Marine and Tropical Sciences Research Facility

Monitoring Revegetation Projects in Rainforest Landscapes

Toolkit, Version 3 (July 2010)

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Australian Government
Department of the Environment, Water, Heritage and the Arts

Griffith UNIVERSITY

terrain NATURAL RESOURCE MANAGEMENT

Reef & Rainforest RESEARCH CENTRE

Monitoring Revegetation Projects in Rainforest Landscapes

Toolkit Version 3

Contains information, protocols and proformas for:

- Designing monitoring programs;
- Recording project details;
- Assessing site condition;
- Monitoring forest structure;
- Monitoring plant species composition;
- Estimating carbon sequestration;
- Monitoring bird species composition; and
- Managing, analysing and evaluating data.

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Reef & Rainforest
RESEARCH CENTRE

July 2010

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Preface

Purpose of this Toolkit

This toolkit has been written to assist community groups and restoration practitioners record the details of their revegetation projects, assess their condition and monitor their outcomes for biodiversity and carbon sequestration. By 'revegetation projects', we mean the reforestation of cleared land, the enhancement or restoration of remnant vegetation and the manipulation of regrowth to promote rainforest regeneration. Additionally, the methods presented here can also be applied to other situations where there is a need to monitor and evaluate change in forest ecosystems, including assessment of the extent of degradation or recovery within remnant forest. The techniques are designed to be usable in very small sites (down to about 0.5 ha). These methods are also targeted at rainforest ecosystems, where the high density of vegetation creates important practical differences from more open forest types. That said, with some judicious adaptation, many of the methods could be applied to other forest types, and some general issues are considered which have relevance to all ecosystems.

Most revegetation projects require years of effort to establish, and decades to develop towards target conditions. During both establishment and development phases, many factors such as the survival and growth of planted stems, the recruitment of new individuals, disturbances and weed invasion can influence the outcomes of a project. Consequently, funding bodies and practitioners need to commit sufficient resources to monitor and maintain revegetation projects over the long-term, if they intend their projects to be successful.

We consider two components of monitoring, record keeping and condition assessment, to be essential for the long-term management of all revegetation projects. In addition, projects which aim to restore biodiversity may need to monitor outcomes for biodiversity to demonstrate progress against target conditions. In this toolkit, we provide protocols and proformas for assessing three components of biodiversity: vegetation structure, plant species (floristic) composition and bird species composition. Given the recent emergence of carbon markets, we also provide tools for estimating above-ground carbon stocks.

Structure of Toolkit Version 3

This toolkit has been written as a series of modules, each dealing with a specific aspect of monitoring, as follows:

1. The design of monitoring programs;
2. Recording project details;
3. Assessing the condition of projects;
4. Monitoring forest structure;
5. Monitoring plant species composition;
6. Estimating carbon sequestration;
7. Monitoring bird species composition; and
8. Managing, analysing and evaluating data.

We have designed several Microsoft Excel workbooks to help store and analyse data collected using this toolkit (listed in Module 8). These workbooks are available for download together with the Toolkit Version 3. Additionally with this version we have provided supporting materials such as data proformas as separate files for download (for full information on downloadable files and documents and for website details see the Supporting Materials section at end of this Preface).

Evolution of Toolkit versions

The toolkit has evolved over time. Version 1 was published by the Rainforest CRC (hard copy and web download) in June 2006, with four modules (monitoring design, project details, forest structure and data management; equivalent to Modules 1, 2, 4 and 8 of the present toolkit). Version 1, Revision 1 was web-published by Griffith University in October 2006, with some amendments following feedback by users. Version 2 (hard copy and web download) was published by the Reef and Rainforest Research Centre and Marine and Tropical Sciences Research Facility in September 2008, with minor revision to the original four modules, plus the addition of three new modules (site condition, plant species composition and carbon sequestration; equivalent to Modules 3, 5 and 6 of the present toolkit). Version 3 (this document) adds one further module (bird species composition, Module 7), with a few other amendments. Version 3 completely replaces Versions 1 and 2.

Expertise required to use this Toolkit

No specialist training is required to use Modules 2, 3 and 4 of the toolkit, that is, to record project details, assess site condition and monitor forest structure. Botanical expertise is required to monitor plant species composition (Module 5) and accurately estimate carbon sequestration (Module 6). However, on many sites, data on forest structure (Module 4, which does not require specialist expertise to collect) can provide robust estimates of carbon sequestration. Bird identification skills are required to monitor bird species composition (Module 7).

Acknowledgements

This toolkit has been produced with assistance and funding from Terrain NRM, the Marine and Tropical Sciences Research Facility, the Rainforest Cooperative Research Centre and Griffith University. Thanks to Rowena Grace and Allan Dale (Terrain NRM) for their support. Stephen McKenna played a key role in developing the floristic monitoring protocols. Wendy Neilan provided invaluable assistance in refining the bird monitoring module and the production of Version 3. Thanks to the restoration practitioners who provided advice on monitoring the outcomes of revegetation projects, and the researchers whose ideas and technical suggestions contributed to the evolution of the methods described here; collectively including Peter Dellow, Rob Kooyman, Dan Metcalfe, Terry Reis, Bronwyn Robertson, Tania Simmons, Nigel Tucker, Grant Wardell-Johnson and Ralph Woodford. We also thank those not named here who have at various times provided feedback and comments on previous versions.

Supporting Materials

Websites

This toolkit and the supporting materials listed below can be downloaded from the following websites:

- Reef and Rainforest Research Centre (visit http://www.rrrc.org.au and follow links to Publications webpage); and
- Griffith University (visit http://www.griffith.edu.au/environment-planning-architecture/environmental-futures-centre/publications).

Ensure that you have downloaded Version 3 of the toolkit (earlier versions do not contain the full set of modules).

The following supporting materials are available for download for use in conjunction with Version 3 of the toolkit:

Data analysis Excel workbooks

- Monitoring toolkit forest structure.xls
- Monitoring toolkit floristic composition.xls
- Monitoring toolkit plant attributes.xls
- Monitoring toolkit wood density.xls
- Monitoring toolkit bird species composition.xls
- Monitoring toolkit bird species composition (demo).xls

Data collection proformas and related materials:

- Project Proforma
- Site Proforma
- Description of On-ground Works
- Project Journal
- Proforma for Assessing Site Condition
- Proforma for Monitoring Forest Structure
- Proforma for Monitoring Floristic Composition
- Proforma for Monitoring Bird Species Composition
- Appendix 1: Reference photographs of canopy cover
- Appendix 4: Recording cyclone damage to trees

Module 1: The Design of Monitoring Programs

Why monitor revegetation projects?

Rainforest restoration is a relatively recent activity in Australia. Most projects have been established in the last two decades, a result of government funded schemes such as the Natural Heritage Trust. In total, these schemes have resulted in the reforestation of over a thousand hectares of cleared land, the restoration of around forty rainforest remnants and the manipulation of perhaps hundreds of hectares of weedy regrowth to promote rainforest regeneration (Goosem and Tucker 1995; Kooyman 1996; Woodford 2000; Big Scrub Rainforest Landcare Group 2005; Catterall and Harrison 2006; Kanowski *et al.* 2008a). Tens of millions of dollars have been invested in rainforest restoration projects over this time.

To date, most people involved in revegetation projects have focussed on ‘getting trees in the ground’ or ‘getting rid of weeds’, rather than on formally monitoring the outcomes of their projects. Reasons for the lack of monitoring include the short-term, insecure funding typically available for revegetation projects, the reliance of community groups on volunteer labour and a lack of expertise amongst practitioners and volunteers (Freeman 2004; Kanowski *et al.* 2008b). Consequently, despite the considerable investment in rainforest restoration, we don’t usually know whether most projects have achieved their objectives, nor have we learnt a great deal about how restoration practices might be improved. In fact, because of a lack of record-keeping, we often have little information on what was actually done in most restoration projects, and sometimes have only a vague idea of where projects are located!

The failure to properly document and monitor restoration projects has greatly undermined their long-term value. For example, a recent audit of revegetation projects established in North Queensland between 1997 and 2002 under the Natural Heritage Trust program found that the actual extent of plantings was only half that stated in project reports (Catterall *et al.*, unpublished data). Of the plantings surveyed, two-thirds were in ‘poor’ or ‘uncertain’ condition, presumably from a lack of ongoing maintenance, and were unlikely to develop into rainforest without significant intervention. That is, within just five to ten years of initial establishment, much of the investment in these projects was at risk of being lost.

Are you serious?

Funding bodies and revegetation practitioners need to decide from the outset whether they seriously intend their projects to make a lasting contribution to the environment. A key indicator of serious intent is the commitment of sufficient resources to monitor and maintain projects over the long-term. Most sites require years of effort to establish and decades to develop towards target conditions (Kooyman 1996; Joseph 1999; Woodford 2000; Kanowski and Catterall 2007). Over this time, many things can potentially go wrong with revegetation projects: planted trees may die, new species may fail to recruit, sites can be invaded by weeds or damaged by floods or storms. Monitoring is required to identify these problems before they cause projects to fail, and a maintenance program is required to fix them.

Monitoring revegetation projects: Essential components

The overall design of a monitoring program for revegetation projects is provided below (Figure 1.1). We consider two components of monitoring, **record keeping** and **condition assessment**, to be essential for the long-term management of all revegetation projects. In addition, projects which aim to restore biodiversity may need to **monitor outcomes for biodiversity** to demonstrate progress towards target conditions. To participate in carbon markets, projects may also need to **estimate carbon sequestration**. These components of a monitoring program are discussed in more detail below.

Record keeping

Basic information about the nature of a project (including its location, size, cost, objectives, and details of on-ground works) needs to be recorded and stored in a properly maintained database (e.g. a regional directory of revegetation projects). Without this information, it will be difficult to locate most revegetation projects in the future, let alone monitor their outcomes. Good record-keeping also requires that practitioners inform funding bodies if their on-ground works vary from project proposals. If such variations are not reported, the extent of revegetation projects in a region is likely to be overestimated. We provide proformas to assist record-keeping, including a table to report variation from project proposals, in Module 2.

Condition assessment

The condition of projects needs to be routinely monitored, so that problems can be identified before they cause the project to fail. This assessment needs to be linked to a maintenance program. We provide an approach to assessing condition in Module 3.

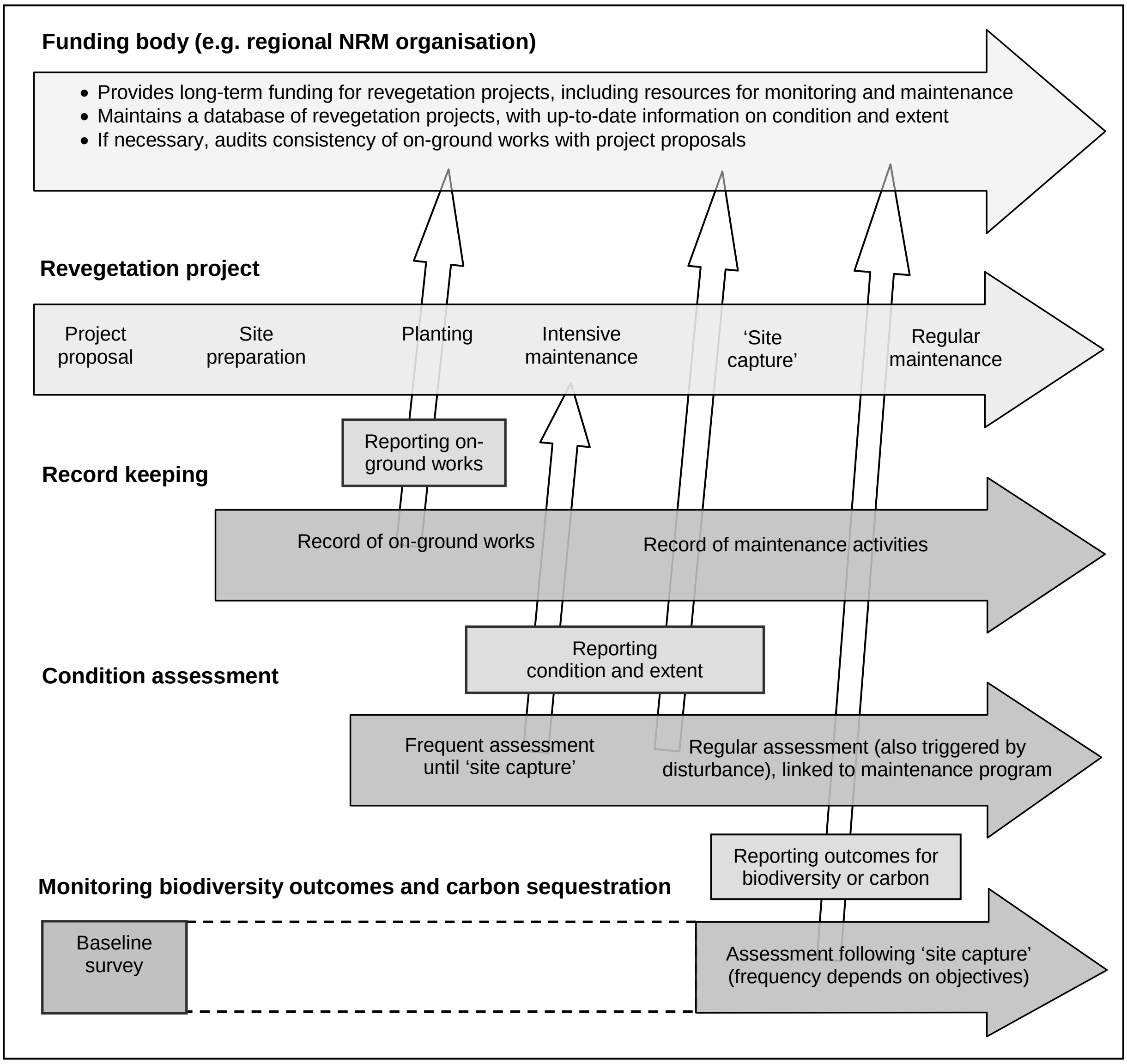

Figure 1.1. Overall design of a monitoring program for revegetated sites.

Monitoring revegetation projects for biodiversity

Many rainforest revegetation projects aim to restore degraded sites and provide habitat suitable for rainforest biota. However, whether revegetation projects actually achieve these objectives is rarely determined by proponents. Monitoring the outcomes of revegetation projects for biodiversity is likely to become increasingly important as funding bodies look for evidence that their investments are producing results. In some cases, e.g. projects which aim to create 'offsets' for habitat cleared elsewhere, it may be a legal requirement to demonstrate outcomes. In the following section, we discuss the design of programs aimed at (i) monitoring the biodiversity outcomes of revegetation projects; and (ii) improving the performance of different revegetation techniques. Protocols and proformas for monitoring three components of biodiversity, forest structure, plant species (floristic) composition and bird species composition, are provided in Modules 4, 5 and 7 respectively.

Monitoring biodiversity outcomes of revegetation projects

Monitoring can show whether revegetated sites are progressing towards target conditions, in terms of habitat structure or other aspects of biodiversity (Figure 1.2). Ideally, monitoring would include a baseline survey of the revegetated site (i.e. prior to on-ground works), so that subsequent surveys can show how much a site has changed following revegetation, and surveys of forest reference sites (e.g. remnants of the pre-clearing forest type) to represent the target conditions (Society for Ecological Restoration 2004). Together, baseline data and surveys of reference sites provide benchmarks to evaluate trends in the revegetated site.

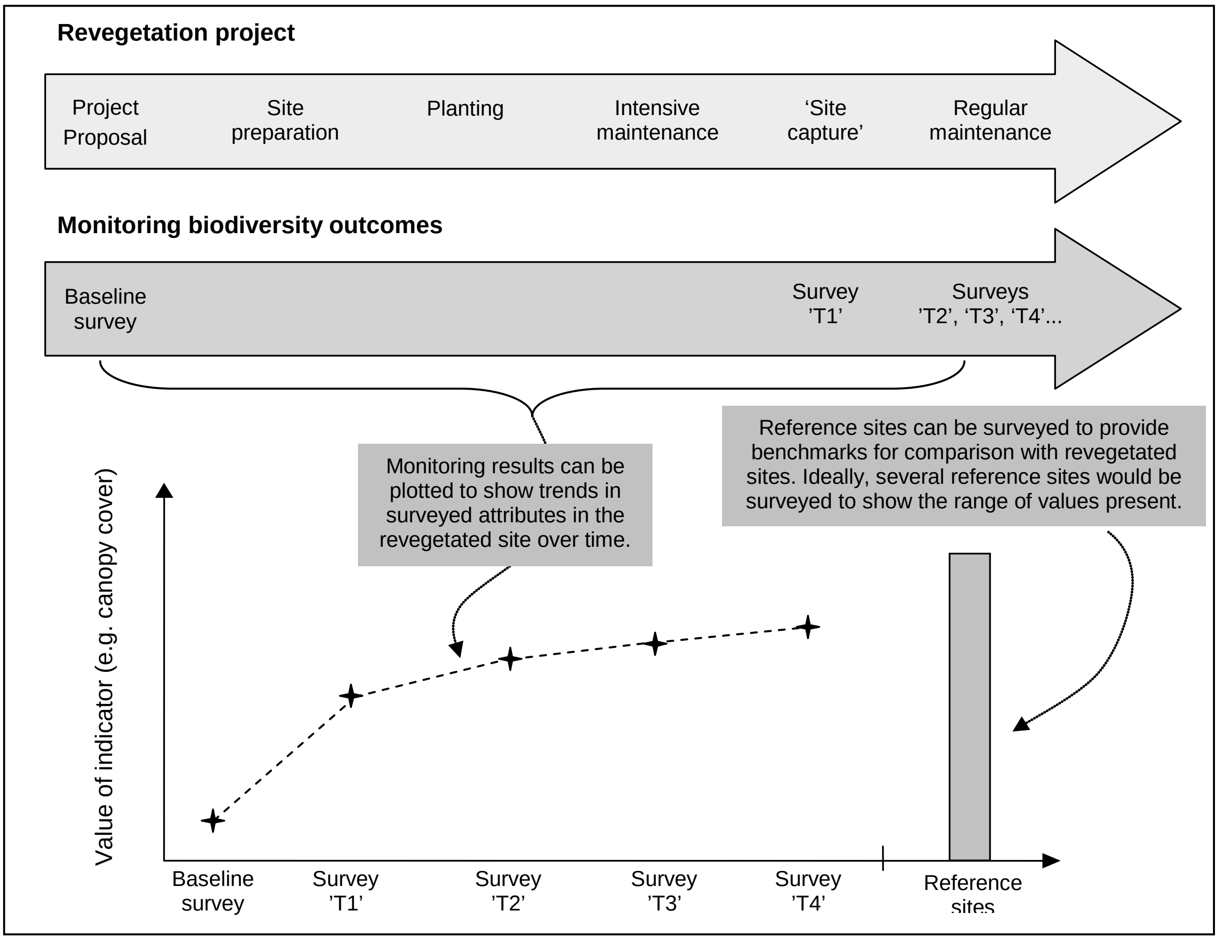

Figure 1.2. Monitoring biodiversity outcomes against target conditions.

A good example of this type of monitoring is the evaluation of the 'Donaghy's corridor' project in North Queensland by Jansen (2005). In the study, rainforest birds were monitored for three years in both replanted and rainforest reference sites. Some replanted sites were surveyed from establishment to provide baseline data. The study showed that even young plantings provided habitat for some 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 to that found in rainforest. On the basis of this study, Jansen concluded that 'habitat restoration [at Donaghy's corridor] has good potential for success'.

Improving the performance of revegetation practices

To improve the design of revegetation projects, monitoring can be used to compare different techniques (e.g. species mixes, stocking rates, planting techniques: Kooyman 1996; Freebody 2007; Tucker 2008). This type of monitoring is essentially ecological research, and usually requires the establishment of replicate plots or sites, some treated with one method (e.g. a 'novel' method) and some with another (e.g. current 'best practice'). In many cases, it is also useful to compare results with baseline conditions and reference sites (Figure 1.3).

