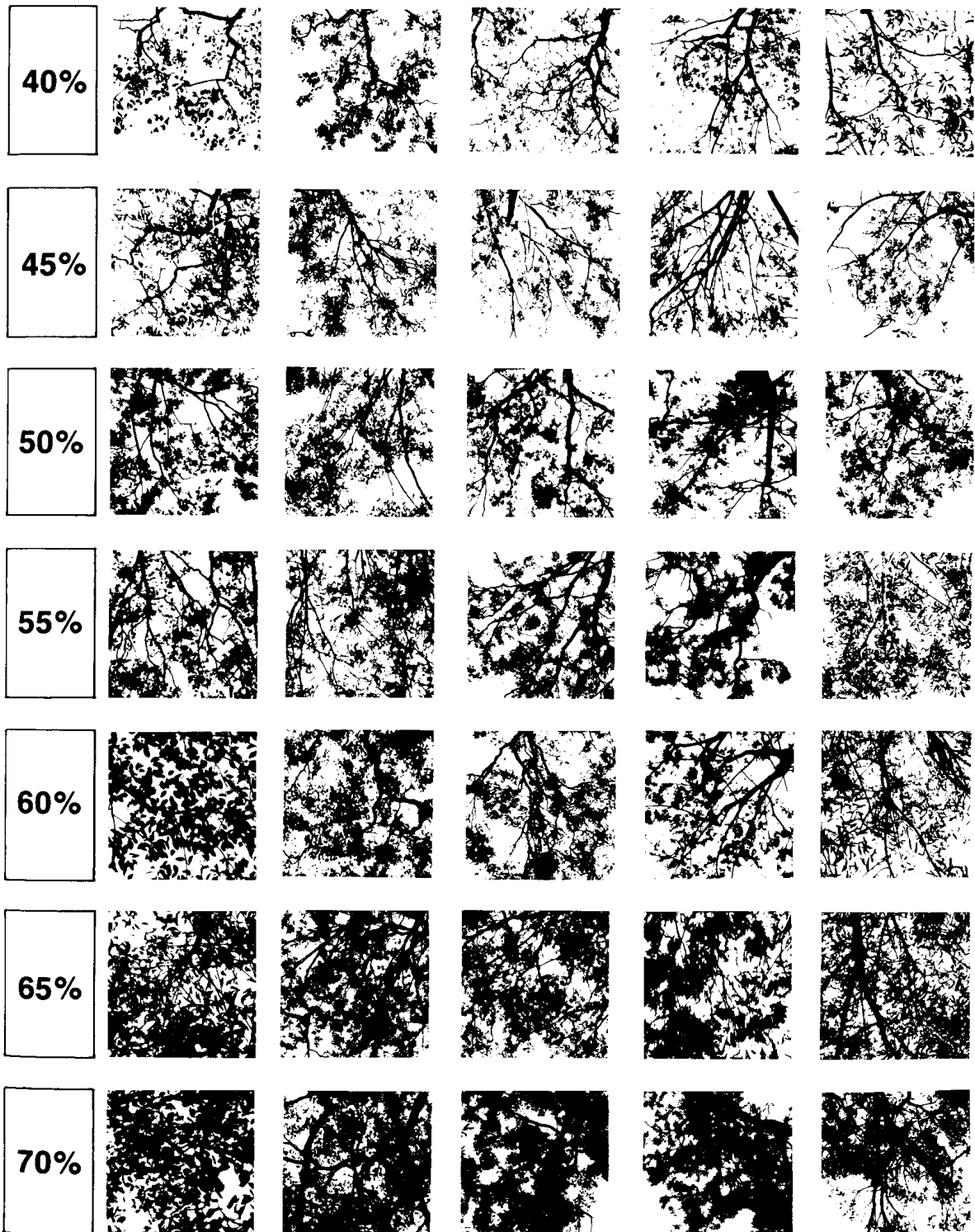
Term	Definition
Establishment statistics	Details of the on-ground works done in a project.
Fine woody debris	Fallen logs and branches 2.5-10 cm diameter, lying within 2 m of the ground
Forest structure	The arrangement of trees and shrubs at a site. In this toolkit, forest structure is assessed by surveying stem density in a range of size classes (shrubs, and trees by dbh class).
Floristic composition	The assemblage of plants present at a site.
Ground cover	The proportion of ground obscured by (a) vegetation <1 m high (scored separately for each of: grass, herbs, ferns, vines and scramblers, trees and shrubs, moss and cryptogams); (b) leaf litter and fine woody debris; (c) coarse woody debris; (d) rock; (e) soil; and (f) other (including tree trunks, roots).
Herbs	Soft-stemmed plants (other than ferns, moss, etc.).
Landform	A description of the topographical location of a site, e.g., plateau, crest, upper slope, mid-slope, lower slope, stream bank, flat.
Leaf litter	Fallen leaves and branches <2.5 cm dbh.
Metadata	A description of a collection of data: usually includes a description of what attributes the data are about, the methodology used to collect the data, where the data are stored and in what format, the names of relevant computer files, etc. The recording of metadata allows someone else to access and understand a datafile.
Monitoring	For the purposes of this toolkit, monitoring is defined as the repeated survey of selected attributes to track and evaluate the progress of revegetation at a site, or to compare the outcomes of different revegetation techniques.
Objectives	The main purposes of the project, in broad terms. Examples include improved biodiversity outcomes (e.g. conservation, habitat restoration), timber production, other forest products (e.g. bush tucker), stream bank stabilisation, catchment protection, erosion control, shelterbelts.
Photopoint	A place from which photos are taken for monitoring changes at a site. In this toolkit, photopoints are to be located at the start of each transect, as well as at a point looking across the revegetated site.
Project ID	Unique code given to a project, for example by a funding body, to simplify the storage of information in a database.
Quadrat	A survey plot of defined dimensions (e.g. 5 m x 10 m).
Recruitment	The process that describes the regeneration of plants at a site. Recruitment can be from plants which already grow at a site ('in-situ') or from dispersal from plants outside a site ('ex-situ').
Reference forest type or condition	A description or example of the type of forest that a project is trying to restore or create at a site. In many cases, this is the forest type that occurred at a site prior to clearing. However, the pre-clearing forest type may not be known, or may no longer be appropriate (e.g. if environmental conditions at the site have changed significantly since clearing). In these cases, another forest type may be chosen as the reference, or if none is suitable, the reference condition may need to be described from scratch.
Reference sites	Examples of the reference condition (e.g. sites in remnant forests of the type that occurred on a site prior to clearing). Comparison with reference sites can show the extent to which revegetated sites have reached target conditions, and what attributes need further development.
Remnant enhancement	Actions undertaken to improve remnant condition, e.g. weed control.
Remnant protection	Actions undertaken to protect a remnant forest, e.g. fencing from stock.
Replicate sites (or plots)	Two or more sites or plots where a particular treatment is repeated, or survey conducted. Replicates help control for site-specific factors (e.g. site history). They increase effort but also the generality of results. Replicate plots within a site are useful when attributes vary widely across a site (e.g. woody debris). If a monitoring program does not include replicate sites, the results may not apply beyond the site studied.

Term	Definition
Revegetation	Planting of cleared or degraded land.
Shrub	For the purposes of this toolkit, a woody-stemmed freestanding plant 1-2 m high. May include tree saplings as defined here.
Site capture	The stage of development reached by a revegetated site when it will continue to develop on its own towards the reference condition, without large management inputs. In rainforest, site capture occurs when the planted trees form a relatively closed canopy and suppress competing grasses and other light-dependent weeds.
Special life forms	Plant life forms characteristic of rainforest and/ or particular forest types. Includes: strangler figs, hemi-epiphytes, vines (<5 cm diameter, >5 cm diameter), vine towers, vine tangles, thorny scramblers, epiphytic ferns, tree ferns, ground ferns, palm trees, understorey palms, cordylines, herbs with long, wide leaves, herbs with strap leaves, cycads, and any other characteristic life form.
Species richness	The number of species in a defined group of animals or plants.
Stag	Dead standing tree.
Stratification	Selection of sites based on particular criteria, e.g. soil, aspect, rainfall. When monitoring replicate sites, stratification can help control for the effects of environmental factors on target variables. Otherwise, natural variation ('noise') may swamp the 'signal' that is being monitored.
Structural damage to trees	Damage to trees resulting from storm or cyclone damage. In this toolkit, structural damage is assessed as: 1 = defoliation and smaller branches broken; 2 = larger branches broken, 3 = trunk broken; 4 = tree pushed over at >45° angle or uprooted.
Surrogate	A variable (often relatively easy to survey) that is monitored in place of another, with which it is correlated. For example, the volume of woody debris might be monitored as a surrogate for the richness of beetles that live in rotting logs.
Survey regime	A term that describes the number and frequency of monitoring surveys. The survey regime should address the timescale over which changes to target variables are expected to occur and the ecology of the target variables (e.g. a monitoring program which targets birds may need to account for seasonal migration). 'One-off' surveys may be strongly affected by chance events (e.g. prevailing weather) or systematic bias (e.g. seasonal variation).
Target variables	Attributes surveyed in a monitoring program (e.g. survival, canopy cover, bird species composition). They should be relevant to the objectives of the project: e.g. a project that aims to provide habitat for birds should ideally monitor use of the site by birds, or at least attributes associated with birds (e.g. forest structure). Target variables vary widely in the effort, skills, permits, etc., required to survey them.
Transect	A survey line of defined length (e.g. 50 m).
Tree	Woody-stemmed freestanding plants >2 m high.
Tree density	Number of tree stems per ha.
Woody debris	Fallen logs and branches, lying on or within 2 m of the ground.