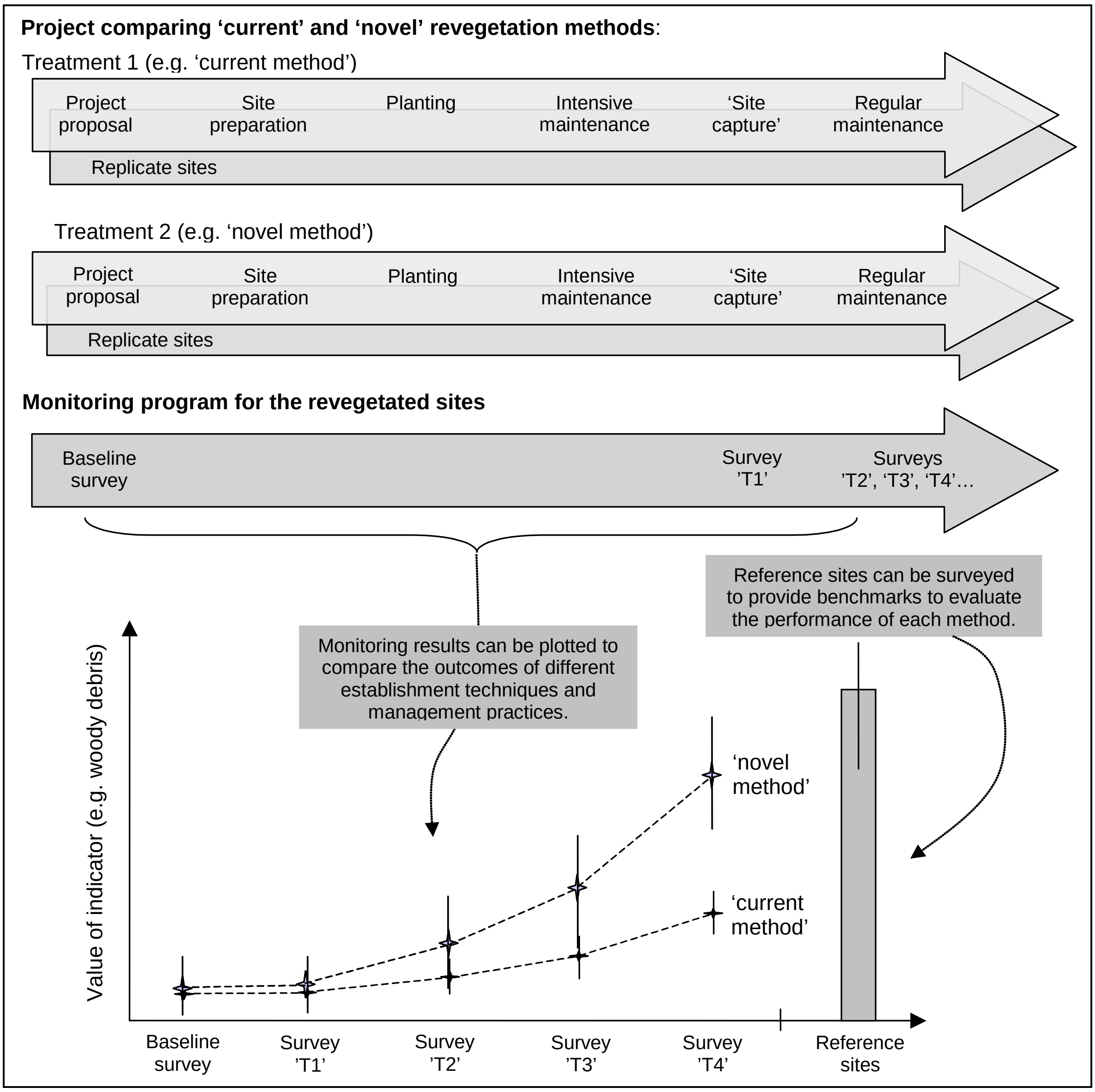

Figure 1.3. Monitoring the outcomes of different revegetation practices.

Harden *et al.* (2004) used this type of monitoring to compare the costs and outcomes of two different restoration treatments in Wingham Brush, a rainforest remnant in northern New South Wales. At the time, the funding body wanted the restoration practitioners to use the 'Bradley' method (an approach developed in sclerophyll forest). However, the practitioners had some problems applying this method to rainforest, and had devised their own approach (the 'Wingham Brush' method, focussed primarily on restoration of the canopy).

To compare the methods, Harden *et al.* (2004) set up a series of paired plots in the remnant. One plot in each pair was treated using the 'Bradley' method and the other with the 'Wingham Brush' method. Plant recruitment and growth was monitored on each plot, and records kept of the effort required for each method. As it turned out, both methods produced similar outcomes for rainforest regeneration, but the Wingham Brush method required just one-tenth the effort of the Bradley method. The results of this study provided strong support for the continued use of the Wingham Brush method by practitioners, and the approach has now been adopted in other rainforest remnants in the region.

Estimating carbon sequestration

To participate in carbon markets, revegetation projects need to be able to make robust estimates of the carbon sequestered in revegetated sites. Typically, these estimates are limited to the carbon sequestered in above-ground biomass (live trees, stags and woody debris) (Australian Greenhouse Office 2006). A monitoring program to estimate carbon sequestration requires a survey of baseline conditions, and one or more subsequent surveys of vegetation structure (specifically, counts of stems by diameter class; as well as counts of stags by diameter and height, and counts of woody debris by diameter class). The accuracy of estimates can be improved if trees are identified to species, so that specific wood density values can be used in calculations. Estimates of carbon sequestration do not require comparison with reference sites. A detailed account of an approach to estimating carbon sequestration in revegetated sites is provided in Module 6 of this toolkit.

Module 2: Recording Project Details

Revegetation is inherently a long-term activity. It takes years for a reforested site to achieve 'site capture', and decades to recruit native plants and animals. Over that time, staff, volunteers and institutions will come and go. Unless basic records are kept of revegetation projects, if will be difficult to monitor and maintain those projects over the long-term.

Unfortunately, good record-keeping practices have not been a feature of most revegetation projects conducted to date. A review of 13,000 revegetation projects funded by the Natural Heritage Trust across Australia found that very few had adequately documented their on-ground works (Freudenberger and Harvey 2003). Obviously, definitions of 'adequate' will vary from person to person, but will surely include such details as the location of sites, the nature of on-ground works, who was responsible for the project and how much it cost.

We acknowledge that it is hard for practitioners to allocate time to recording project details at the start of a project, when there is so much else to be done. However, this information is extremely difficult to recover in later years. In this module, we provide a series of proformas to assist practitioners in recording basic information about revegetation projects.

- **Project proforma:** A description of the project, its objectives, proponent and location.
- **Site proforma:** More detailed information on the sites where revegetation activities occur.
- **Description of on-ground works:** The activities conducted at each site, categorised as:
  - **Reforestation** (planting trees on cleared or degraded land);
  - **Remnant enhancement** (e.g. fencing from stock, weed control in remnants); and
  - **(Weedy) regrowth management** (e.g. poisoning of weeds such as camphor laurel to promote the regeneration of rainforest plants).
- **Project journal:** A record of maintenance activities and significant events in the project.

The information requested by the proformas should be self-explanatory. We use the term '**project**' to describe a set of revegetation activities, usually conducted within a particular locality, with broad overall objectives. An example is the 'Peterson Creek Wildlife Corridor project', which aims to establish a rainforest corridor between Lake Eacham and Curtain Fig National Park in North Queensland (see: http://www.treat.net.au/projects/Peterson.html). Each project will take place at one or more **sites**, which may be separated spatially (e.g. on different properties) or established in different years (Figure 2.1). To facilitate storage of information in a database (e.g. a regional directory of revegetation projects), the proformas include the fields **Project ID** and **Site ID**, for unique codes to identify each project and site.

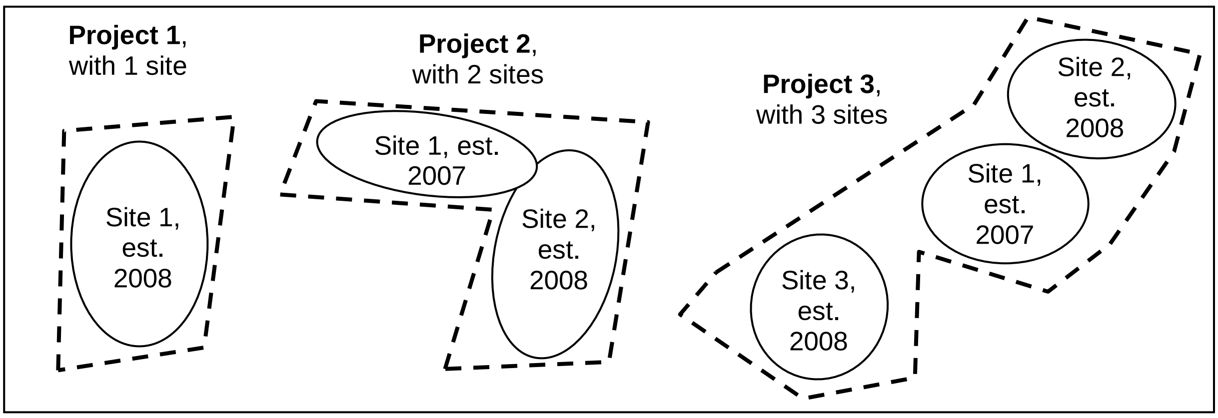

Figure 2.1. How we define revegetation 'projects' and 'sites'.

PROJECT Proforma

PROJECT DESCRIPTION

Project name:	**Project ID:**
Year project commenced:	
Total number of sites within this project:	

PROPONENT DETAILS

Project **proponent** (*e.g. Malanda Landcare*)
Project **contact person**:
Proponent contact details: Address:: Telephone: Email:

PROJECT OBJECTIVES

Main objective of project (mark an '**X**' next to the <u>one</u> most relevant objective):	• Biodiversity conservation/ restoration .... • Timber production .... • Carbon sequestration .... • Other forest products................................ • Shelterbelt/ windbreak..............................	• Water quality improvement....................... • Stream bank stabilisation .... • Other (describe).......................................
Other objectives of project (mark an '**X**' near <u>any</u> relevant objective):	• Biodiversity conservation/ restoration .... • Timber production .... • Carbon sequestration .... • Other forest products................................ • Shelterbelt/ windbreak..............................	• Water quality improvement....................... • Stream bank stablisation........................... • Other (describe).......................................
If necessary, **provide further details on project objectives** *(e.g. restoration of cassowary habitat)*		
What **forest type** is the project trying to create or restore? Describe or provide a classification of the reference forest type *(e.g. 'Mabi' forest, Regional Ecosystem 7.8.3)*. What are the names or locations of possible **reference sites**? (A reference site is an example of the target conditions, such as a remnant of the forest type that occurred on the site prior to clearing: *e.g. for 'Mabi' forest, a reference site could be Curtain Fig NP)*		

PROJECT Proforma

PROJECT LOCATION

Location of project at a landscape scale: *(e.g. along Peterson Creek between Lake Eacham and Yungaburra)*
Grid / GPS coordinate(s), sufficient to locate project on a 1:25,000 or 1:50,000 map. Datum:
Catchment:
Local Government Area:

PROJECT MAP

In the box, insert a map to show the general location of the project at a landscape scale.

Note: useful maps with property boundaries can be often be downloaded from Google Maps (http://maps.google.com.au/)

Include an approximate scale (include a scale bar, e.g. 0________100 m) and North arrow.

SITE Proforma

SITE DESCRIPTION

Project name:	**Project ID:**
Site name:	**Site ID:**

SITE DETAILS

Address/ location of site *(include access details)*
Tenure (*e.g. council reserve*)
Lot and Plan No.
Grid / GPS coordinate(s) sufficient to locate site on a 1:25,000 or 1:50,000 map. Datum:
Name of landholder/ manager
Landholder/ manager contact details: Address: Telephone: Email:
What **practitioners/ contractors** were responsible for on-ground works at this site?

SITE Proforma

SITE MAP

In the box, insert a detailed map of the site, *ideally an annotated aerial photo including a property boundary overlay (DCDB)* showing: location of on-ground works; notable features of the site (e.g. property boundaries, roads, waterways); location of any monitoring plots.

Include a scale bar (e.g. 0________100 m) and North arrow.

SITE Proforma

OVERVIEW OF ON-GROUND WORKS AT THIS SITE

What are the dimensions of the on-ground works at this site? (for length and width, give a range if dimensions vary across site)		
Length: m	**Width:** m	**Area:** ha
Specifically, over what area/s were the following on-ground works conducted? *(provide details in 'Description of on-ground works')*		
Reforestation (tree planting) ha	**Remnant enhancement** (e.g. weed control in existing remnant) ha	
(weedy) Regrowth management (e.g. poisoning exotic trees) ha	**Other** (describe) ha	

VARIATION FROM PROJECT PROPOSAL

Do the on-ground works established at this site vary from the project proposal? (put an '**X**' near relevant term) YES…… *or* NO……		
If *Yes*, complete the following table, clearly showing how established on-ground works vary from the project proposal *(e.g. Length: 100 m less than proposal; Width: same as proposal; Area: 0.5 ha less than proposal)*		
Length:	**Width:**	**Area:**
Specifically, how do the area/s of the following actions vary from the project proposal? *(e.g. Reforestation 0.5 ha less than proposal)*		
Reforestation	**Remnant enhancement**	
(Weedy) regrowth management	**Other** (describe)	
Reason(s) for variation: (e.g. funding reduced, seedlings unavailable, area miscalculated, part of area inaccessible)	**Date of variation:**	

ENVIRONMENTAL DESCRIPTION OF SITE

Landform (put an '**X**' near the relevant term)	Ridge/ Crest .... Upper slope .... Mid slope .... Lower slope................ Stream bank .... Floodplain .... Plateau .... Other (describe):
Altitude:	
Geology / soils:	
What was the pre-clearing vegetation on the site? (if known: *e.g. 'Mabi forest'*)	
What was the vegetation on the site prior to restoration works? (*e.g. pasture*)	
Is this a riparian site? (put an '**X**' near relevant term)	YES…… *or* NO…… If *Yes*, name/ describe the waterway (e.g. Davis Creek/ permanent creek)
Surrounding land cover types/ uses (*e.g. mostly bananas and sugarcane, with some regrowth forest along creek)*	
Has the site been subject to **major disturbances**? Describe: **what** and **when** (*e.g. Cyclone Larry March 2006; frost June 2007*)	

Description of ON-GROUND WORKS

REFORESTATION

Project name:	**Project ID:**
Site name:	**Site ID:**

*Notes: (1) Where options are given, put an **'X'** next to the appropriate term(s). (2) If some details are not known precisely, write 'approx'.*

Details of reforestation activities *(note: reforestation = tree planting, usually on cleared or degraded land)*

Site preparation (briefly describe):

Does a **species list** exist for this site? YES........ *or* NO..........
If *Yes*, is the species list available? YES........ *or* NO..........
Is the species list attached? YES........ *or* NO..........
If *No*, where can it be obtained from?

Number of species planted:	**Number of stems** planted:

Planting stock: Seeds……… *or* Seedlings……. If seedlings, what age / size?

Stocking rate: stems/ ha *or* **Spacing of plants**: …… m x …… m

What type of **life forms** were planted?
Trees…………… Shrubs………… Vines………….. Groundcovers……………. Other (describe)……………………………………

What was the biogeographical **origin of the species** planted?
Local provenance ………. from same Region ………. from Australia, but outside region ………. Exotic………………

What was the **source of the plants**? (e.g. commercial nursery, council nursery): provide name(s) if possible

Approximate **mix of species** by successional range (if known):
Pioneers: % of stems Intermediate spp.: % of stems Mature phase spp.: % of stems

What **planting model** was used? Name/ describe the model (e.g. 'framework species' model of: Goosem and Tucker 1995):

Was **fertilizer** added to plants? YES...... *or* NO.........
If *Yes*, what product was used? Application rate (approx.)?

Was **mulch** added to plants? YES...... *or* NO.........
If *Yes*, what product was used?

Was the planting **fenced**? YES...... *or* NO.........
If *Yes*, what length of fencing?

Location: Provide a set of GPS coordinates that define where reforestation occurred at this site (also show area on site map)	Datum: Does the area of *reforestation* defined above include any other land use? Yes...... *or* No .... If *Yes*, what type of land use? What percentage of the area? %

Date/s of on-ground works:

Cost of reforestation activities:
Cash $
In-kind $
What was **the source(s) of funds**?

Extract from: Kanowski, J. *et al.* (2010) *Monitoring Revegetation Projects in Rainforest Landscapes. Toolkit Version 3*. Reef and Rainforest Research Centre Limited, Cairns (98pp.).

Description of ON-GROUND WORKS

Project name:	**Project ID:**
Site name:	**Site ID:**

List of species used in planting	Life form*	Origin**	No. 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			
31			
32			
33			
34			
35			

Note: If more than 35 species planted, mark an '**X**' here.................. and add extra pages as necessary.

***Life form**: **T**ree / **S**hrub / **V**ine / **G**roundcover

****Origin**: **L**ocal provenance / from **R**egion but not local / from **A**ustralia but not region / **E**xotic

Description of ON-GROUND WORKS

Project name:	**Project ID:**
Site name:	**Site ID:**

*Notes: (1) Where options are given, put an **'X'** next to the appropriate term(s). (2) If some details are not known precisely, write 'approx'.*

Details of remnant enhancement activities *(Note: remnant enhancement includes fencing from stock, weed control. Remnant enhancement does **<u>not</u>** include tree planting. Record any tree planting under 'reforestation'.*

Provide details of main remnant enhancement activities below:

Was **weed control** conducted at this site? YES…. *or* NO……

If *Yes*, describe the main target weeds and control methods

Was **fencing** installed at this site? YES…. *or* NO……

If *Yes*, what length of fencing was installed?

Provide details of **any other remnant enhancement activities**:

Was a formal conservation agreement concluded with the landholder? YES…. *or* NO…… If *Yes*, provide details:

Location: Provide a set of GPS coordinates that define where <u>remnant enhancement</u> occurred at this site (also show area on site map)	Datum: Does the area of *remnant enhancement* defined above include any other land use? YES… *or* NO… If *Yes*, what type of land use? What percentage of the area? %

Date/s of on-ground works:

Cost of remnant enhancement activities:

Cash $

In-kind $

What was **the source(s) of funds**?

Extract from: Kanowski, J. *et al.* (2010) *Monitoring Revegetation Projects in Rainforest Landscapes. Toolkit Version 3*. Reef and Rainforest Research Centre Limited, Cairns (98pp.).

Description of ON-GROUND WORKS

Project name:	**Project ID:**
Site name:	**Site ID:**

*Notes: (1) Where options are given, put an **'X'** next to the appropriate term(s). (2) If some details are not known precisely, write 'approx'.*

Details of regrowth management activities *(e.g. weed control to promote rainforest regeneration)*	
Describe main target weeds and control methods: Provide details of any other regrowth management activities (e.g. native vine control, thinning of pioneer species):	
Location: Provide a set of GPS coordinates that define where <u>regrowth management</u> occurred at this site (also show area on site map)	Datum: Does the area of *regrowth management* defined above include any other land use? YES… *or* NO... If *Yes*, what type of land use? What percentage of the area? %
Date/s of on-ground works:	
Cost of regrowth management activities: **Cash** **$** **In-kind** **$** **What was the source(s) of funds?**	

Project Journal

Project name:	**Project ID:**
Site name:	**Site ID:**

Date(s)	**What happened?** (describe events: e.g. maintenance activities, field days; significant disturbance events)	**Who and what were involved?** (e.g. number of people; hours of effort; materials, costs)

Note: Mark an '**X**' here……… if journal continues. Add extra pages as needed.

Extract from: Kanowski, J. *et al.* (2010) *Monitoring Revegetation Projects in Rainforest Landscapes. Toolkit Version 3*. Reef and Rainforest Research Centre Limited, Cairns (98pp.).

Module 3: Assessing Site Condition

Once a revegetation project has been established for a couple of years, can the proponents walk away and notch up another 'success'? From the short-term nature of the funding currently available to most revegetation projects, you would think this was the case. But what really happens to rainforest revegetation projects funded for just a few years?

In Module 1, we recounted our audit of reforestation projects in North Queensland funded by the Natural Heritage Trust. Just five to ten years after establishment, over half the projects were in poor or very poor condition, with a relatively open canopy and an understorey of grasses and weeds (Catterall *et al.*, unpublished data). By the time of our assessment, these projects would have required major maintenance effort (or complete replanting) to return them towards target conditions. However, if these projects had been regularly monitored, it is likely that many of the problems with the sites would have been identified at an early stage and could have been fixed with a small maintenance effort.

Point # 1: Monitoring condition is crucial for protecting investment in revegetation projects.

Without routine monitoring of condition, proponents and funding bodies are likely to have an inflated idea of the success and current extent of their revegetation projects. For example, based on data reported by proponents, Catterall and Harrison (2006) calculated that 650 ha of restoration plantings had been established in North Queensland under the Natural Heritage Trust program between 1997-2002, at an average cost of $25,000 per ha. However, in our audit of these projects, we found that only half the area claimed to be planted had actually been reforested – presumably because proponents had overestimated the areas planted, or had included patches of remnant vegetation in their estimates, or had failed to report variations in on-ground works from proposals (Catterall *et al.*, unpublished data). Regardless of the reason for the discrepancy, the audit data revealed the real cost of establishing plantings under the NHT program to be more like $50,000 per ha.

Point # 2: Monitoring condition is necessary to provide reliable data on the current extent and real cost of revegetation projects.

In this module, we provide a methodology for assessing the condition of revegetation projects that is simple, rapid and informative. By condition, we mean the extent to which a project is 'on track' towards target conditions, considering its age and stage of development, and other relevant factors. The methodology has been developed from the experience of restoration practitioners (e.g. Kooyman 1996; Tucker and Murphy 1997; Freebody 2007; and see Acknowledgments) and from relevant research (e.g. Grundon *et al.* 2002; Catterall *et al.* 2004, 2008; Kanowski and Catterall 2007; Kanowski *et al.* 2008a, 2008b; 2008c; 2008d).

Purpose of condition assessment

The main purposes of condition assessment are:

1. To inform practitioners of the condition of sites and to help prioritise maintenance effort;
2. To inform funding bodies of the condition and extent of revegetation projects; and
3. When combined with data on biodiversity outcomes (Modules 4, 5 and 7) and carbon sequestration (Module 6), to allow estimation of the overall 'biodiversity value' and carbon sequestered by revegetated sites.

Attributes used to assess site condition

We have based our assessment of condition primarily on the following attributes (Table 3.1):

- **The survival of planted trees** (a major influence on establishment success);
- **Canopy cover** (a key regulator of the rainforest environment);
- **Ground cover** (influences plant recruitment and growth);
- **Problem weeds** (plants which can adversely affect site development); and
- **Recruitment** (determines the long-term composition of a site).

These attributes are strongly interlinked, e.g. sites where mortality of planted trees is high tend to have a relatively open canopy and a grassy ground cover. The particular attributes used have been selected for their relevance to reforested sites; additional attributes may need to be used for remnant enhancement and regrowth management projects.

Criteria to guide the assessment of condition are provided in Tables 3.2 and 3.3. Note that the attributes selected for assessment vary somewhat between young sites (i.e. prior to initial canopy closure) and established sites. These criteria are not intended to be absolute, because revegetation projects can vary in establishment techniques, and environmental conditions will vary between sites and over time. The experience of practitioners with particular sites and types of projects should strongly inform the assessment of condition.

Table 3.1. Attributes used to assess the condition of revegetated sites.

Stage of development of sites	Survival of planted trees	Canopy cover	Ground cover	Problem weeds	Recruitment (seedlings)
Young (before initial canopy closure, often around 3-5 years)	✓	✓	✓	✓	
Established (after initial canopy closure)		✓	✓	✓	✓

How often should site condition be assessed?

One of the main purposes of condition assessment is to detect problems with a revegetation project before the problems require major effort to fix. **Consequently, we suggest that condition be assessed annually until sites are well-established**, around ten years after establishment. **Rapidly-developing young sites may require more frequent assessment**, **perhaps three to four times a year**, until canopy closure is achieved. **Occasional assessment may be required indefinitely at most sites**, e.g. to detect problem weeds, particularly after major disturbance events such as cyclones.

To facilitate regular assessment, the methodology we have developed is simple and rapid. Further, when sites are monitored frequently, there is an option to conduct a brief assessment of condition when sites remain ‘on track’ towards target conditions. However, if condition has deteriorated on part or the entire site since previous assessment, we suggest assessing condition in more detail.

Condition can also be assessed in ‘one-off’ surveys of existing sites (e.g. audits). For example, we used an earlier version of the methodology presented here to assess the condition of revegetation projects that were funded by the Natural Heritage Trust in North Queensland between 1997 and 2002 (Catterall *et al.*, unpublished data).

Protocol for assessing site condition

The steps in condition assessment are listed below. A proforma for assessing site condition, based on this protocol, is provided on the following pages.

1. **Obtain any previous condition assessment of the site, including maps, and other relevant documentation of the site**.
2. **Conduct a field inspection of the site**. Based on the criteria listed in Table 3.2 or 3.3, determine whether all or part of the site is:

   OK (‘on track’ towards target conditions, requires only routine maintenance);

   Uncertain (significant problems identified, requires intervention); or

   Poor (major problems identified, likely to fail without major intervention).

   If outcomes vary across a site, divide the site into zones, and record outcomes for each zone separately (see Table 3.4 for an example).
3. **Make overall comments on the condition of the site.**
4. **Determine whether the condition of the site has changed since last assessment**, and comment on any changes.

DETAILED ASSESSMENT OF CONDITION (to be conducted annually, or if part or all of the site has changed in condition since last assessment)

5. **Complete the table describing site condition in detail.** Where outcomes vary across the site, divide the site into zones (‘A’ = OK, ‘B’ = uncertain; ‘C’ = poor) and record outcomes for each zone separately (see Table 3.4 for an example). Comment on the attributes of each zone, particularly the factors that appear to be affecting outcomes, such as the species mix used, stocking rates, weeds, disturbance or maintenance.
6. **Draw a map of the site** showing any variation in outcomes (see Figure 3.1 for an example). Calculate the area of each zone and the proportion of the site in each zone.
7. **Make recommendations for maintenance**, where relevant. The rating system is closely linked to maintenance requirements:

   Zone A = routine maintenance only required;

   Zone B = additional maintenance required, more than routine (need to describe);

   Zone C = major maintenance effort required (need to describe).

   Note that what comprises ‘routine’ maintenance will often change, e.g. from regular spraying to spot-checking and control of weeds, as sites mature. However, after major disturbance, routine maintenance may revert to regular broad-scale weed control.
8. If desired, **calculate an overall ‘site condition’ score**. This score reflects the proportion of the site in good, uncertain or poor condition, and ranges from 0% (when the entire site is in poor condition) to 100% (when the entire site is ‘on track’ to target conditions). Various intermediate scores are possible (e.g. a score of 50% could mean 50% of the site is ‘OK’ and the rest ‘poor’; it could also mean that 40% is ‘OK’, 20% ‘uncertain’, and the rest ‘poor’).

   To calculate the score, multiply the percentage of the site zoned as A, B or C by a suggested ‘condition rating’ for each zone : Zone A (OK) = 1; Zone B (uncertain) = 0.5; Zone C (poor) = 0), and add the products (see Table 3.4 for an example).

Table 3.2. Criteria for assessing the condition of young revegetated sites before initial canopy closure.

Rating / zone	Status	Canopy cover	Ground cover	Problem weeds	Tree survival	Maintenance requirements
A	**OK** On track to target conditions.	Developing well towards closed canopy.	Leaf litter, mulch or soil around trees. Grass/ weeds not suppressing tree growth (i.e. sparse around trees).	Not present or minor occurrence.	High (at least 90%)	Routine maintenance only.
B	**Uncertain** if will develop towards target conditions. Significant problems.	Not developing well towards closure, or outcomes are patchy.	Grass/ weed cover sufficiently dense to suppress the growth of planted trees, at least in places.	If present, have the potential to impede site development.	Moderate (60-90%), or patchy	Extra effort required to fix problems, additional to routine maintenance.
C	**Poor** Major problems. Likely to fail.	Poorly developed. Unlikely to achieve closure.	Dense cover of grass/ weeds which is likely to strongly suppress tree growth.	May be common, or likely to impede site development.	Poor (less than 60%)	Major effort required to address problems.

Table 3.3. Criteria for assessing the condition of established sites after initial canopy closure.

Rating / zone	Status	Canopy cover	Ground cover	Problem weeds	Recruitment (e.g. seedlings)	Maintenance requirements
A	**OK** On track to target conditions	>70%	Mostly leaf litter, bare soil, woody debris and recruits.	Not present or minor occurrence.	Numerous recruits of native species given site location and stage of development.	Routine maintenance only.
B	**Uncertain** if will develop towards target conditions. Significant problems.	50-70%	Mixed or patchy leaf litter / bare soil and grass.	If present, have the potential to impede site development.	Not many recruits of native species given location or stage of development; exotic species may be common recruits.	Extra effort required to fix problems, additional to routine maintenance.
C	**Poor** Major problems. Likely to fail.	<50%	Mostly dense grass or weeds.	May be common, or likely to impede site development.	Very little recruitment of native species and/ or recruitment dominated by exotic species.	Major effort required to address problems.

Notes

Canopy cover: Shade cast by vegetation >2 m height if the sun is directly overhead (see Module 4). Typically, canopy cover must exceed 70% to suppress vigorous grasses and light-demanding weeds.

Ground cover: Includes various plant life forms, organic debris, and soil and rocks (see Module 4). Important components of ground cover to consider when assessing condition include, (i) leaf litter (or mulch), (ii) bare soil, and (iii) grass and weeds. These components reflect canopy closure and/ or maintenance and affect plant recruitment and growth.

Problem weeds: Plants that may degrade the canopy or other elements of vegetation structure, suppress planted trees or prevent the establishment or growth of recruits (e.g. some vines, grasses, scramblers: the actual species will vary with locality).

Table 3.4. Example of the assessment of the condition of a revegetated site.

PROJECT DESCRIPTION *Note: where options are given, put an* ***'X'*** *next to the appropriate term(s).*

Project name: Greenhill Estate corridor		**Project ID:** 2000 - 2
Site name: Brown's farm		**Site ID:** 2000 - 2 - 3
Type of on-ground-works: Reforestation …X Remnant enhancement …… Regrowth management ……	**Years since site commenced:** 8 years	**When was this site last assessed?** July 2007
Current assessment conducted by: JK	**Date of current assessment:** 30 July 2008	

Overall comments on site condition: **Most of this site is doing well, and needs only routine maintenance (spot-spraying of weeds). However, there are two exceptions: (1) Cattle have gained access to northern section, and trashed it. Needs replanting. (2) The species mix used in swales (dominated by pioneers, esp. *Homalanthus*) has resulted in an open canopy, as the pioneers have senesced, which has allowed grass and Lantana to establish. The grass and lantana in this section needs to be sprayed and it needs infill planting with intermediate phase and mature phase tree species.**

Has the condition of the site changed since last assessment? YES … X *or* NO ..... *If Yes, briefly describe changes in this box, and provide details in table below.*

Last assessment (one year ago); site was in good condition. Parts of the site have deteriorated since then, due to (1) cattle gaining access to northern section; and (2) *Homalanthus* in the swales have started to senesce, opening up the canopy.

DETAILED DESCRIPTION OF SITE CONDITION *Complete table annually, or if conditions have changed since last assessment. Also draw map.*

Rating/ zone	Area (ha)	% of site	Location and factors affecting outcomes	Canopy cover (%)	Ground cover	Problem weeds	~~Tree survival~~ or Recruitment	Other comments	Suggested maintenance
A = OK On track to target	1.4	70	Mix of pioneers and mature phase spp. at 2 m spacing, covers most of site	80-90	Mostly leaf litter and bare soil	none	Native species common as seedling recruits	Trees growing well	(Should be routine: describe if necessary) Minor weeding along edges
B = Uncertain Significant problems	0.4	20	Parts of site where pioneers spp. (esp. *Homalanthus*) are relatively common, mostly in swales near creek	50-60	Patchy/ mix of leaf litter, grass	*Lantana* present in some patches	Some native recruits, but none in dense patches of grass	Mature phase spp. suppressed by grass	(Describe) *Lantana* requires control. Infill planting with mature phase spp needed to close canopy
C = Poor Major problems	0.2	10	Between northern edge of site and creek, unfenced, grazed by cattle	20-40	Mostly dense grass	*Lantana*, pasture grasses	Almost no recruitment of native species	Many trees damaged by cattle	(Describe) Area needs to be completely replanted. Fence needs fixing.
Overall Condition Score: Multiply percentage of site occupied by each zone (A, B or C), by the condition rating for each zone (A = 1; B = 0.5; C = 0), **(Ranges from 0-100%)** and add the products: e.g. (70% x 1) + (20% x 0.5) + (10% x 0) = 80%									80%

MAP OF SITE CONDITION *Note: also describe the condition of the site (previous page).*

Draw a map of the site, showing variation in outcomes as zones (Zone A = OK, Zone B = Uncertain, Zone C = Poor).
Include an approximate scale (e.g. 0______100 m) and North arrow.
Note: useful maps with property boundaries can be often be downloaded from Google Maps (http://maps.google.com)

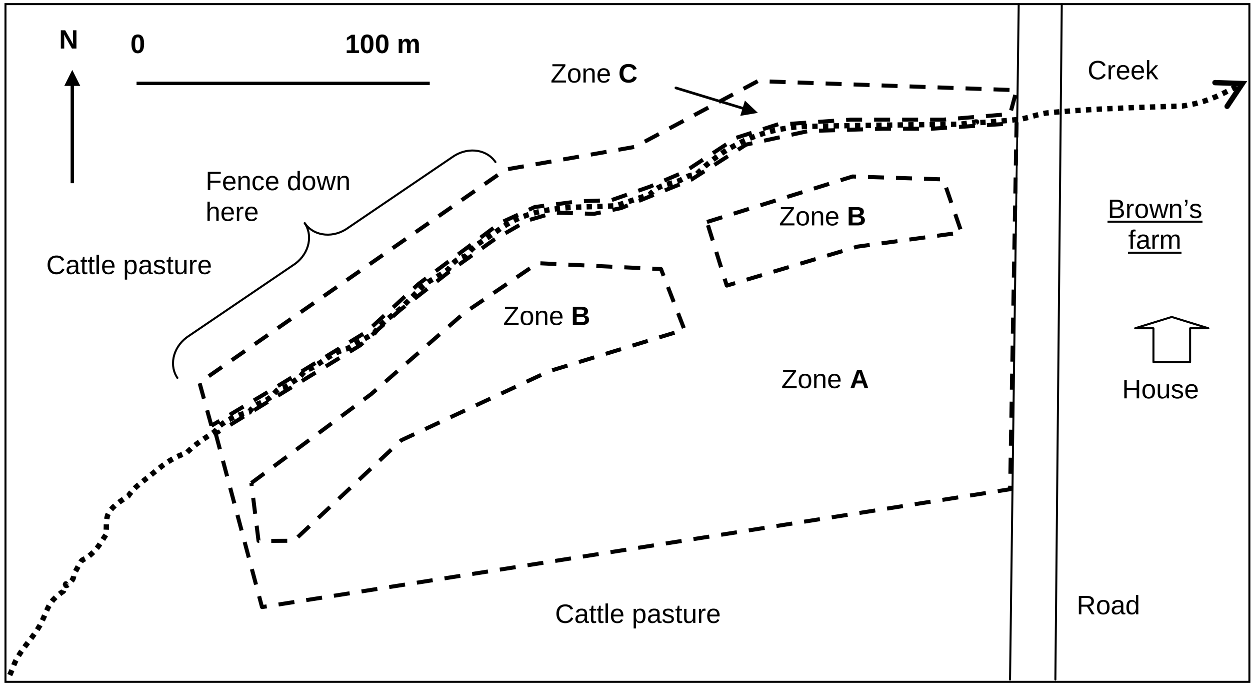

Figure 3.1. Example of a map showing variation in the recorded condition of a revegetated site.

Proforma for Assessing Site Condition

PROJECT DESCRIPTION *Note: where options are given, put an **'X'** next to the appropriate term(s)*

Project name:		**Project ID:**
Site name:		**Site ID:**
Type of on-grounds: Reforestation .... Remnant enhancement....... (weedy) Regrowth management	**Years since site commenced:**	**When was this site last assessed?**
Current assessment conducted by:	**Date of current assessment:**	

Overall comments on site condition:
Has the condition of the site changed since last assessment? YES ….. *or* NO ..... *If Yes, briefly describe changes in this box, and provide details in table below.*

DETAILED DESCRIPTION OF SITE CONDITION *Complete table annually, or if conditions have changed since last assessment. Also draw map.*

Rating/ zone	**Area (ha)**	**% of site**	**Location and factors affecting outcomes**	**Canopy cover** (%)	**Ground cover**	**Problem weeds**	**Tree survival or Recruitment**	**Other comments**	**Suggested maintenance**
A = OK On track to target									(Should be routine: describe if necessary)
B = Uncertain Significant problems									(Describe)
C = Poor Major problems									(Describe)

Overall Condition Score: Multiply percentage of site occupied by each zone (A, B or C), by the condition rating for each zone (A = 1; B = 0.5; C = 0), **(Ranges from 0-100%)** and add the products: e.g. (70% x 1) + (20% x 0.5) + (10% x 0) = 80%	

Extract from: Kanowski, J. *et al.* (2010) *Monitoring Revegetation Projects in Rainforest Landscapes. Toolkit Version 3*. Reef and Rainforest Research Centre Limited, Cairns (98pp.)

Proforma for Assessing Site Condition

MAP OF SITE CONDITION. *Note: also describe the condition of the site (previous page).*

Draw a map of the site, showing variation in outcomes as zones (Zone A = OK, Zone B = Uncertain, Zone C = Poor). Include an approximate scale (e.g. 0_______100 m) and North arrow. Note: useful maps with property boundaries can be often be downloaded from Google Maps (http://maps.google.com.au/).

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Module 4: Monitoring Forest Structure

Many revegetation projects aim to provide habitat for rainforest wildlife, although whether projects achieve this objective is rarely determined. One reason for this is that surveys of rainforest wildlife require specialist expertise. However, it is often relatively easily to assess the habitat itself, particularly elements of vegetation structure (McElhinney *et al.* 2005).

In this module, we present protocols and proformas for monitoring the development of forest structure on revegetated sites. The attributes of forest structure selected for survey include canopy cover, canopy height, the number and arrangement of trees and other life forms, ground cover and woody debris. These attributes are correlated with the use of sites by wildlife (Table 4.1) and provide useful information on the development of revegetated sites (Kanowski *et al.* 2003). All attributes can be readily surveyed by non-specialists.

The survey of forest structure also provides data which can be used to estimate the carbon sequestered by revegetated sites (Module 6), when the area of the site is known (Module 3).

Table 4.1: Relationship between forest structure and the occurrence of rainforest wildlife in reforested sites in tropical and subtropical Australia. The '+' symbols represent the number of significant correlations between structural attributes and wildlife (total from four analyses). All correlations are positive, except for grass cover.

Structural attribute	Correlation with rainforest wildlife:				
	Plants	Birds	Reptiles	Mites	Beetles
Canopy (foliage) cover	++++	+++	+++	+	+++
Canopy height	+++	+++	+	++	++
Density of trees	++++	++++	+	+	+++
Basal area of trees	++++	++++	++	++	++
Density of small trees and shrubs	+	++++		+++	++
Tree size (dbh) diversity	+++	++++	++		++++
Frequency of special life forms	++	+++	+	++	++
Grass cover	(+++)	(++++)	(+)	(+)	(+++)
Leaf litter cover	++	+			+
Woody debris	+	+	+	+	+

Data are from 64 reforested sites aged 5-70 years old. Analyses were conducted for all reforested sites and young replanted sites only, for each of the tropics and subtropics. For details of studies, see: Kanowski *et al.* 2003; Proctor *et al.* 2003; Catterall *et al.* 2004; Wardell-Johnson *et al.* 2005; Kanowski *et al.* 2006; Grimbacher *et al.* 2007. For a summary of analyses, see Kanowski *et al.* 2008b.

Monitoring forest structure: Standard design

In this toolkit, forest structure is surveyed on two 50 m x 20 m plots per site (Figure 4.1), the same basic plot layout used to monitor floristic composition (Module 5). In assessing structure, however, plants are not identified to species. In fact, no distinction is made between native and exotic plants in the structural survey, as both contribute to forest structure. The attributes of forest structure assessed in this toolkit are listed in Table 4.2.

Data on the size class distribution of trees and stags comprise much of the structural survey. These data can also be obtained through a floristics survey (Module 5). If both floristic composition and forest structure are assessed at a site, the structural survey can be reduced to assessing canopy cover and height, ground cover, special life forms and woody debris.

Table 4.2: Forest structural attributes surveyed in this toolkit.

Attributes	Definition
Canopy (foliage) cover	The projective cover of vegetation (i.e. leaves, branches and trunks) >2 m above ground level (= shade cast by vegetation >2 m high, if the sun was directly overhead).
Canopy height	The canopy is the layer of foliage forming the 'roof' of the forest; it may be broken by gaps or incomplete. Canopy height is defined as the height of the tallest tree in the canopy within each quadrat. Note: in some sites, it may be necessary to distinguish canopy trees from emergent trees (i.e. trees projecting <u>well</u> above the canopy with crowns exposed on all sides).
Ground cover	Proportion (percentage) of ground covered by: (a) Vegetation <1 m high (recorded separately for: grass, herbs, ferns, vines and scramblers, trees and shrubs, moss); (b) Leaf litter and fine woody debris (<10 cm diameter); (c) Coarse woody debris (>10 cm diameter); (d) Rock; (e) Bare soil; and (f) Other. Ground cover is assessed by looking down at a 1 m x 1 m plot from above one metre above the ground, and scoring what can be seen from this vantage point (as if looking at a photo). The total must equal100%.
Special life forms	Plant life forms characteristic of rainforest or particular rainforest types (see illustrations, Appendix 5). Includes: strangler figs, hemi-epiphytes, vines ('slender' <5 cm, 'robust' >5 cm diameter), vine towers, vine tangles, thorny or thicket-forming scramblers, clumping epiphytic ferns, other epiphytes, tree ferns, ground ferns, palm trees, understorey palms, cordylines, herbs with long wide leaves such as gingers, herbs with strap leaves such as lillies, cycads (either with, or without above-ground stems), pandanus, or any other life forms characteristic of a site (describe).
Woody debris	Fallen logs/ branches, lying on or within one metre of the ground. Tallied by diameter class at the point of intersection with a 50 m transect. Diameter classes: 2.5-5 cm, 5-10 cm, 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, 50-75 cm, 75-100 cm, >100 cm. Summarised as fine (<10 cm) and coarse (>10 cm diameter) debris.
*** Size class distribution of trees**	Counts of free-standing woody-stemmed plants >1 m high by dbh class: <2.5 cm, 2.5-5 cm, 5-10 cm, 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, 50-75 cm, 75-100 cm, >100 cm. The survey area varies by dbh class: stems <10 cm dbh on 250 m^2 per plot; stems 10-50 cm on 500 m^2 per plot; stems >50 cm on 1,000 m^2 per plot.
*** Stags (dead trees)**	Dead free-standing woody-stemmed plants >1 m high and >10 cm dbh, tallied by dbh class: 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, 50-75 cm, 75-100 cm, >100 cm. The survey area varies by dbh class as for live trees (above). It is also necessary to estimate the height of each stag to estimate carbon sequestration.