# APPENDIX 1

## CANOPY COVER PHOTOGRAPHS



Source: Walker and Hopkins (1990). Note: Canopy cover in rainforest is often > 90%.



## APPENDIX 2

### HOW TO CALCULATE CANOPY COVER FROM DIGITAL PHOTOGRAPHS

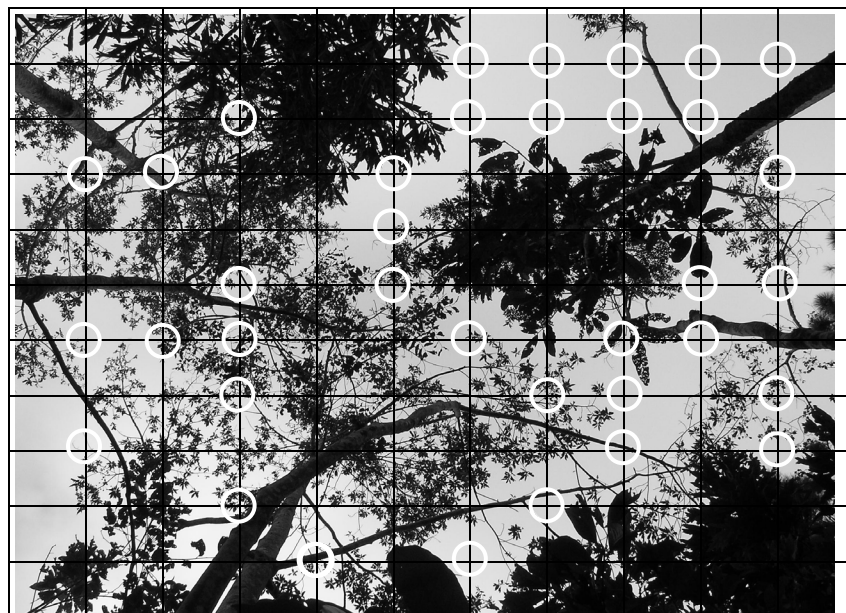
Visual estimates of canopy cover can be very subjective, and it may often be desirable to use a more objective, repeatable method. One such method uses digital photographs to estimate canopy cover. This method has the additional advantage that the photos can be stored for later reference or used for showing changes in cover over time.

The method presented below estimates canopy cover from digital photos using the word processing program, Microsoft Word. Essentially, it is based on superimposing a 10 x 10 grid (the internal gridline intersections of a 11 x 11 table) over a digital image of the canopy. Canopy cover (percentage) is estimated by counting the number of grid intersections with vegetation (or by counting grid intersections with the sky, and subtracting this number from 100).

Two versions of the method are given. The first version, below, is intended for users who are familiar with manipulating images and tables in Microsoft Word. The second version, on the following pages, is intended for users with a more basic knowledge of computer programs.

#### **Short Description: Method for Estimating Canopy Cover from a Digital Image**

1. Start Microsoft Word and open a new document.
2. Create an 11 x 11 table with closely spaced (e.g. 0.7 cm) columns and rows.
3. Insert a picture of the canopy into the document.
4. Format the picture so that it sits behind the text.
5. Move the picture so that it sits just inside the top left edges of the table.
6. Resize table, so that its right and lower boundaries extend just outside the edges of the picture.
7. Resize the columns and rows so that they form a regularly spaced grid over the picture.
8. Count the number of grid intersections with vegetation to calculate the percentage of canopy cover, or count intersections with the sky, and subtract from 100 to determine canopy cover (see example, below). To more accurately determine canopy cover, view the document at 200% zoom.