* Note, data on these attributes can also be obtained through a floristic survey (Module 5).

Optional attributes for survey	
Cyclone/ storm damage	If assessed, damage to living trees is categorised as: 1 = defoliation, minor branches broken; 2 = larger branches broken; 3 = trunk snapped; 4 = tree uprooted. Damaged trees are tallied by dbh class and damage class. See Appendix 4 for proforma.

Protocol for monitoring forest structure

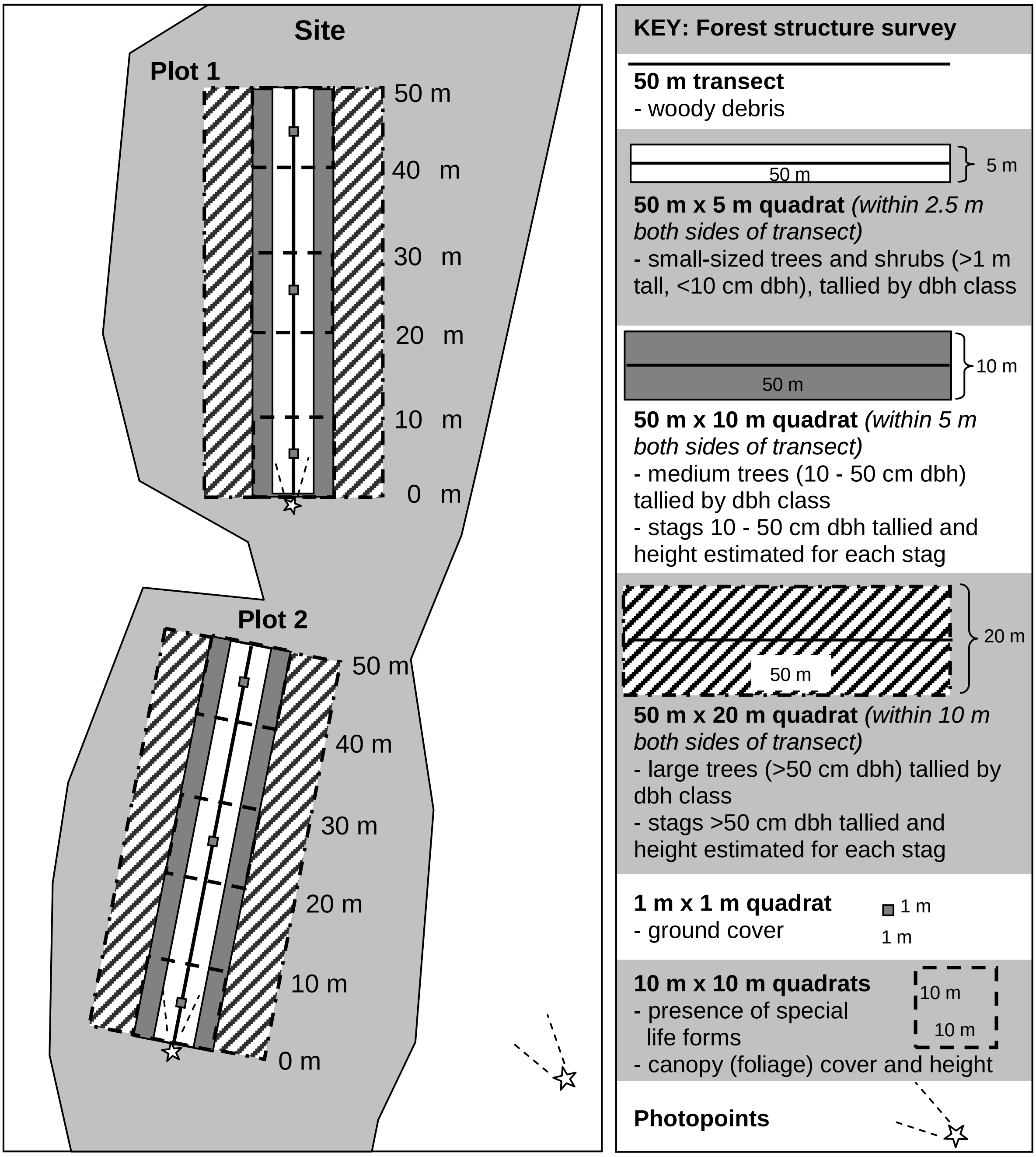

Figure 4.1(a) Layout of survey plots for surveying forest structure. Each **survey plot** is fifty metres long and twenty metres wide. Where possible, two plots are surveyed per site.

Note: At some sites, it may be necessary to 'bend' or 'break' a transect at one or more points, or to alter the layout of plots. In these cases, the total area surveyed should be preserved, e.g. in narrow sites, it may be necessary to split each 50 m x 20 m plot into two 50 m x 10 m subplots (see Figure 4.1(b), following page), the first being the inner 50 m x 10 m quadrat of the standard plot, and the second the remaining 50 m x 10 m used to survey stems >50 cm dbh. Variations on the standard layout should be clearly documented and drawn on a site map.

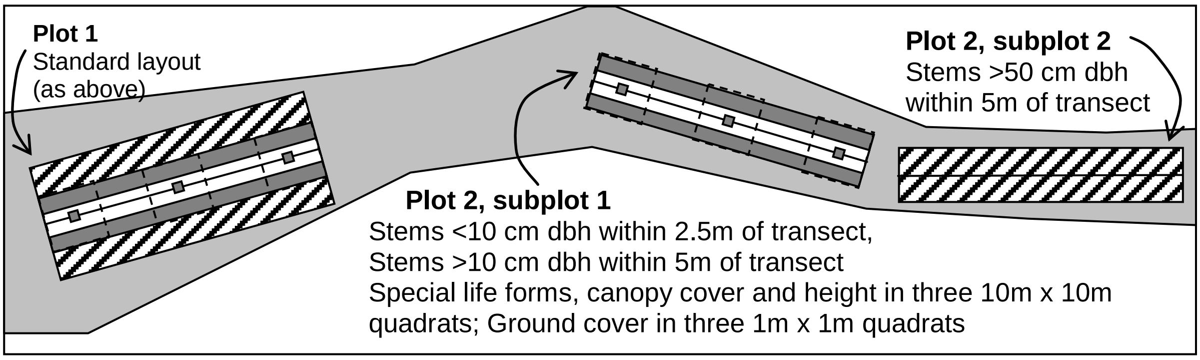

Figure 4.1(b) Layout of a 'bent' or 'broken' survey transect for surveying forest structure.

Equipment required

- 50 m tape
- flagging tape
- 2.5 m pole marked at 2.5, 5, 10, 20, 30, 40, 50, 75 and 100 cm (you may also want to use a ruler or dbh tape)
- four x 1 m sticks
- compass
- camera
- clipboard and proforma
- (Useful: GPS, clinometer, range finder)

Before conducting the survey of forest structure

- **Select (or relocate) the locations of two 50 m x 20 m plots** representative of the site (see Figure 4.1(a) and (b) and notes on previous page in relation to plot layout).
- **Describe the location and environmental context** of sites and survey plots, and **draw a map** of the site.

Forest structure survey protocol

For each plot:

Step 1: **Lay out a 50 m transect**. Every ten metres along each transect, define the survey areas (Figure 4.1a) by marking with flagging tape points 2.5 m, 5 m and 10 m away from the transect, on both sides of the transect.

Step 2: **Count trees and shrubs** (> 1 m high) and **stags** (>10 cm dbh) as follows:

Tally <u>small trees and shrubs</u> (>1 m high, <10 cm dbh) by dbh class (<2.5 cm, 2.5-5 cm, 5-10 cm dbh) within 2.5 m of the transect, on both sides of the transect (area surveyed per plot = 50 m x 5 m = 250 m^2).

Tally <u>medium trees 10-50 cm dbh</u> by dbh class (10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm dbh) within 5 m of the transect, on both sides of the transect (area surveyed per plot = 50 m x 10 m = 500 m^2).

Tally <u>large trees (>50 cm dbh)</u> by dbh class (50-75 cm, 75-100 cm, >100 cm dbh) within 10 m of the transect, on both sides of the transect (area surveyed per plot = 50 m x 20 m = 1,000 m^2).

(Note: On many sites, the survey is easiest to do by walking up one side of the transect, then down the other)

Stags (dead trees) >10 cm dbh are tallied by dbh class as for live trees: i.e. stags 10 - 50 dbh cm within 5 m of transect; stags >50 cm dbh within 10 m of transect. Estimate and record the height of each stag.

Assign any multi-stemmed plants to a notional dbh class, based on the combined cross-sectional area of stems using the formula: *Combined dbh* $=\sqrt{\sum dbh_i^2}$ *where* $\sqrt{}$ *= square root,* $\sum$ *= 'sum',* dbh_i *is the dbh of each stem. e.g. a tree with 3 stems of 5, 10 and 10 cm dbh, has a combined dbh of 15 cm (i.e.* $\sqrt{(25+100+100)}$*).*

(Note: To allow estimation of the carbon sequestered by a revegetation project, it is necessary to record remnant trees (i.e. mature individuals, known or likely to be present on the site prior to revegetation) separately from planted stems and recruits. Circle any remnant trees on data sheet and mark with 'R')

Step 3: Progressively survey **ground cover, canopy (foliage) cover, canopy height, and special life forms** in the quadrats centred on the 5 m, 25 m and 45 m points (see Figure 4.1a), as follows:

- Survey **ground cover** on a 1 m x 1 m quadrat. Use four 1 m sticks to define the quadrat. Look down on the quadrat and estimate the percentage of the quadrat covered by each type (e.g. as seen in a photo), with total cover = 100%. Categories of ground cover include: (a) vegetation within one metre of the ground (recorded by life form); (b) leaf litter and fine woody debris, (c) coarse woody debris; (d) rock, (e) bare soil; or (f) other.
- Survey **canopy (foliage) cover** on the 10 m x 10 m quadrat (i.e. the projective cover of vegetation >2 m above ground level = shade cast by foliage and stems above the observer, if the sun was overhead). It can be estimated directly or calculated from a digital photo. We suggest using both methods.
- **Canopy height:** assess the height of the tallest trees forming the canopy above the 10 m x 10 m quadrat. Note: estimating height is difficult: where possible, quantify height, e.g. using a clinometer, or by the 'ruler method' (see Appendix 3). 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 10 m x 10 m quadrat. Note also if special life forms are present on site, if not recorded in one of the plots. For illustrations of special life forms, see Appendix 5.

Step 4: Survey **woody debris** by walking along the fifty-metre transect. Count the number of times the transect intersects with fallen logs lying on or within one metre of the ground. Logs are tallied by diameter class at the point of intersection. One log may be counted several times if the transect intersects with it at several points.

Step 5: Take a **photo of each monitoring plot** from the 0 m point, along the transect. Also take at least one **'landscape photo'** of the site, and record its location and direction.

Step 6: Make **general comments** on the vegetation, and whether attributes vary markedly across the site. Note the recruitment of species to the site, and any weed problems or site maintenance issues.

(Note: Plants contributing to forest structure are assessed regardless of their origin (native or exotic))

OPTIONAL: Cyclone/ storm damage to stems can be assessed using the additional proforma in Appendix 4.

Proforma For Monitoring Forest Structure

Project name:	**Project ID:**
Site name:	**Site ID:**
Assessed by:	**Date:**

LOCATION OF MONITORING PLOTS

Provide details and also mark on the map of the site	Plot 1	Plot 2
Location at 0 m point of plot (grid / GPS coordinates): **Datum:**		
Compass bearing / direction of transect (from 0 m point)		
Landform (e.g. plateau, crest, upper slope, mid-slope, lower slope, stream bank, floodplain)		
Slope (measure with clinometer, or describe: e.g. steep)		
Aspect (compass bearing / direction of fall of slope)		

MAP OF MONITORING PLOTS

In the box, insert a map of the site showing the location of monitoring plots, including bird monitoring plots if established (Module 7) (mark 0 m point) in relation to notable features of the site (e.g. property boundaries, roads, waterways). Also show notable features of the monitoring plots (e.g. non-standard layout, presence of remnant trees) and location of any landscape photopoints. Include a scale bar (e.g. 0________100 m) and North arrow.

Proforma for Monitoring Forest Structure

Site: **Date:**

GROUND COVER, CANOPY COVER and CANOPY HEIGHT

For each survey plot, lay out a 50 m transect. Then survey quadrats centred on the 5 m, 25 m and 45 m points (Figure 4.1a).

Ground cover = Proportion of ground covered by (a) vegetation within one metre of ground (categorised by life form), (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, using four 1 m sticks. Looking down at the quadrat from one metre, estimate the percentage of ground covered by each type (as would be seen in a photo: total must add to 100%).

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

Canopy (foliage) cover = Projective cover of vegetation >2 m above ground level (shade cast by foliage and stems, if the sun was overhead, assessed (approximately) above the entire 10 m x 10 m quadrat around each point. It can be estimated by eye (although this can be very subjective) or from a photo. We suggest using both methods.

1. *Estimate foliage cover visually, e.g. by comparison with reference photos (see Appendix 1).*
2. *Take a wide-angled digital photo looking up from the centre of each 10 m x 10 m quadrat, and use to calculate foliage cover (see Appendix 2). Record the number of each photo for later reference.*

Canopy (foliage) cover	**Plot 1**			**Plot 2**		
Location of quadrat:	**5 m**	**25 m**	**45 m**	**5 m**	**25 m**	**45 m**
Visual estimate of canopy (foliage) cover	%	%	%	%	%	%
Canopy (foliage) cover calculated from photo	%	%	%	%	%	%
Record number of canopy photo for reference						

Canopy height The height of the tallest tree in the canopy of each 10 m x 10 m quadrat (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 well above the canopy with crowns exposed on all sides

Note: Estimating height is difficult. Use a clinometer and tape measure, or range finder, or other measure (see Appendix 3). Alternatively, place a 2.5 m pole against a tree, and standing at a distance, estimate height in multiples of 2.5 m.

Canopy height	**Plot 1**			**Plot 2**		
Location of quadrat:	**5 m**	**25 m**	**45 m**	**5 m**	**25 m**	**45 m**
Canopy height (tallest trees in canopy)						
Height of emergent trees (if present)						

Proforma for Monitoring Forest Structure

Site: **Date:**

SPECIAL LIFE FORMS *Record **presence** ('1') of life forms in each 10 m x 10 m quadrat centred on the 5 m, 25 m and 45 m points. If life forms are present on site, but not in quadrats, record in last column. Do not count no. of individuals.*

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

Woody debris = Fallen logs and branches lying on or within one metre of the ground.

Tally the number of times logs are intercepted by each 50 m transect, by diameter class at the point of intersection. If a log is intercepted by the transect more than once, it is tallied each time, by diameter at each of the points of intersection

Tally intercepts with fallen logs by diameter class on each transect	**Fine woody debris <10 cm dia**		**Coarse woody debris (CWD) > 10 cm diameter**						
	2.5-5 cm	**5-10** cm	**10-20**	**20-30**	**30-40**	**40-50**	**50-75**	**75-100**	**>100**
Plot 1 50 m transect									
Plot 2 50 m transect									

Proforma for Monitoring Forest Structure

Site: **Date:** **Page 4 of 6**

SIZE CLASS DISTRIBUTION OF TREES AND STAGS: *(Plot 1)*

Tally trees, shrubs and saplings (>1 m high) **by dbh class**. Stems <10 cm dbh within 2.5 m of transect; stems 10-50 cm dbh within 5 m of transect; stems >50 cm dbh within 10 m of transect.

Count stags 10-50 cm dbh within 5 m of transect, >50 cm dbh within 10 m. Estimate the height of each stag.

Assign multistemmed individuals to a notional dbh class, based on the combined cross-sectional area of stems using the formula: Combined dbh = $\sqrt{\sum dbh_i^2}$ *where* dbh_i *is the diameter of each stem.*

In revegetated sites, note any remnant trees (circle remnant trees on data sheet and mark with 'R')

PLOT 1: Trees, shrubs and saplings (>1 m high). Tally plants by dbh class (cm)									
Small-sized trees and shrubs (stems <10 cm dbh): count within 2.5 m of transect			Medium stems 10-50 cm dbh: count within 5 m of transect				Large stems >50 cm dbh: count within 10 m of transect		
<2.5 cm	**2.5-5** cm	**5-10** cm	**10-20** cm	**20-30** cm	**30-40** cm	**40-50** cm	**50-75** cm	**75-100** cm	>**100** cm
Total:	**Total:**	**Total:**	**Total:**	**Total:**	**Total:**	**Total:**	**Total:**	**Total:**	**Total:**
STAGS (dead trees) >10 cm dbh For each stag, **record height (m),** in relevant dbh class. Separate stags in same dbh class by commas: e.g. if three stags are encountered with a dbh of 10-20 cm, and their heights are 7 m, 2 m and 6 m, write: '7, 2, 6' in the 10-20 cm dbh column.									

Proforma for Monitoring Forest Structure

Site: **Date:**

SIZE CLASS DISTRIBUTION OF TREES AND STAGS *(Plot 2): same protocols as for Plot 1 (repeated below)*

Tally trees, shrubs and saplings (>1 m high) **by dbh class**. Stems <10 cm dbh within 2.5 m of transect; stems 10-50 cm dbh within 5 m of transect; stems >50 cm dbh within 10 m of transect.

Count stags 10-50 cm dbh within 5 m of transect, >50 cm dbh within 10 m. Estimate the height of each stag.

Assign multistemmed individuals to a notional dbh class, based on the combined cross-sectional area of stems using the formula: Combined dbh = $\sqrt{\sum dbh_i^2}$ *where* dbh_i *is the diameter of each stem.*

In revegetated sites, note any <u>remnant trees</u> (circle remnant trees on data sheet and mark with 'R')

PLOT 2: Trees, shrubs and saplings (>1 m high). Tally plants by dbh class (cm)									
Small-sized trees and shrubs (stems <10 cm dbh): count within 2.5 m of transect			Medium stems 10-50 cm dbh: count within 5 m of transect				Large stems >50 cm dbh: count within 10 m of transect		
<2.5 cm	**2.5-5** cm	**5-10** cm	**10-20** cm	**20-30** cm	**30-40** cm	**40-50** cm	**50-75** cm	**75-100** cm	>**100** cm
Total:	**Total:**	**Total:**	**Total:**	**Total:**	**Total:**	**Total:**	**Total:**	**Total:**	**Total:**
STAGS (dead trees) >10 cm dbh For each stag, **record height (m),** in relevant dbh class. Separate stags in same dbh class by commas: e.g. if three stags are encountered with a dbh of 10-20 cm, and their heights are 7 m, 2 m and 6 m, write: '7, 2, 6' in the 10-20 cm dbh column.									

Extract from: Kanowski, J. *et al.* (2010) *Monitoring Revegetation Projects in Rainforest Landscapes. Toolkit Version 3.* Reef and Rainforest Research Centre Limited, Cairns (98pp.).

Proforma for Monitoring Forest Structure

Site: **Date:** **Page 6 of 6**

GENERAL COMMENTS *on the structure or composition of vegetation at the site (e.g. dominant or notable species, variation across the site): record by strata as follows*:

Canopy:

Midstorey:

Understorey/ Ground cover:

RECRUITMENT: What species are common recruits to the site? Any other comments about recruitment?

Does this site have any **WEED** or **MAINTENANCE ISSUES** that need attention?

Any other comments on the site? Mark an '**X**' here _______ and add extra page(s) as required.

Module 5: Monitoring Plant Species Composition

Plant species composition is the main thing manipulated by restoration practitioners at revegetated sites, both through the culling of exotics and through the addition of native species. This module of the toolkit presents protocols and proformas for monitoring plant species composition and recruitment at revegetated sites. This information can be used to:

- Determine whether a revegetated site has achieved a plant species composition similar to reference sites, typically a major goal of revegetation projects;
- Identify 'gaps' in the composition of a site, or in the species being recruited to a site, and hence the species that may need to be added to the site (e.g. Tucker and Murphy 1997);
- Identify whether plant species known to provide particular resources for target wildlife are present at a site (e.g. cassowary food plants); and
- Estimate carbon sequestration in revegetation projects, when combined with data on forest structure (see Module 6) and the extent of a revegetated site (Module 3).

Monitoring plant species composition: Standard design

In this toolkit, plant species composition is monitored on two 50 m x 20 m transects per site (Figure 5.1), the same basic plot layout also used for surveying forest structure (Module 4). The methods used in this toolkit to survey various plant life forms are listed in Table 5.1

Table 5.1. Plant life forms surveyed in this toolkit.

Plant life forms	Definition and survey methodology
Seedlings	Live free-standing woody-stemmed plants <1 m high. Identified to species if present within 2.5 m of transect (total area surveyed = 50 m x 5 m per plot).
Trees and shrubs	Live free-standing woody-stemmed plants >1 m high. Identified to species and tallied by dbh class (= stem diameter 1.3 m above ground) in the following categories: <2.5 cm, 2.5-5 cm, 5-10 cm, 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, 50-75 cm, 75-100 cm, >100 cm. The survey area varies with dbh, as follows: Small trees and shrubs (>1 m high, <10 cm dbh) within 2.5 m of transect, on both sides of the transect (area surveyed = 50 m x 5 m = 250 m^2 per plot). Medium trees 10-50 cm dbh within 5 m of transect, on both sides of the transect (area surveyed = 50 m x 10 m = 500 m^2 per plot). Large trees (>50 cm dbh) within 10 m of transect, on both sides of the transect (area surveyed = 50 m x 20 m = 1000 m^2 per plot). Assign multi-stemmed plants to a dbh class based on the combined cross-sectional area of stems, using the formula: *Combined dbh =* $\sqrt{\sum dbh_i^2}$ *where √ = square root, ∑= 'sum', dbh_i is the dbh of each stem. e.g. a tree with 3 stems of 5, 10 and 10 cm dbh, has a combined dbh of 15 cm (i.e. √(25+100+100)).* In revegetated sites, record remnant trees separately from planted stems and from recruits: e.g. on data sheet, circle planted stems (*or recruits – note which*), and circle any remnant trees and mark them with an 'R'.
Stags (dead trees)	Dead free-standing woody-stemmed plants >10 cm dbh, tallied by dbh class: 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, 50-75 cm, 75-100 cm, >100 cm. The survey area is the same as for trees: stag 10 - 50 cm dbh within 5 m of transect (i.e. 50 m x 10 m per plot), stags >50 cm dbh within 10 m of transect (i.e. 50 m x 20 m per plot). Estimate the height of each stag (for estimates of carbon sequestration).
Other life forms: e.g. vines, ground covers, epiphytes	All plants other than trees and shrubs. Identified to species on three 10 m x 10 m quadrats per plot, centred on the 5 m, 25 m and 45 m points of the transect (Fig.5.1a) (a) For ground covers (ferns, herbs, grasses and scramblers), estimate % cover in each quadrat (Note: in a 10 m x 10 m quadrat, 1 m^2 = 1% cover). (b) For vines, epiphytes and other life forms, note presence in each quadrat.

Protocol for monitoring floristic composition

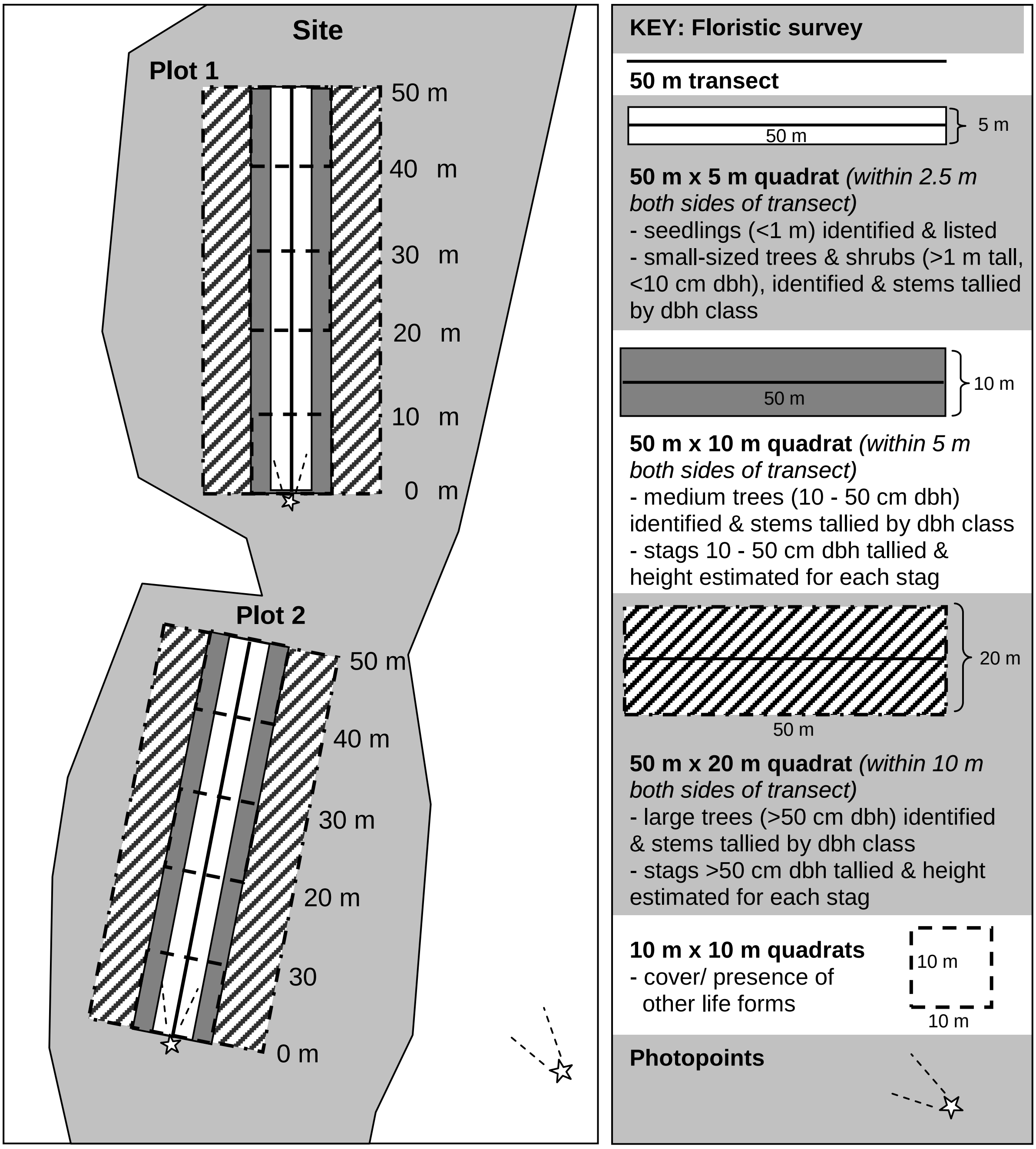

Figure 5.1(a) Layout of survey plots for surveying floristic composition. Each **survey plot** is fifty metres long and twenty metres wide. Where possible, two plots are surveyed per site.

Note: At some sites, it may be necessary to 'bend' or 'break' a transect at one or more points, or to alter the layout of plots. In such cases, the total area surveyed should be preserved, e.g. in narrow sites, it may be necessary to split each 50 m x 20 m plot into two 50 m x 10 m subplots (see Figure 5.1(b), following page), the first being the inner 50 m x 10 m quadrat of the standard plot, and the second the remaining 50 m x 10 m used to survey stems >50 cm dbh. Variations on the standard layout should be clearly documented and drawn on a site map.

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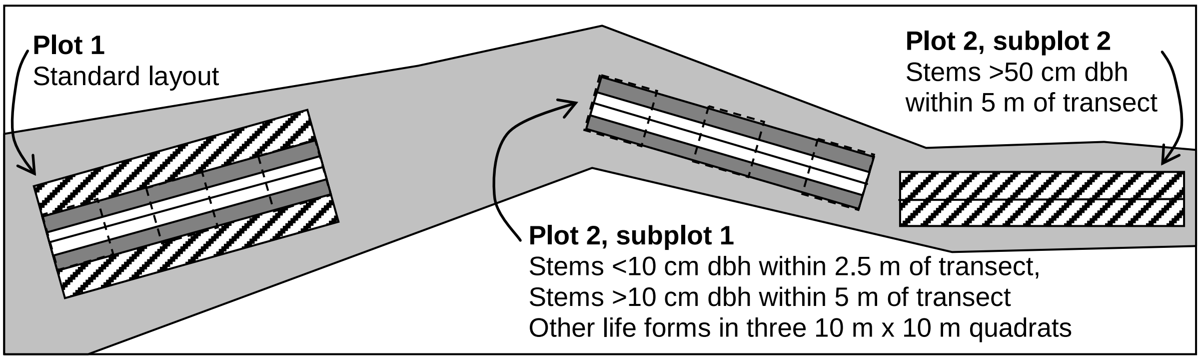


Figure 5.1(b) Layout of a 'bent' or 'broken' survey transect for surveying floristic composition.

Equipment required

- 50 m tape
- flagging tape
- 2.5 m pole, marked at 2.5, 5, 10, 20, 30, 40, 50, 75 and 100 cm (you may also want to use a ruler or dbh tape)
- Compass
- Camera
- clipboard and proforma
- (Useful: clinometer, binoculars, GPS; equipment for collecting specimens such as secateurs, bags, tags. Note: collecting plant specimens may require a permit on some sites)

Before conducting the floristic survey

- **Select (or relocate) the locations of two 50 m x 20 m plots** representative of the site (see diagram and notes on previous page in relation to plot layout).
- **Describe the location and environmental context** of sites and survey plots, and **draw a map** of the site.

Floristic survey protocol

For each plot:

Step 1: **Lay out a 50 m transect**. Every ten metres along each transect, define the survey areas (Figure 5.1) by marking with flagging tape points 2.5 m, 5 m and 10 m away from the transect, on both sides of the transect.

Step 2: **Survey species of trees and shrubs** (including seedlings and saplings, note: palms are considered a tree or shrub in floristic survey), and count **stags**, as follows:

Seedlings (<1 m high): Identify species within 2.5 m of the transect, on both sides of the transect (total area surveyed per plot = 50 m x 5 m = 250 m^2). Note the presence of species; do not count number of individuals.

Identify trees and shrubs (>1 m high) and tally by dbh class:

Identify small trees and shrubs (>1 m high, <10 cm dbh) and tally by dbh class (<2.5 cm, 2.5-5 cm, 5-10 cm dbh) within 2.5 m of the transect, on both sides of the transect (area surveyed per plot = 50 m x 5 m = 250 m^2)

Identify medium trees 10-50 cm dbh and tally by dbh class (10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm dbh) within 5 m of the transect, on both sides of the transect (area surveyed per plot = 50 m x 10 m = 500 m^2).

Identify large trees (>50 cm dbh) and tally by dbh class (50-75 cm, 75-100 cm, >100 cm dbh) within 10 m of the transect, on both sides of the transect (area surveyed per plot = 50 m x 20 m = 1,000 m^2).

(Note: On many sites, the survey is easiest to do by walking up one side of the transect, then down the other)

Stags (dead trees) >10 cm dbh are tallied by dbh class as for live trees: i.e. stags 10-50 dbh cm within 5 m of transect; stags >50 cm dbh within 10 m of transect. Estimate the height of each stag.

Assign any multi-stemmed plants to a notional dbh class, based on the combined cross-sectional area of stems using the formula: *Combined dbh* $=\sqrt{\sum dbh_i^2}$ *where* √ *= square root,* ∑*= 'sum',* dbh_i *is the dbh of each stem e.g. a tree with 3 stems of 5, 10 and 10 cm dbh, has a combined dbh of 15 cm (i.e.* $\sqrt{(25+100+100)}$*).*

In revegetated sites, it may be useful to record planted trees separately from recruits and remnant trees (remnants = mature individuals, present on site prior to revegetation), to allow separate analysis of these components of the flora, and to allow estimation of carbon sequestration without remnant trees. On data sheets, circle planted stems (*or recruits – note which*), and circle any remnant trees and mark with 'R'. Note: it may not be possible to distinguish planted stems from recruits on all revegetated sites.

Step 3: **Identify other life forms** (e.g. vines, ground-covers, epiphytes) on each of three 10 m x 10 m quadrats per transect. For ground covers, estimate percent cover (Note: in 10 m x 10 m quadrat, 1 m^2 = 1% cover). For vines, epiphytes and other life forms, note presence in each quadrat. If a life form/ species is present on site, but not in one of the quadrats, note its presence in the 'on site' column.

Step 4: Take a **photo of each monitoring plot** from the 0 m point, along the transect. Also take at least one **'landscape photo'** of the site, and record its location and direction.

Note on taxonomic resolution: Ideally, all trees and shrubs and most vines would be identified to species; this may not be possible for other life forms, or for seedlings. In such cases, identify plants to genus or family (if known). It may not be worth identifying all transient agricultural weeds to species, but plants that are abundant at a site should be identified if possible.

Combining the floristics survey with a survey of vegetation structure:

The floristic survey provides a tally of trees and stags by dbh class which comprise much of the data on forest structure sought by Module 4. A complete survey of forest structure requires additional data on ground cover, foliage cover, canopy height and special life forms from surveys of quadrats centred on the 5 m, 25 m and 45 m points of each transect. These data can be obtained by completing the relevant pages of the forest structure proforma (Module 4).

Proforma for Monitoring Floristic Composition

Project name:	**Project ID:**
Site name:	**Site ID:**
Assessed by:	**Date:**

LOCATION OF MONITORING PLOTS

Provide details and also mark on the map of the site	**Plot 1**	**Plot 2**
Location at 0 m point of plot (grid / GPS coordinates): **Datum:**		
Compass bearing / direction of transect (from 0 m point of plot)		
Landform (e.g. plateau, crest, upper slope, mid-slope, lower slope, stream bank, floodplain)		
Slope (measure with clinometer, or describe: e.g. steep)		
Aspect (compass bearing / direction of fall of slope)		

MAP OF MONITORING PLOTS

In the box, insert a map of the site showing the location of monitoring plots (mark 0 m point) in relation to notable features of the site (e.g. property boundaries, roads, waterways). Also show notable features of the monitoring plots (e.g. non-standard layout, presence of remnant trees) and location of any landscape photopoints. Include a scale bar (e.g. 0________100 m) and North arrow.

Proforma for Monitoring Floristic Composition

1. TREES AND SHRUBS

Identify seedlings (<1 m high) within 2.5 m of transect (tick cell if species present, do not count individuals).

Identify trees and shrubs (>1 m high) and **tally by dbh class**. Count stems <10 cm dbh within 2.5 m of transect, on both sides of transect; stems 10-50 cm dbh within 5 m of transect, on both sides of transect; stems >50 cm dbh within 10 m of transect, on both sides of transect. *In revegetated sites, where possible, distinguish <u>planted stems</u> from <u>recruits</u> (circle one type: note which); circle <u>remnant trees</u> and mark with 'R'*

Count stags by dbh class and **estimate height** of each. Survey area varies with dbh class as for live trees.

Assign multistemmed trees or stags to a notional dbh class, based on the combined cross-sectional area of stems using the formula: Combined dbh = $\sqrt{\sum dbh_i^2}$ *where* dbh_i *is the diameter of each stem.*

Plot number ____ of ____	Seedlings < 1 m high	Trees and shrubs >1 m high: identify and tally by dbh class.									
Species list	Tick cell if present within 2.5 m of transect	Stems <10 cm dbh: count within 2.5 m of transect			Stems 10 - 50 cm dbh: count within 5 m of trans.				Stems >50 cm count within 10 m		
		<2.5 cm dbh	2.5-5 cm dbh	5-10 cm	10-20	20-30	30-40	40-50	50-75	75-100	> 100
1											
2											
3											
4											
5	Seedling	<2.5 cm dbh	2.5-5 cm	5-10	10-20	20-30	30-40	40-50	50-75	75-100	> 100
6											
7											
8											
9											
10	Seedling	<2.5 cm dbh	2.5-5 cm	5-10	10-20	20-30	30-40	40-50	50-75	75-100	> 100
11											
12											
13											
14											
15	Seedling	<2.5 cm dbh	2.5-5 cm	5-10	10-20	20-30	30-40	40-50	50-75	75-100	> 100
16											
17											
18											
19											
20											

Note: If more than 20 species are encountered on plot, mark with an '**X**' here ___ and continue to next page.

Stags (dead trees) >10 cm dbh only: Survey by dbh class as for live trees, i.e.: stags 10-50 cm dbh within 5 m of transect, on both sides of transect; stags >50 cm dbh within 10 m of transect, on both sides of transect. ***For each stag, record height in metres, in relevant dbh class.*** Separate stags in the same dbh class by commas, e.g. if three stags are encountered with a dbh of 10-20 cm, with heights of 7 m, 2 m and 6 m, write '7, 2, 6' in the 10-20 cm dbh column. *Use this box to tally all stags in this plot*	10-20	20-30	30-40	40-50	50-75	75-100	> 100

Proforma for Monitoring Floristic Composition

1. TREES AND SHRUBS

Site: **Date:**

Plot number ____ of ____	Seedling < 1 m high	Trees and shrubs >1 m high: identify and tally by dbh class									
Species list	Tick cell if spp present within 2.5 m of transect	Stems <10 cm dbh: count within 2.5 m of transect			Stems 10-50 cm dbh: count within 5 m of tran.				Stems >50 cm count within 10 m		
		<2.5 cm dbh	2.5-5 cm dbh	5-10 cm	10-20	20-30	30-40	40-50	50-75	75-100	> 100
21											
22											
23											
24											
25	Seedling	<2.5 cm dbh	2.5-5 cm	5-10	10-20	20-30	30-40	40-50	50-75	75-100	> 100
26											
27											
28											
29											
30	Seedling	<2.5 cm dbh	2.5-5 cm	5-10	10-20	20-30	30-40	40-50	50-75	75-100	> 100
31											
32											
33											
34											
35	Seedling	<2.5 cm dbh	2.5-5 cm	5-10	10-20	20-30	30-40	40-50	50-75	75-100	> 100
36											
37											
38											
39											
40	Seedling	<2.5 cm dbh	2.5-5 cm	5-10	10-20	20-30	30-40	40-50	50-75	75-100	> 100
41											
42											
43											
44											
45	Seedling	<2.5 cm dbh	2.5-5 cm	5-10	10-20	20-30	30-40	40-50	50-75	75-100	> 100
46											
47											
48											
49											
50											

Note: If more than 50 species are encountered on plot, mark with an '**X**' here ___ and continue to next page.

Proforma for Monitoring Floristic Composition

1. TREES AND SHRUBS

Site: **Date:**

Plot number ____ of ____	Seedling < 1 m high	Trees and shrubs >1 m high: identify and tally by dbh class									
Species list	Tick cell if spp present within 2.5 m of transect	Stems <10 cm dbh: count within 2.5 m of transect			Stems 10 - 50 cm dbh: count within 5 m of tran.				Stems >50 cm count within 10 m		
		<2.5 cm dbh	2.5-5 cm dbh	5-10 cm	10-20	20-30	30-40	40-50	50-75	75-100	> 100
51											
52											
53											
54	Seedling	<2.5 cm dbh	2.5-5 cm	5-10	10-20	20-30	30-40	40-50	50-75	75-100	> 100
55											
56											
57											
58											
59	Seedling	<2.5 cm dbh	2.5-5 cm	5-10	10-20	20-30	30-40	40-50	50-75	75-100	> 100
60											
61											
62											
63											
64	Seedling	<2.5 cm dbh	2.5-5 cm	5-10	10-20	20-30	30-40	40-50	50-75	75-100	> 100
65											
66											
67											
68											
69	Seedling	<2.5 cm dbh	2.5-5 cm	5-10	10-20	20-30	30-40	40-50	50-75	75-100	> 100
70											
71											
72											
73											
74	Seedling	<2.5 cm dbh	2.5-5 cm	5-10	10-20	20-30	30-40	40-50	50-75	75-100	> 100
75											

Note: If more than 75 species are encountered on plot, mark with an '**X**' here ___ and continue to next page.

Proforma for Monitoring Floristic Composition

1. TREES AND SHRUBS

Site: **Date:**

Plot number ____ of ____	Seedling < 1 m high	Trees and shrubs >1 m high: identify and tally by dbh class									
Species list	Tick cell if spp present within 2.5 m of transect	Stems <10 cm dbh: count within 2.5 m of transect			Stems 10 - 50 cm dbh: count within 5 m of tran.				Stems >50 cm count within 10 m		
		<2.5 cm dbh	2.5-5 cm dbh	5-10 cm	10-20	20-30	30-40	40-50	50-75	75-100	> 100
76											
77											
78											
79											
80											
81	Seedling	<2.5 cm dbh	2.5-5 cm	5-10	10-20	20-30	30-40	40-50	50-75	75-100	> 100
82											
83											
84											
85											
86	Seedling	<2.5 cm dbh	2.5-5 cm	5-10	10-20	20-30	30-40	40-50	50-75	75-100	> 100
87											
88											
89											
90											
91	Seedling	<2.5 cm dbh	2.5-5 cm	5-10	10-20	20-30	30-40	40-50	50-75	75-100	> 100
92											
93											
94											
95											
96	Seedling	<2.5 cm dbh	2.5-5 cm	5-10	10-20	20-30	30-40	40-50	50-75	75-100	> 100
97											
98											
99											
100											

Note: If more than 100 species are encountered on this plot, mark with an '**X**' here ___ and add extra page(s).

Extract from: Kanowski, J. *et al.* (2010) *Monitoring Revegetation Projects in Rainforest Landscapes*. *Toolkit Version 3*. Reef and Rainforest Research Centre Limited, Cairns (98pp.).

Proforma for Monitoring Floristic Composition

2. OTHER LIFE FORMS

Site: **Date:**

Other life forms: For ground covers estimate percent cover on each quadrat. *Note: in 10 m x 10 m quadrat, 1 m^2 = 1% cover.* For other life forms, note if species is present ('P') in quadrat. If spp. present on site, but not quadrats, note in last column.