Note: A similar method could be used to estimate canopy cover from photos taken with print film, if necessary, by using a 10 x 10 grid drawn on clear plastic.

### Detailed Description: Method for Estimating Canopy Cover from a Digital Image

Note: These instructions have been written for versions of Microsoft Office 2000 and 2003. Where necessary, separate instructions are given for users of Microsoft Office 97.

1. Start Microsoft Word and open a new document.
2. Create an 11 x 11 table with closely spaced (e.g. 0.7 cm) columns and rows.
  - From the menu Table, go to Insert, then Table.
  - A new window will appear. In this window, under Table size, specify 11 columns and 11 rows. In the same window, under Autofit behaviour, specify Fixed column width and click the top arrow of the adjacent panel so that 0.7 cm appears (this ensures that the table is initially smaller than the picture).
  - Click OK when finished. The table should appear within the new document, as shown below.


#### Microsoft Office 97 Users:

- From the menu Table, go to Insert, then Table.
- A new window will appear. In this window, under Table size, specify 11 columns and 11 rows. In the same window, for Column width, click the top arrow of the adjacent panel so that 0.7 cm appears (two clicks).
- Click OK when finished. The table should appear within the new document, as shown above.

3. Insert a picture of the canopy into the document under the table.
  - Place the cursor below the table.
  - From the menu Insert, go to Picture, then From file. A new window will appear. Locate and select the appropriate image and click Insert.





4. Format the picture so that it sits behind the text.
  - *Place the cursor over the picture and right click your mouse. A menu will appear.*
  - *Select Format picture. A window with several tabs will appear. Select the Layout tab, then select Behind text. Click on OK.*
  - *Note: It may be necessary to repeat this step in some versions of Microsoft Word.*

**Microsoft Office 97 Users:**

- *Place the cursor over the picture and right click your mouse. A menu will appear.*
- *Select Format picture. A window with several tabs will appear. Select Position and then Float over text. Next, select Wrapping, and then None. Click on OK.*
- *Place the cursor over the picture and right click your mouse again. A menu will appear. Select Order, then Send behind text.*

5. Move the picture so that it sits just inside the top left edges of the table.
  - *Place the cursor over the picture, left click your mouse, and drag the picture to the desired position.*
  - *The gridlines of the table should appear in front of the picture. If not, repeat Step 4, above.*



6. Resize the table so that its right and lower boundaries extend just outside the edges of the picture.
  - Place the cursor over the right edge of the table. The cursor should change to two parallel lines. Left click your mouse and drag so that the edge of the table lies just outside the picture.
  - Then place the cursor over the lower edge of the table. The cursor should change to two parallel lines. Left click your mouse, and drag so that the edge of the table lies just below the picture.



7. Resize the columns and rows so that they form a regularly spaced grid over the picture.
  - Place the cursor to the left of the table; it should change into an arrow. Left click your mouse and drag down so that all the rows of the table are highlighted.
  - From the menu Table, go to Autofit, then click on Distribute rows evenly.
  - Then, while the table is still highlighted, go to the Table menu, select Autofit, then click on Distribute columns evenly.
  - The table should now form a regularly spaced grid over the picture.



**Microsoft Office 97 Users**

*As above, except Autofit does not occur in the menu.*

*Instead, from the Table menu, click on Distribute rows evenly. Visit the Table menu again to Distribute columns evenly.*

8. Count the number of grid intersections with vegetation to calculate the percentage of canopy cover (or count intersections with the sky, and subtract from 100 to determine canopy cover).
  - Carefully count the number of grid intersections that coincide exactly with vegetation cover. This number is the percentage of canopy cover. For example, if 25 grid intersections coincide with vegetation in a photo, then canopy cover is 25%. Note: If canopy cover is dense, it will be easier to count intersections with the sky, and subtract this number from 100 to determine canopy cover. In the example below, there are 36 intersections of the grid with the sky, so canopy cover is  $100 - 36 = 64\%$
  - Note: To more accurately determine whether the grid intersects with vegetation or the sky, view the document at 200% zoom.