Species list	* Life form	Plot 1, Quadrat at			Plot 2, Quadrat at			On site?
		5 m	25 m	45 m	5 m	25 m	45 m	
1								
2								
3								
4								
5								
6								
7								
8								
9								
10		5 m	25 m	45 m	5 m	25 m	45 m	
11								
12								
13								
14								
15								
16								
17								
18								
19								
20		5 m	25 m	45 m	5 m	25 m	45 m	
21								
22								
23								
24								
25								
26								
27								
28								
29								
30		5 m	25 m	45 m	5 m	25 m	45 m	

***Life forms:** **V**ine, **F**ern, **H**erb, **G**rass or sedge, **E**piphyte, **Hemi**-epiphyte, other (specify).

Proforma for Monitoring Floristic Composition

2. OTHER LIFE FORMS

Site: **Date:**

Other life forms: For <u>ground covers</u> estimate percent cover on each quadrat. *Note: in 10 m x 10 m quadrat, 1 m^2 = 1% cover.* For <u>other life forms</u>, note if species is present ('P') in quadrat. If spp present on site, but not quadrats, note in last column

Species list	* Life form	Plot 1, Quadrat at			Plot 2, Quadrat at			On site?
		5 m	25 m	45 m	5 m	25 m	45 m	
31								
32								
33								
34								
35								
36								
37								
38								
39								
40		5 m	25 m	45 m	5 m	25 m	45 m	
41								
42								
43								
44								
45								
46								
47								
48								
49								
50								
51								
52								
53		5 m	25 m	45 m	5 m	25 m	45 m	
54								
55								
56								
57								
58								
59								
60								

***Life forms: V**ine, **F**ern, **H**erb, **G**rass or sedge, **E**piphyte, **Hemi**-epiphyte, other (specify).

Extract from: Kanowski, J. *et al.* (2010) *Monitoring Revegetation Projects in Rainforest Landscapes. Toolkit Version 3*. Reef and Rainforest Research Centre Limited, Cairns (98pp.).

Proforma for Monitoring Floristic Composition

2. OTHER LIFE FORMS

Site: **Date:**

Other life forms: For ground covers estimate percent cover on each quadrat. *Note: in 10 m x 10 m quadrat, 1 m^2 = 1% cover.* For other life forms, note if species is present ('P') in quadrat. If spp present on site, but not quadrats, note in last column

Species list	* Life form	Plot 1, Quadrat at			Plot 2, Quadrat at			On site?
		5 m	25 m	45 m	5 m	25 m	45 m	
61								
62								
63								
64								
65								
66								
67								
68								
69								
70								
71								
72								
73								
74								
75								
76								
77		5 m	25 m	45 m	5 m	25 m	45 m	
78								
79								
80								
81								
82								
83								
84								
85								
86								
87		5 m	25 m	45 m	5 m	25 m	45 m	
88								
89								
90								

***Life forms:** **V**ine, **F**ern, **H**erb, **G**rass or sedge, **E**piphyte, **Hemi**-epiphyte, other (specify).

Note: If >90 species are encountered on these plots, mark with an '**X**' here ___ and add extra page(s)

Proforma for Monitoring Floristic Composition

Site: **Date:**

GENERAL COMMENTS *on the structure or composition of vegetation at the site (e.g. dominant or notable species, variation across the site): record by strata as follows*:

Canopy:

Midstorey:

Understorey/ Ground cover:

RECRUITMENT: What species are common recruits to the site? Any other comments about recruitment?

Does this site have any **WEED** or **MAINTENANCE ISSUES** that need attention?

Any other comments on the site? Mark an '**X**' here _______ and add extra page(s) as required.

Module 6: Monitoring Carbon Sequestration

Due to increasing concern about anthropogenic emissions of greenhouse gases, and the recent emergence of carbon markets to help offset these emissions, revegetation projects can potentially obtain income from the carbon they sequester (Australian Greenhouse Office 2006). Forests store carbon in the stems and foliage of living trees, in dead trees and woody debris (collectively, in above-ground biomass, or ‘AGB’), as well as in roots and soil. In most cases, only the carbon sequestered by revegetation projects in AGB is assessed for sale in carbon markets, as root biomass and soil carbon can be difficult to measure. Live trees comprise a high proportion of AGB (>90%) in most tropical and subtropical rainforests.

Estimates of AGB are typically obtained from allometric equations. These are mathematical relationships between AGB and more easily measured plant attributes, such as dbh and/ or tree height. Chave *et al.* (2005) recently published a set of allometric equations for the AGB of rainforest trees, based on an extensive, worldwide dataset. These equations require, as a minimum, measures of the dbh of each tree and estimates of wood density (of each tree or a stand average). Measuring the height of trees can increase the precision of estimates, but only if height can be measured precisely, which is usually difficult in rainforests.

Methods for estimating carbon sequestration

In this module, we present two alternative methods for estimating AGB, and hence carbon sequestration, in revegetated sites. The choice of method depends partly on the precision required of estimates and partly on the expertise available.

Method 1 is based on a survey of forest structure (i.e. Module 4), specifically:

(i) trees tallied by dbh class,

(ii) stags tallied by dbh and height, and

(iii) woody debris tallied by diameter class.

This method is relatively quick to complete and does not require specialist expertise. However, it is reliant on the availability of reasonable stand-level estimates of wood density for the site-types being assessed. Based on our analyses of a range of site-types including timber plantations, restoration plantings and rainforests, this method produces estimates of AGB that are, on average, within 0-4% of ‘true’ values when reasonable stand-level estimates of wood density are available.

Method 2 is based on a floristics survey (i.e. Module 5), specifically:

(i) trees tallied by dbh class, with stems identified to species;

(ii) stags tallied by dbh and height, and

(iii) woody debris tallied by diameter class (this last attribute is obtained from a survey of forest structure: Module 4).

Method 2 produces more accurate estimates of AGB than Method 1, because species-specific wood density values are used in calculations. This is an important consideration on sites where reasonable stand-level estimates of wood density are not available. However, Method 2 requires botanical expertise and takes longer to complete than Method 1.

To facilitate rapid assessment of AGB, we recommend that stems be tallied by dbh class rather than precisely measuring the dbh of each stem (for both methods). Based on our analyses of timber plantations, restoration plantings and rainforests, categorising stems by dbh produces estimates of AGB within 3-6%, on average, of estimates derived from precisely measuring dbh. We consider this is likely to be sufficiently precise for most purposes, because estimates of AGB derived from actual dbh data are only accurate to ± 10-20% of 'true' values anyway, due partly to error inherent in the allometric equations linking dbh to AGB and partly to spatial variation in AGB across sites (Chave *et al.* 2004, 2005). Rapid assessment methods, which allow the survey of larger plots for a given effort, can help reduce the error arising from spatial variation in AGB across a site.

Wood density

For trees, stags and woody debris, estimates of AGB are directly proportional to wood density (Chave *et al.* 2005). As density can vary widely between species, accurate estimates of the AGB of revegetation projects require accurate data on wood density. In rainforests, fast-growing pioneers tend to have low-density wood (mostly in the range 0.21 g cm^{-3} to 0.43 g cm^{-3}), conifers (*Araucaria*, *Agathis*, *Podocarpus*, etc) tend to have moderately dense wood (0.40 g cm^{-3} to 0.45 g cm^{-3}), while mature phase species generally have moderate to high density wood (0.45 g cm^{-3} to 0.88 g cm^{-3} (Ilic *et al.* 2000). *Eucalyptus* and related genera (e.g. *Corymbia*, *Lophostemon*) have relatively dense wood (range 0.60 g cm^{-3} to 0.90 g cm^{-3}).

The wood densities of selected species commonly used in rainforest revegetation projects are listed in Table 6.1. A more comprehensive database, with density data compiled at the species, genus and family levels, may be downloaded from the websites of the Reef and Rainforest Research Centre (visit http://www.rrrc.org.au/ and follow links to Publications webpage) and Griffith University (visit http://www.griffith.edu.au/environment-planning-architecture/environmental-futures-centre/publications). Locate the file 'Monitoring toolkit wood density.xls'.

At present, wood density data are not available for all species used in revegetation projects. In these cases, mean wood density values for the relevant genus or family should be used (e.g. if there are no density data for *Argyrodendron trifoliatum*, use the mean value for the genus *Argyrodendron*; failing that, use the mean value for the family Sterculiaceae). If family-level data are not available, the stand-level mean should be used instead. In our analyses, species level wood density data were available for 85% of stems encountered in rainforest restoration projects. Genus- and family-level data were available for a further 9% and 5% of stems, respectively.

Calculating stand-level mean wood density

Estimates of the average wood density of a stand are required to calculate the AGB of revegetated sites using Method 1 (i.e. an assessment of forest structure: Module 4). Average wood density estimates are also required to calculate the AGB of any trees lacking family-level density data when using Method 2 (see above), and to calculate the AGB of stags (dead trees) and woody debris for both methods. Indicative stand-level mean wood density values for some types of rainforest revegetation projects are listed in Table 6.2.

However, the values provided in Table 6.2 are not comprehensive. For revegetation projects not covered by Table 6.2, it will be necessary to calculate a stand-level mean wood density value based on component species. This calculation requires that stems are weighted by their contribution to stand basal area, as large trees contribute disproportionately to AGB. The general formula for calculating stand-level mean wood density is:

Stand-level mean wood density = $\Sigma (p_i * d_i)$

where Σ = 'sum', * = 'multiply', p_i = the proportion of stand basal area contributed by stem *i*, and d_i = the wood density of stem *i*.

For example, a plantation comprising 70% *Eucalyptus pellita* by basal area (density = 0.81 g cm^{-3}) and 30% *Araucaria cunninghamii* (density = 0.43 g cm^{-3}) would have a mean stand-level wood density of 0.70 g cm^{-3} (i.e. 0.7 * 0.81 g cm^{-3} + 0.3 * 0.43 g cm^{-3}). Another example of the calculation of stand-level mean wood density is given in Table 6.3.

Table 6.1. Wood density of selected rainforest and eucalypt tree species. Data compiled from Ilic *et al.* (2000). Data for an additional 360 species may be downloaded from the web (see text).

Scientific name	Basic density (g/cm^3)	Scientific name	Basic density (g/cm^3)
Acacia celsa	0.58	*Eucalyptus microcorys*	0.81
Acacia melanoxylon	0.52	*Eucalyptus pellita*	0.81
Agathis robusta	0.40	*Eucalyptus tereticornis*	0.78
Aleurites moluccana	0.39	*Euroschinus falcatus*	0.41
Alphitonia excelsa	0.56	*Ficus coronata*	0.39
Alphitonia petriei	0.43	*Ficus macrophylla*	0.30
Alstonia scholaris	0.34	*Ficus obliqua*	0.51
Araucaria cunninghamii	0.44	*Flindersia australis*	0.78
Argyrodendron peralatum	0.62	*Flindersia bourjotiana*	0.52
Argyrodendron trifoliolatum	0.74	*Flindersia brayleyana*	0.44
Beilschmiedia bancroftii	0.52	*Flindersia schottiana*	0.59
Beilschmiedia obtusifolia	0.63	*Franciscodendron laurifolium*	0.38
Beilschmiedia tooram	0.67	*Geissois biagiana*	0.50
Bischofia javanica	0.53	*Glochidion ferdinandi*	0.56
Blepharocarya involucrigera	0.45	*Gmelina spp.*	0.45
Brachychiton acerifolius	0.34	*Grevillea baileyana*	0.73
Bridelia exaltata	0.65	*Grevillea robusta*	0.53
Buckinghamia celsissima	0.73	*Harpullia pendula*	0.73
Caldcluvia paniculosa	0.53	*Homalanthus spp.*	0.27
Callistemon viminalis	0.64	*Jagera pseudorhus*	0.63
Callitris macleayana	0.47	*Litsea leefeana*	0.41
Cardwellia sublimis	0.44	*Lophostemon confertus*	0.69
Carnarvonia araliifolia	0.56	*Macaranga tanarius*	0.46
Casearia grayi	0.58	*Mallotus discolor*	0.59
Castanospermum australe	0.58	*Mallotus philippensis*	0.60
Castanospora alphandii	0.57	*Melia azedarach*	0.38
Casuarina cunninghamiana	0.59	*Melicope elleryana*	0.50
Ceratopetalum apetalum	0.49	*Myristica insipida*	0.46
Chionanthus ramiflora	0.69	*Nauclea orientalis*	0.46
Citronella moorei	0.56	*Pittosporum undulatum*	0.68
Commersonia bartramia	0.41	*Placospermum coriaceum*	0.56
Corymbia torelliana	0.72	*Planchonella australis*	0.69
Cryptocarya glaucescens	0.51	*Podocarpus elatus*	0.46
Cryptocarya mackinnoniana	0.72	*Polyscias elegans*	0.40
Cryptocarya triplinervis	0.60	*Polyscias murrayi*	0.27
Cupaniopsis anacardioides	0.70	*Prunus turneriana*	0.44
Darlingia darlingiana	0.61	*Pullea stutzeri*	0.65
Dendrocnide photinophylla	0.21	*Rhodosphaera rhodanthema*	0.58
Diploglottis australis	0.56	*Schizomeria ovata*	0.52
Doryphora sassafras	0.49	*Sloanea australis*	0.46
Duboisia myoporoides	0.38	*Stenocarpus sinuatus*	0.59
Dysoxylum fraserianum	0.59	*Symplocos cochinchinensis*	0.51
Dysoxylum mollissimum	0.54	*Synoum glandulosum*	0.51

Scientific name	Basic density (g/cm^3)	Scientific name	Basic density (g/cm^3)
Ehretia acuminata	0.49	*Syzygium australe*	0.59
Elaeocarpus angustifolius/ grandis	0.41	*Syzygium gustavioides*	0.57
Endiandra palmerstonii	0.57	*Toona australis*	0.39
Endiandra pubens	0.60	*Trema orientalis*	0.33
Eucalyptus cloeziana	0.81	*Xanthophyllum octandrum*	0.64
Eucalyptus grandis	0.60	*Xanthostemon whitei*	0.81

Table 6.2. Indicative mean stand-level wood density values for some types of revegetation projects and rainforest.

Vegetation type	Composition	Mean wood density (g/cm^3)
Hoop pine monoculture	100% hoop pine overstorey (including mature plantations with an understorey of rainforest spp.)	0.44
'Ecological restoration' planting	20-40 (or more) species of rainforest trees, including at least 10% pioneers	0.49
Mixed species cabinet timber (1)	10% eucalypts, 90% rainforest species (by basal area)	0.52
Mixed species cabinet timber (2)	50% eucalypts, 50% rainforest species (by basal area)	0.60
Mixed species cabinet timber (3)	70% eucalypts, 30% rainforest species (by basal area)	0.70
Primary rainforest on basalt, Atherton Tableland	Diverse range of species characteristic of complex notophyll/ mesophyll rainforest	0.54

Table 6.3. Calculating stand-level mean wood density for revegetated sites. In this simple example, the stand is comprised of three different species, each represented by a single stem. The general formula for calculating stand-level mean wood density is: Mean density = Σ (p_i * d_i), where Σ = 'sum', * = 'multiply', p_i = proportion of stand basal area contributed by stem *i*, and d_i = wood density of stem *i*.

Species	**dbh** (cm)	**Basal area** (cm^2)	**Proportion of stand basal area** ('A')	**Wood density** (g/ cm^3) ('B')	**Wood density weighted by proportion of stand basal area** (='A' x 'B')
Argyrondendron trifoliatum	5	20	0.05	0.74	0.04
Diospyros fasiculosa	10	79	0.19	0.69	0.13
Homalanthus novoguineensis	20	314	0.76	0.27	0.20
Stand basal area		413			
Stand-level mean wood density (weighted by basal area)					**0.37** (= sum of weighted values)

Equations used to calculate AGB and carbon sequestration

The equations used to calculate AGB and carbon sequestration in this toolkit are listed below. These equations are embedded in the Excel files developed for the toolkit (Module 8).

Live trees

For live trees, AGB is calculated on the basis of the 'best' equations developed by Chave *et al.* (2005, p. 92). There are separate models for forests in 'moist' and 'wet' climates. Most Australian tropical and subtropical rainforests would be defined as 'moist' (having a dry season of several months, up to 3,500 mm rainfall per year, sometimes with a semi-deciduous canopy). A few localities might be defined as 'wet' (lowland forests with > 3,500 mm rainfall/ year, only a short (<1 month) dry season; montane cloud forests).

Moist forest equation:

$$\text{AGB (tonnes)} = \text{wood density (g cm}^{-3}\text{)} * \exp(-1.499 + 2.148 \ln(\text{dbh}) + 0.207 (\ln(\text{dbh}))^2 - 0.0281 (\ln(\text{dbh}))^3 / 1000$$

Wet forest equation:

$$\text{AGB (tonnes)} = \text{wood density (g cm}^{-3}\text{)} * \exp(-1.239 + 1.98 \ln(\text{dbh}) + 0.207 (\ln(\text{dbh}))^2 - 0.0281 (\ln(\text{dbh}))^3 / 1000$$

Note in these equations, wood density may be the stand-level mean (if using Method 1) or the species-specific value (if using Method 2). See section on 'wood density', above, for details.

These equations calculate the AGB of individual trees. To derive the total AGB of live trees at a site, the additional steps below must be followed. Note that the calculations in steps 1-3, below, are incorporated in the Excel files developed for this toolkit (Module 7).

1. Determine the total AGB for each dbh class by summing the AGB of trees in each dbh class (in Method 1, this will simply be the number of stems multiplied by the AGB per stem).
2. Determine the total AGB per ha for each dbh class, by dividing the total AGB in (1) by the area surveyed for each dbh class. In this toolkit, the total area surveyed (if two plots are surveyed per site) is 0.05 ha for trees <10 cm dbh, 0.1 ha for trees 10-50 cm dbh, and 0.2 ha for trees >50 cm dbh.
3. Determine the total AGB per ha for the surveyed area, by summing the total AGB per ha in (2) for all dbh classes.
4. Determine the total AGB for live trees for the site, by multiplying the total AGB per ha in (3) by the size of the revegetated site (see Module 3).

Dead trees (stags)

For stags, AGB is calculated by multiplying volume by wood density. Volume is estimated from dbh and height, using an equation presented in Cannell (1984) which uses a 'form factor' to account for stem taper:

$$\text{Volume (m}^3\text{)} = \pi\, (\text{dbh (cm)}^2) / 4 * \text{Height (m)} * \text{Form factor} / 10000$$

Cannell (1984) suggests the 'form factor' of trees with few branches (the typical case for stags) = 0.5. However, in cases where stags comprise only part of the original tree (e.g. where the trunk has been snapped by a cyclone), this factor will overestimate taper. In this toolkit, taper was assumed to be proportional to the height of the stag, relative to the presumed height of the original tree. This latter value was derived from modal values for trees in dbh classes in data collected by Kanowski *et al.* (2003). Hence:

If stag height ≥ modal height of dbh class,
Form factor = 0.5

If stag height < modal height of dbh class,
Form factor = 0.5 + 0.5 * (Modal height - Actual height) / Modal height

As stags are not usually identified to species, the wood density of stags is assumed to be the stand-level mean, modified by a 'conversion factor' to account for changes in wood density with decay. Based on data presented by Baker *et al.* (2007), this conversion factor is assumed to be 0.75 (i.e. stags are assumed to have 75% the density of live trees). Hence:

AGB (tonnes) = volume (m^3) * stand mean wood density (g cm^{-3}) * 0.75

which is equivalent to:

AGB (tonnes) = π (dbh $(cm)^2$) / 4 * Height (m) / 10000 *
Form factor * stand mean wood density (g cm^{-3}) * 0.75

These equations calculate the AGB of individual stags. To derive the total AGB of stags at a site, the additional steps described for live trees (above) must be taken: i.e. the total AGB of stags needs to be calculated for each dbh class; then converted to AGB per ha based on the area surveyed for each dbh class; then summed to give the total AGB per ha, and then multiplied by the area of the site to give the total AGB of stags for the site. Again, except for this last step, these calculations are incorporated in the Excel files developed for the toolkit (Module 7).

Woody debris

The AGB of woody debris is estimated by multiplying the volume of woody debris by the wood density of the debris. Volume is calculated from line transect counts, using the method of van Wagner (1968) (see Module 4):

V (m^3 per ha) = (π^2 / 8 L) * $\Sigma\, n_i d_i^2$

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

As debris is not usually identified to species, stand-level mean wood density values need to be used, modified by a 'conversion factor' to account for changes in wood density with decay. Based on data presented by Baker *et al.* (2007), and consistent with data collected by Kanowski *et al.* (2003), this conversion factor is assumed to be 0.75 (i.e. woody debris is assumed to have 75% the density of live trees). Hence:

AGB (tonnes per ha) = volume (m^3) * mean density (g cm^{-3}) * 0.75

which is equivalent to:

AGB (tonnes per ha) = (π^2 / 8 L) * $\Sigma\, n_i d_i^2$ * mean density (g cm^{-3}) * 0.75

These calculations are incorporated into the Excel files developed for this toolkit (Module 8). To derive the total AGB of woody debris at a site, the AGB per ha of woody debris needs to be multiplied by the area of the site.

Converting estimates of AGB to carbon or CO_2 equivalents

For trading in carbon markets, estimates of AGB at a site need to be converted to carbon or to CO_2 equivalents (often the traded quantity), as follows (Australian Greenhouse Office 2006):

Carbon (tonnes) = AGB (tonnes) * 0.5 (i.e. on average, one-half of AGB by weight is carbon)

CO_2 equivalents (tonnes) = Carbon (tonnes) * 3.67

which is equivalent to:

CO_2 equivalents (tonnes) = AGB (tonnes) * 1.835

Module 7: Monitoring Bird Species Composition

Revegetation projects often make the assumption that rebuilding the vegetation will result in arrival of the desired animal species over time. However, there are many reasons why this may not happen as expected, and therefore fauna need to be monitored as well as the vegetation.

Different types of animals pose particular opportunities and challenges for monitoring programs. Birds are often a first choice for use as faunal indicators of a revegetated site's progress over time. This is because birds as a group have the following properties.

- <u>Birds are responsive to vegetation change</u>. Birds are diverse in species and in their habits and diets, which means that they can be better indicators of a range of ecological changes than less diverse groups such as mammals or reptiles.
- <u>Birds are ecologically important</u>. For example the majority of rainforest plant species produce fleshy fruits. Frugivorous birds play an important role in dispersing seeds of these plants across the landscape.
- <u>Birds are well known</u>. Good field identification guides are readily available, and the ecological characteristics of most bird species are known. Birds are also interesting to people in their own right.
- <u>Birds are readily surveyed</u>. Though fauna surveying is subject to regulation (e.g. animal ethics approval, scientific permits), birds are conspicuous and mostly diurnal, and do not usually need to be captured for identification.

We are still discovering how birds respond to forest restoration in rainforest landscapes. However there have been several recent studies of the response of birds to rainforest clearing and revegetation in eastern Australia (e.g. Catterall *et al*. 2004, Jansen 2005, Catterall *et al.* 2008, Freeman *et al*. 2009) and their findings have revealed the patterns described below.

Bird communities change quickly as a revegetated site develops from grass to tree cover. As tree cover is established, bird species that inhabit grassland give way to forest-associated species and these continue to increase in both abundance and numbers of species as the site develops. Figure 7.1 (below) illustrates the rapid rate of increase in rainforest bird species richness and the decrease in grassland/wetland bird species richness with increasing age of revegetation for sites in the Wet Tropics lowlands and uplands. However, it takes longer for revegetated sites to attract the most specialised forest bird species and even when such species have colonised a site they may be lower in abundance than in mature forest. The style of revegetation also influences the bird community that becomes established. For example, sites planted for timber can be expected to attract fewer rainforest bird species than those planted for ecological restoration.

Revegetation projects have succeeded in providing habitat for many species of forest-associated birds during the first two decades after establishment. However, we do not know whether bird communities in older revegetated sites will progress to become even more like rainforest bird communities and, if they do, how long it will take for them to reach a truly forest-like species composition (if indeed they ever do). Long-term monitoring as revegetated sites develop is needed to shed more light on this question.

One important aspect of recovering a rainforest-like bird community is a site’s capacity to attract and support the full range of fruit-eating birds that are responsible for dispersing the seeds of rainforest trees, shrubs and vines. This is essential if the site is to develop in the desired manner. There are some simple characteristics of bird and plant species that help predict these seed-dispersal interactions, and these are discussed in Moran *et al*. (2004, 2010), Neilan *et al*. (2006) and Westcott *et al*. (2008).

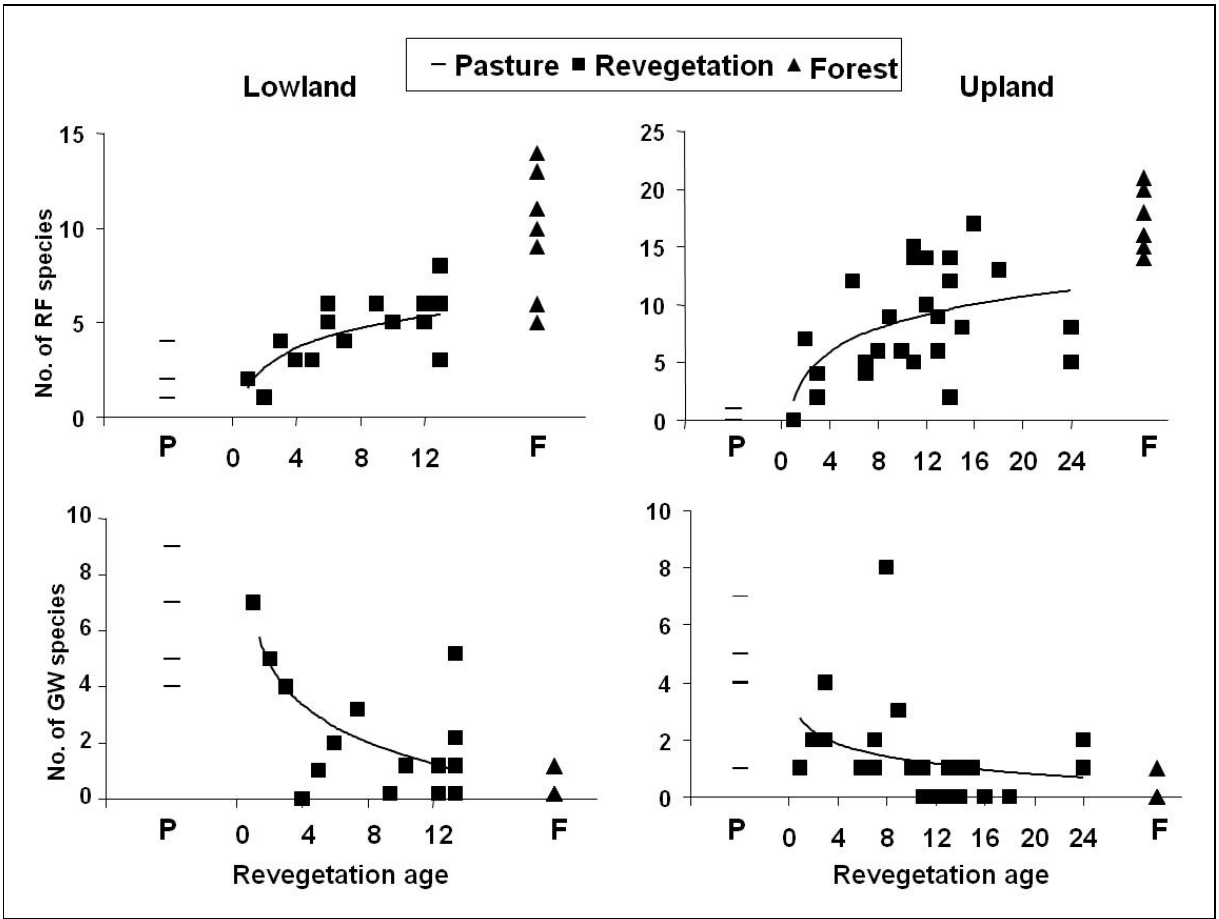


Figure 7.1. The relationship between revegetation age (years) and the numbers of species of Rainforest (RF) and Grassland/Wetland (GW) birds recorded during six thirty-minute searches of 0.3 ha sites in the Wet Tropics. There were five pasture (P), eight forest (F) and 16 revegetated sites in the lowlands and five pasture, eight forest and 25 revegetated sites in the uplands. (Catterall *et al*. unpublished data).

Monitoring bird species composition: Standard design

A wide range of forest bird survey methods are currently in use. These include fixed-time searches, standard-sized transects, distance sampling and results-based sampling (e.g. Bibby *et al* .1992, Rosenstock *et al*. 2002, Watson 2004). The various methods rely to different degrees on visual and acoustic identification of species, and different methods have different limitations and biases and suit different purposes.

This module of the toolkit presents protocols and proformas for monitoring birds in a manner that can detect changes in species composition with either forest degradation or restoration. It has been designed to suit the needs of monitoring by people with a range of backgrounds, from scientific researchers to volunteer community groups. The method is designed to provide useful quantitative data while also being relatively simple and time-efficient and as robust as possible to the potential effects of changes in survey personnel. The method is suitable for surveying small sites including fairly narrow linear plantings and is compatible with the vegetation structure and floristics survey methods provided elsewhere in this toolkit.

The method presented here is a fixed-effort search for birds seen and/or heard during thirty minutes within an area of 0.3 ha. The aim is to get a quantitative picture of the bird species in a site and their relative abundances, and to be able to compare this with the bird species using reference sites that represent the 'origin' and/or 'target' of vegetation management. The search area is established as two 50 m x 30 m survey plots for compatibility with the vegetation monitoring (see Modules 4 and 5 of this toolkit, in which forest structure and florisitcs are surveyed in two 50 m x 20 m plots).

Surveys in revegetated sites

Bird surveys should be conducted along two plots (transects), each fifty metres long, with the same basic layout as described for vegetation monitoring (see Module 4 of this toolkit). Each bird survey plot is thirty metres wide (compared with twenty metres for the vegetation), and wherever possible the two survey plots should be established end to end, giving a 100 m x 30 m total search area (see also suggestions for establishing transects in sites where this configuration is not possible Figure 4.1b). As it can be difficult for observers to accurately judge distance, and hence whether a bird is seen or heard within the survey area, it is very helpful to mark the edges of survey plots with flagging tape. Biodegradable flagging tape can last for several years in the field and has the advantage of not inadvertently littering sites if the tape is tampered with and dispersed by animals or people.

Bird surveys should be repeated four to six times in each plot, in order to give an adequate picture of its biodiversity. Typically these 4-6 surveys would be spread over a sufficient period to encompass seasonal changes (such as over a year). The spreadsheet that accompanies this module ('Monitoring toolkit bird species composition.xls') has been set up to record and analyse data for one revegetated site surveyed four to six times annually for ten years.

Baseline survey and surveys in reference sites

To provide a context for interpreting the outcomes of surveys in revegetated sites it is important to also conduct surveys at 'reference' sites that are selected to represent the target vegetation type (e.g. intact rainforest), and the pre-planting condition (e.g. pasture). It is also desirable to conduct 'baseline' surveys (in the site to be revegetated before planting / restoration works occur). Sampling at least four of each of these types of reference site is recommended. If there are not enough reference sites available, either establish additional transects in the available sites or survey available sites more frequently. Ideally, the reference sites should be surveyed every year along with the revegetated site(s). However, this is time-consuming and if birds vary little from year to year it may be adequate to survey reference sites a minimum of four times over the course of a single year only. The spreadsheet that accompanies this module ('Monitoring toolkit bird species composition.xls') has been set up for four pasture and four forest reference sites to be surveyed four to six times over one year.

Observers

Observers need to be suitably skilled in bird identification and survey techniques. Bird identification involves experience and field skills, which usually require several years to acquire, especially in rainforests where knowing the calls of local species is an important aid to identification. If surveys are done by observers who differ greatly in skill level, the data collected may reflect the observers' capacity rather than the birds present. While anyone can use the methods described here, they will be most useful if surveys are conducted by observers with sufficient prior experience. There are several good guides available to assist with identification and local bird-observer organisations may offer field trips or courses that can improve observers' skills. These organisations could also be approached to find suitably-skilled personnel to help with bird surveys (see Appendix 6).

Use one, two or three observers for a survey. Using more than three observers in a site may cause disturbance to birds and the vegetation. Ideally, the number of observers surveying a site should not change through time.

Equipment

The main items of essential equipment are reasonable quality binoculars (8x40 magnification are best for tropical and subtropical forest and revegetation situations), data sheets and a means of keeping time during the survey. Pencil is best for recording on data sheets as it is flexible and water resistant. Appropriate clothing (generally long trousers and long-sleeved shirt in subdued colours) and footwear are also needed. Consider using a small satchel or shoulder bag to contain a clipboard for the data sheet(s), leaving both hands free to use binoculars. A device capable of recording sound (such as a mobile phone) can also be handy to record calls of birds you are unable to identify in the field. These calls may possibly then be identified at a later date by a bird expert or by checking against sources of pre-recorded bird calls (see Appendix 6). At the time of writing this toolkit module, the availability of electronic devices and bird recordings was rapidly increasing. It is now also becoming easier to take pre-recorded bird calls into the field on compact e-devices. However great caution should be exercised if playing these call recordings audibly in the field as this could disrupt the behavior of the birds at the site, and affect survey results.

Survey time and conditions

Surveys should be conducted in either the morning or afternoon, avoiding the midday period when birds are inactive, especially in summer. The potential morning survey time extends from half an hour after sunrise (to avoid the dawn chorus) until bird activity wanes in the hotter part of the day (often around 10:00am in summer, 11:00am in winter in northeastern Australia). The afternoon survey time begins when bird activity picks up (often from about 4:00pm in summer, 3:00pm in winter) until one hour before sunset. Surveys should be restricted to days when the weather is fairly fine, with no more than a light breeze or drizzle as wind and rain may substantially depress bird activity. If a survey is interrupted briefly by rain, stop and then continue on afterwards and finish the observation, noting what happened in the ‘comments’ section of the data sheet. It will be necessary to exercise judgement, informed by local knowledge of bird activity patterns, over whether the conditions are suitable for surveying.

Surveying and recording the birds

The data sheet ‘proforma’ (Figure 7.2 and pages 62-63, this toolkit) is designed to be largely self-explanatory. Fill in the details at the top of the sheet before beginning the survey to ensure that this important information is not forgotten. This process also gives a few moments for birds to settle and the observer to get oriented before the timed observation period begins. Weather observations refer to the average conditions during the survey (note if variable in the notes section).

The basic method is a thirty-minute bird count in a site 30 m x 100 m. If the same transect is used as for vegetation monitoring, the 30 m x 100 m area consists of two end to end sections, each fifty metres long, that correspond to Plots 1 and 2 on the field data sheet and spreadsheet (but with the bird survey area being ten metres wider than the vegetation survey area). The observer progresses slowly along the transect, meandering a little from one side to another to avoid dense vegetation and to get the best lines of sight for the birds, occasionally stopping quietly and listening for calls (also recording birds behind the direction of progress if they are considered new birds). It is the nature of bird surveying that the amount of time spent at any particular point along a transect is dictated by bird activity; however it is important that this effort is balanced against the need to cover the whole plot area during the allotted survey time. Spend fifteen minutes surveying each 30 m x 50 m plot.

Each row on the data sheet is a 'record'. A record is a group of individuals of the same species that are judged to be 'together' (i.e. socially-coordinated). This may be a pair or a flock or some other form of grouping. Sometimes the other group members are not detected (or not present on the site) until after the first was seen – in this case adjust the number of individuals. If an independent individual or group of the same species is detected later in the survey, this new record is written on a separate row. This may involve some judgement concerning whether the individuals were likely to be different ones (if not, don't record them twice). If a record is based on sound alone, you still must be reasonably confident that the bird(s) really were in the transect area and not just somewhere nearby. If you see evidence of breeding (such as an identifiable nest) make a note in the notes section, and also in the comments column if related to the activity of a bird recorded during the survey (e.g. 'seen attending nest').

Record 'off-transect' birds in the 'off-plot' column. 'Off-transect' birds are those inside the transect area but only recorded before or after the actual thirty-minute survey, or those not within the transect area but judged to be within the patch of vegetation in which the transect is located. This provides further information about the species of birds using the habitat. It is very important that only birds observed within the same habitat patch (e.g. planting of similar age) are recorded in this column and entered in the worksheet, as they will be counted in the species list for that site.

If a bird cannot be positively identified to species, record it to the finest known taxonomic level (e.g. as 'gerygone sp.' or 'scrubwren-Atherton or large-billed', or 'large raptor'), and make further notes in the comments column. If the bird was heard on the site but you were unsure of the call, record the species as 'unidentified' and make a note of the type of call. It is possible that after further surveys (or through discussions, etc.) you may later figure out what the call was. If you are using the Excel worksheet that accompanies the toolkit, use the code '999' for unidentified birds that are definitely a different species from anything else recorded and use the code 'ZZZ' to record unidentified birds that could belong to a species previously recorded during this or other visits to the site.

Recording useful environmental information

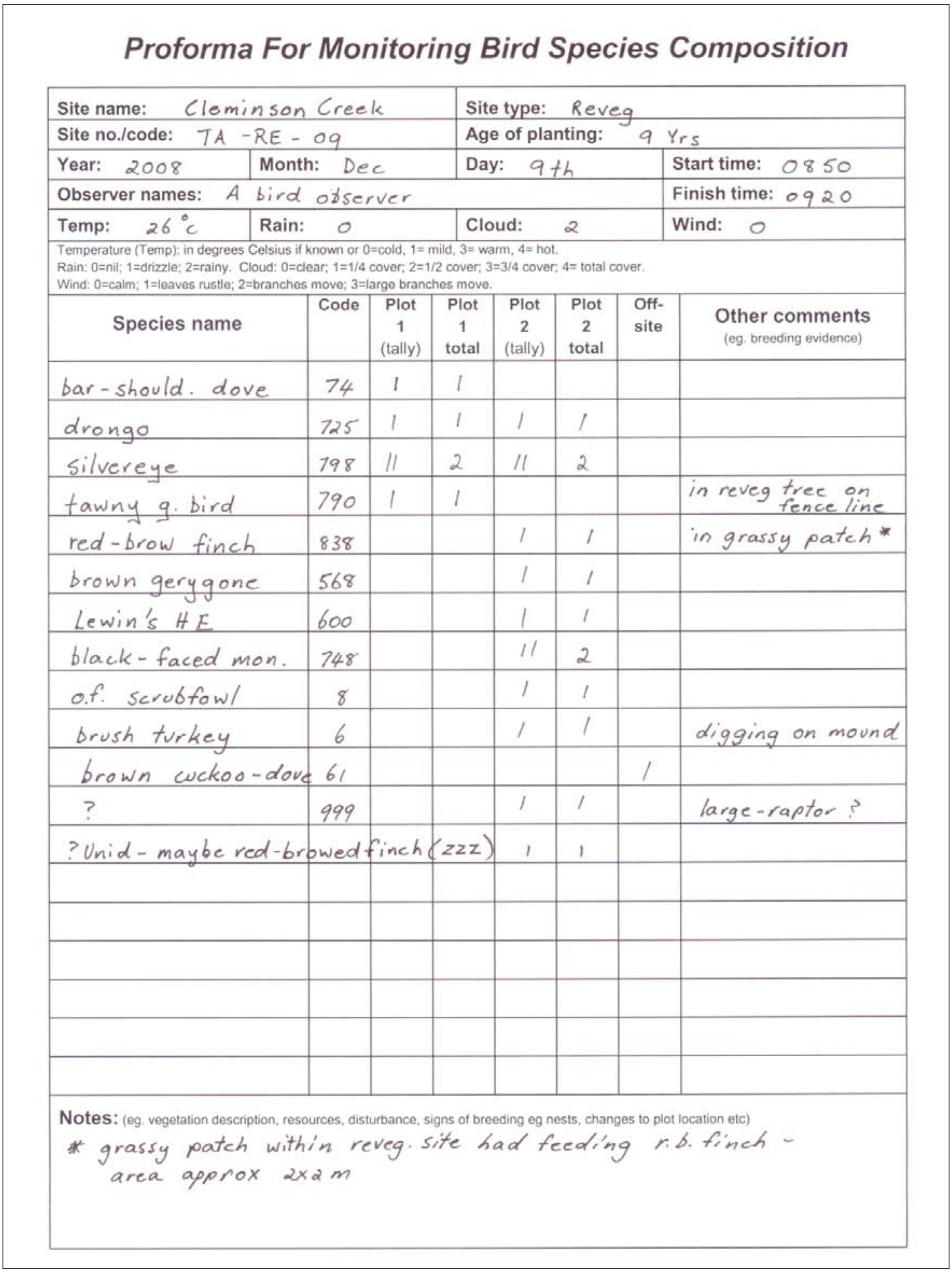
In the notes section of the data sheet, record any environmental information you think may be useful. For example, record resources in the transect or nearby that may be important for birds such as fruit, nectar, water, and tree hollows. Also make a note of any conditions that may limit survey effectiveness such as wind, dense vegetation or disturbance. Make a simple description of the vegetation cover in revegetated sites (e.g. grass still present in gaps, canopy closed over majority of site), especially if bird monitoring is unlikely to be coincident with vegetation monitoring.

Repeat surveys

The abundance and detectability of birds varies seasonally, and migratory species may disappear entirely in some seasons. Short-term movements can also mean that resident birds happen to be outside of the survey transect on a survey day. Therefore, repeat surveys at a site within a year are essential to measure the diversity of birds using the site. Based on our experience using this and similar methods to survey rainforest birds (see Appendix 7) we recommend that four to six surveys be conducted annually to obtain an adequate picture of the birds using the site in any given year.

Aim for at least four survey visits as fewer visits than this are likely to inadequately represent the bird diversity and species composition at the site. Four surveys provides for a reasonable compromise between data sufficiency and time expenditure, but five or six surveys will provide more reliable data (Appendix 7 provides some further justification for this recommendation). The Microsoft Excel workbook that accompanies this module ('Monitoring toolkit bird species composition.xls') will not calculate correctly unless data from at least four survey visits are entered in the worksheets.

Whatever the number of surveys, comparisons between years require the number of repeats to be the same in different years, so it is a good idea to start with the number of surveys that can be realistically sustained.



Proforma For Monitoring Bird Species Composition

Site name: Creek Cleminson Creek		Site type: Reveg	
Site no./code: TA -RE - 09		Age of planting: 9 Yrs	
Year: 2008	Month: Dec	Day: 9th	Start time: 0850
Observer names: A bird observer			Finish time: 0920
Temp: 26 °c	Rain: 0	Cloud: 2	Wind: 0

Temperature (Temp): in degrees Celsius if known or 0=cold, 1= mild, 3= warm, 4= hot.
Rain: 0=nil; 1=drizzle; 2=rainy. Cloud: 0=clear; 1=1/4 cover; 2=1/2 cover; 3=3/4 cover; 4= total cover.
Wind: 0=calm; 1=leaves rustle; 2=branches move; 3=large branches move.

Species name	Code	Plot 1 (tally)	Plot 1 total	Plot 2 (tally)	Plot 2 total	Off-site	Other comments (eg. breeding evidence)
bar-should. dove	74	I	1				
drongo	725	I	1	I	1		
silvereye	798	II	2	II	2		
tawny g. bird	790	I	1				in reveg tree on fence line
red-brow finch	838			I	1		in grassy patch *
brown gerygone	568			I	1		
Lewin's HE	600			I	1		
black-faced mon.	748			II	2		
o.f. scrubfowl	8			I	1		
brush turkey	6			I	1		digging on mound
brown cuckoo-dove	61					1	
?	999			I	1		large-raptor ?
? Unid - maybe red-browed finch (zzz)				I	1		

Notes: (eg. vegetation description, resources, disturbance, signs of breeding eg nests, changes to plot location etc)
* grassy patch within reveg. site had feeding r.b. finch - area approx 2x2 m

Figure 7.2. Sample of a completed field data sheet for monitoring bird species composition.

Proforma for Monitoring Bird Species Composition

Site name:		**Site type:**	
Site no./code:		**Age of planting:**	
Year:	**Month:**	**Day:**	**Start time:**
Observer names:			**Finish time:**
Temp:	**Rain:**	**Cloud:**	**Wind:**

Temperature:	(Temp) In degrees Celsius if known, or 0 = cold, 1 = mild, 3 = warm, 4 = hot.
Rain:	0 = nil; 1 = drizzle; 2 = rainy.
Cloud:	0 = clear; 1 = ¼ cover; 2 = ½ cover; 3 = ¾ cover; 4 = total cover.
Wind:	0 = calm; 1 = leaves rustle; 2 = branches move; 3 = large branches move.

Species name	**Code**	**Plot 1** (tally)	**Plot 1 total**	**Plot 2** (tally)	**Plot 2 total**	**Off-site**	**Other comments** (e.g. breeding evidence)

Proforma for Monitoring Bird Species Composition

Species name	**Code**	**Plot 1** (tally)	**Plot 1 total**	**Plot 2** (tally)	**Plot 2 total**	**Off-site**	**Other comments** (e.g. breeding evidence)

Notes (e.g. vegetation description, resources, disturbance,
signs of breeding such as nests, changes to plot location, etc.):

Module 8: Data Management, Analysis and Evaluation

We have designed a series of Excel workbooks to facilitate the storage and analysis of data collected using the protocols presented in this toolkit (Table 8.1), each available for download from the Reef and Rainforest Research Centre website (visit http://www.rrrc.org.au/ and follow links to Publications webpage) and Griffith University website (visit http://www.griffith.edu.au/environment-planning-architecture/environmental-futures-centre/publications).

Table 8.1. List of Microsoft Excel workbooks written to support use of this toolkit.

File name	Details
Monitoring toolkit forest structure.xls	Contains spreadsheets to store, analyse and graph data from repeated surveys of forest structure at a revegetated site. Calculates structural attributes listed in Table 8.2 and estimates carbon sequestration. If data are available for reference sites, will compare trends in revegetated site with mean and range of values in reference sites.
Monitoring toolkit floristic composition.xls	Contains spreadsheets to store and analyse data from surveys of floristic composition at a revegetated site. Facilitates compilation of attributes listed in Table 8.3. If wood density values are available, will calculate carbon sequestration in trees and stand-level mean wood density.
Monitoring toolkit plant attributes.xls	Contains data on life-history attributes of plants (e.g. life form, successional stage, fruit type and dispersal vectors) to facilitate analysis of floristic data.
Monitoring toolkit wood density.xls	Contains data on the wood density of rainforest tree species and some eucalypts, at species, genus and family levels, to facilitate estimation of carbon sequestration.
Monitoring toolkit bird species composition.xls	Contains spreadsheets to store, analyse and graph data from repeated bird surveys at a revegetated site and pasture and forest reference sites. If data are available for reference sites, will compare trends in species richness of grassland and rainforest-associated birds, and of seed dispersers, through time.
Monitoring toolkit bird species composition (demo).xls	This is a demonstration copy of the workbook 'Monitoring toolkit bird species composition.xls'. An example is provided to demonstrate results generated by entering data from two pasture and two rainforest reference sites and two years of monitoring a revegetation site in the Wet Tropics.

Monitoring forest structure

We have developed an Excel workbook 'Monitoring toolkit forest structure.xls' to store, analyse and summarise data on forest structure. The workbook includes spreadsheets to store data from a baseline survey and up to eight monitoring surveys of a revegetated site; as well as worksheets to record data from surveys of up to five forest reference sites. The data entry worksheets are in a similar format to the survey proformas.

Each worksheet calculates the values of structural attributes from the data entered into it, using the formulae listed in Table 8.2. Note that some of the attributes can only be calculated if data are available for forest reference sites (e.g. the 'ground cover index' compares the similarity of ground cover in the revegetated site to forest reference sites).

From these data, the workbook automatically graphs trends in attributes at a revegetated site over time, and compares these with the mean and range of the values observed in forest reference sites, if surveyed (Figure 8.1). The workbook also estimates carbon sequestration in above-ground biomass.

Note, while the workbook is intended to meet the needs of most users wishing to monitor the progress of revegetated sites, there may be situations where formal statistical analyses of monitoring data are required (e.g. where there are contractual requirements to restore sites to a particular condition). We presume that practitioners needing to conduct such analyses will seek advice from professional ecologists early in the life of a project.

Enter data from field proforma into cells in tables below			Information required for estimating carbon
Site name			Stand-level mean wood density (g/ cm^3)
Age of revegetation/ on-ground works (yrs)			Climate zone: 'moist' = 1; 'wet' = 2
Assessed by:			Default value for wood density is for rainfores
Date of assessment:			Default climate is 'moist' (defined as less than
			Wet climate >3500 mm rainfall p.a. & only sh

Ground cover	Plot 1: quadrats at:			Plot 2: quadrats at:		
Enter % cover for cover types present	5 m	25 m	45 m	5 m	25 m	45 m
a) Vegetation within 1m of ground						
Grass and sedges						
Herbs = soft-stemmed plants						
Ferns						
Vines & scramblers						
Trees, shrubs, seedlings						
Moss & liverworts & lichens						
b) **Leaf litter** and fine woody debris <10 cm diam						
c) **Coarse woody debris** >10 cm diam						
d) Rock						
e) Soil						
f) **Other** inc. tree trunks, roots						
TOTAL (note: must add up to 100%)	0	0	0	0	0	0

Canopy (foliage) cover	Plot 1: quadrats at:			Plot 2: quadrats at:		
Enter % cover.	5 m	25 m	45 m	5 m	25 m	45 m
Visual estimate						
Calculated from photo						

Canopy height	Plot 1: quadrats at:			Plot 2: quadrats at:		
Enter height in metres	5 m	25 m	45 m	5 m	25 m	45 m
Canopy height (m)						

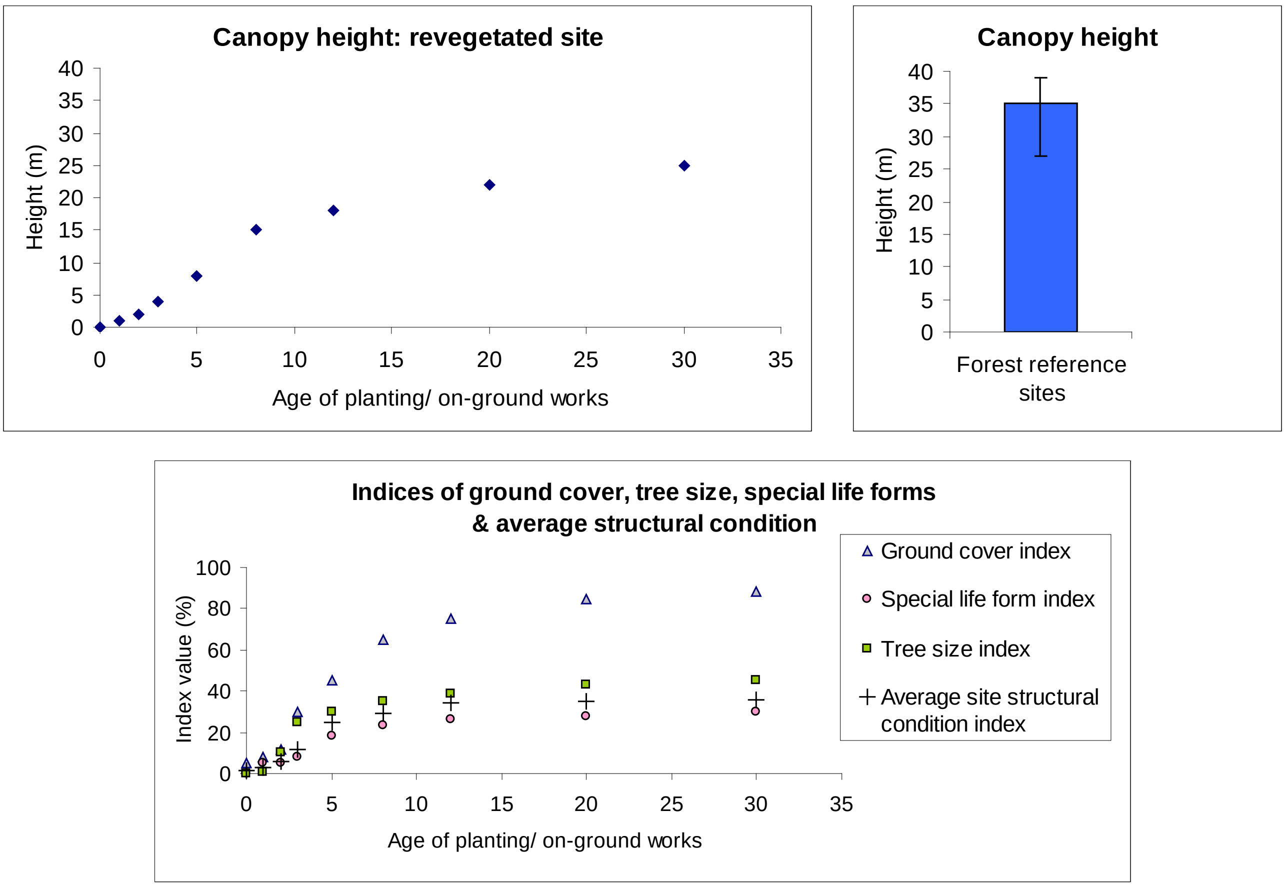


Figure 8.1. Examples from the workbook designed for forest structure data ('Monitoring toolkit forest structure.xls'). (*Top*) Part of data entry worksheet; (*Centre*) Graph of trends in a revegetated site compared with values in reference sites; (Bottom) Graph of trends in structural indices in a revegetated site (see Table 8.2 for definitions of these indices).

Table 8.2. Derivation of forest structural attributes from data collected using this toolkit.

Attribute	Derivation
Canopy cover	Average of cover estimates.
Canopy height	Average of height estimates.
Tree density	Number of tree stems per ha, calculated for each dbh class and for all tree stems.
Tree size (dbh) diversity	An index of the size-class distribution of trees, comparable across sites, correlated with the richness of birds and other fauna (McElhinney *et al.* 2005; see also Table 4.1). Values are higher when distributions are more evenly distributed across more size classes. Calculated as Shannon (H) index of proportion of tree & shrubs in each dbh class: $H = -\Sigma\, p_i * \ln(p_i)$, where p_i is the proportion of stems in the i^{th} size class.
Number of tree strata present	Number of tree size classes represented by at least one stem. Size classes are: <2.5 cm, 2.5-5 cm, 5-10 cm, 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, 50-75 cm, 75-100 cm, >100 cm (i.e. maximum value = 10).
Basal area trees	Cross-sectional area of trees, calculated from dbh classes: BA (m^2 per ha) = $\Sigma\, n_i\, \pi\, (dbh_i)^2/40000$, where n_i is the number of stems in the i^{th} size class/ ha, and dbh_i is the notional mean diameter (cm) of the i^{th} size class (= midpoint of class – 5% of class range; from Kanowski *et al.* 2008d). Calculated for all trees and remnant trees
Basal area stags	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 per ha) = $(\pi^2 / 8\, L)\ \Sigma\, n_i d_i^2$ 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 (= midpoint of class, – 5% of class range, see Basal area trees). Calculated for fine (2.5 – 10 cm diameter), coarse (>10 cm diameter) and total woody debris.
Ground cover	Average of cover estimates for each category.
Special life form frequency	The proportion of quadrats where each life form was recorded (range 0-1). If recorded on site but not on quadrats, a life forms is given an arbitrary value of 0.1
Number life forms	The number of special life forms recorded at a site (maximum value = 22).
Ground cover index*	The overall similarity of ground cover in revegetated sites relative to forest reference sites. Cover types are weighted by their average values in reference sites. The index does not include rock or 'other' cover which are treated as 'noise'. Index = $\Sigma\, p_i * u_i$, where p_i is the value of the i^{th} ground cover at a site, relative to its mean value in forest reference site(s), and u_i is the mean % cover contributed by the i^{th} ground cover in forest reference site(s). p_i is capped at 1.
Special life form index*	The overall similarity of the occurrence of special life forms in revegetated sites relative to forest reference site(s). Life forms recorded in revegetated sites but not reference sites neither add to, nor detract from, the index score. Index = $\Sigma\, p_i /n*100$, where p_i is the frequency of the i^{th} life form, relative to its mean frequency in forest reference site(s), and n is the number of life forms encountered in forest reference site(s). p_i is capped at 1.
Tree size index*	A measure of the overall similarity of the abundance of trees and shrubs in each dbh class relative to forest reference site(s). Index = average (p_i)*100, where p_i is the abundance of the *i* th size class, as a proportion of its average abundance in forest reference site(s). Note: p_i is capped at 1: i.e. the value of the index increases as stem density in a dbh class increases, until it is equivalent to or greater than the average value of reference sites.
Average site structural condition index*	A measure of the average development of structural attributes in a revegetated site, relative to forest reference site(s). E.g. a score of 40% means that, on average, the value of selected attributes at a site were at least 40% of values in reference sites. Attributes are: canopy cover, canopy height, total tree density, tree basal area, stag basal area, tree size diversity, woody debris, ground cover index, special life form index, tree size index. Index = average p_i *100, where p_i is the value of the i^{th} attribute, relative to its mean value in forest reference site(s). Note: p_i is capped at 1.

* Note: these indices compare revegetated sites with reference sites, and are only calculated if data are available for one or more forest reference sites. All indices range from 0-100%.

Monitoring floristic composition

We have developed a Microsoft Excel workbook (‘Monitoring toolkit floristic composition.xls’) to provide a template for storing and analysing data from floristic surveys. When compared with data from forest reference sites, this information can be used to determine how closely revegetated sites resemble reference sites in plant species composition and to identify the species that are ‘missing’ from revegetated sites.

Analyses of floristic composition can be especially informative when combined with data on plant life-history attributes (such as life form, successional stage and dispersal vectors: Table 8.3). For example, several studies have found that plants with small, fleshy fruits dominate recruitment in revegetated sites (Tucker and Murphy 1997; Neilan *et al.* 2006). Consequently, practitioners may need to deliberately add wind-dispersed and large-seeded plants to revegetated sites, if those sites are to approach target conditions (Tucker *et al.* 2004). A useful way of summarising these data would be in terms of the number, abundance or proportion of species possessing each attribute (e.g. the number of native *versus* exotic species; the abundance of early *versus* later successional species: e.g. Tucker and Murphy 1997; White *et al.* 2004; Neilan *et al.* 2006; Kanowski *et al.* 2008a). We have compiled a table of plant attributes (‘Monitoring toolkit plant attributes.xls’) to assist these analyses.

Due to the complexity of floristics data, we have not attempted to design an automated spreadsheet to analyse data from repeated floristics surveys. We presume that practitioners wishing to conduct such analyses will engage a professional ecologist for assistance.

Table 8.3. Suggested list of attributes for plant species recorded in floristic surveys. The categories used for each attribute may vary with the purpose of the monitoring exercise: e.g. for projects aiming to provide habitat for Cassowaries, classifying plants by whether they are eaten by Cassowaries would be useful; for projects aiming to restore biodiversity, a more general categorisation may suffice.

Attribute	Definition and proposed categories
Origin	Biogeographical origin of plant species: e.g. Local provenance / from Region but not local / from Australia but not region / Exotic
Life form	e.g. Tree / Shrub / Vine / Epiphyte / Hemi-epiphyte / Palm / Cycad / Fern / Herb / Grass / Cryptogram
Successional stage	Widely used categories are: Pioneer (light-demanding) / Intermediate (gap-demanding) / Mature phase (shade tolerant). Some people use two categories (pioneer / mature), others four (pioneer / early secondary / late secondary / mature). The categories are defined by a suite of traits (growth rate, shade tolerance, persistence of seeds) which tend to be associated with species in particular stages of succession following disturbance.
Fruit type	Simple categories are: Fleshy (providing a food reward for dispersers) / ‘Dry’
Main dispersal vectors	Simple categories are: Vertebrate / Invertebrate / Wind / Water. These categories are not always exclusive. They could be further subdivided (e.g. the vertebrate category could be subdivided as: bird, bat, non-flying mammal, Cassowary)
Diaspore size	A diaspore is the effective dispersal unit of a plant (e.g. the fruit for drupes, the arillate seed for capsular fruit, or the individual seeds for soft fruits such as figs). Diaspore size is the smallest dimension of the diaspore, i.e. the dimension that constrains consumption by typical frugivores. A useful set of categories are: Small (< 10 mm) / Medium (10-20 mm) / Large (>20 mm) (see Moran *et al.* 2004). Most vertebrates can disperse small seeds, many specialist frugivores can disperse medium seeds, and few flying vertebrates can disperse large diaspores.
Wood density	‘Basic density’: i.e. oven-dry weight of wood divided by the green volume (see Table 6.1). Necessary to estimate carbon sequestration (Module 6).

Monitoring carbon sequestration

In Module 6, we suggested two approaches for estimating carbon sequestration: Method 1, based on a survey of forest structure; and Method 2, based on a floristics survey, with additional data on woody debris. Data obtained from these surveys are analysed as follows.

Method 1: The Excel workbook we have developed to analyse data from a survey of forest structure ('Monitoring toolkit forest structure.xls') will automatically estimate carbon sequestration at a site (in tonnes per ha), using the formulae presented in Module 6. Note that the method relies on a robust estimate of stand-level mean wood density (see Tables 6.2 and 6.3). This value needs to be entered in the appropriate cell in the relevant spreadsheet.

Method 2: The Excel workbook we have developed for floristic survey data ('Monitoring toolkit floristic composition.xls') will calculate carbon sequestration for live trees recorded at a site (in tonnes per ha), using the formulae presented in Module 6. Specific wood density data need to be provided in the appropriate field for each species recorded. These data should be used at the finest taxonomic level available: i.e. the species level, if possible; if not, then genus, or family; or failing that, the stand-level mean. Density data for selected species are presented in Table 6.1, additional species and mean density values for genera and families have been compiled in the workbook ('Monitoring toolkit wood density.xls'). The workbook will summarise the total carbon sequestered in live trees in the surveyed plots, and calculate a stand-level mean wood density value.

To calculate the additional carbon sequestered in stags and woody debris, enter the relevant survey data into the Excel workbook designed for data on forest structure ('Monitoring toolkit forest structure.xls'), along with the value for stand-level mean wood density calculated from the floristics data. The results of these analyses then need to be entered into the relevant cells in the summary page of the floristics data workbook, to calculate the total carbon sequestered in AGB (in tonnes per ha) at a site.

For both methods, the total carbon sequestered in AGB at a site is calculated by multiplying the total carbon sequestered in AGB (in tonnes per ha) by the area of the site, in hectares. The area of the site can be determined from the assessment of site condition (Module 3).

Removing remnant trees from estimates of carbon sequestration

Some revegetated sites include remnant trees. While remnant trees contribute to the structure and composition of a site, it may be desirable to exclude these trees from some estimates of the carbon sequestered by a revegetation project.

The Excel workbook designed for data on forest structure ('Monitoring toolkit forest structure.xls') includes a table to record the size class distribution of all trees (including remnants), and another to record the size class distribution of remnant trees only. If data are entered in the latter table, the workbook will calculate carbon sequestration with, and without, the remnant trees.

The Excel workbook designed for data on floristic composition ('Monitoring toolkit floristic composition.xls') includes a worksheet to record all trees (including remnants), and another to record remnant trees. If data are entered in the latter worksheet, the workbook will calculate carbon sequestration with, and without, the remnant trees.

Note in both cases, it is important to also record data on remnant trees in the table or worksheet where all trees are recorded, so that the remnant trees can be included in analyses of the overall structure and composition of sites.

Monitoring bird species composition

We have developed a Microsoft Excel workbook ('Monitoring toolkit bird species composition.xls') to provide a template for storing and analysing data from bird surveys. When data from revegetated sites are compared through time and with data from forest reference sites, this information can be used to determine how bird communities are changing and how closely revegetated sites resemble forest sites in bird species composition.

The workbook has been written in Microsoft Excel 2000. It is designed to store and analyse data from a baseline survey and up to ten years of surveys at a single revegetated site. If you are monitoring more than one revegetated site, use a different workbook for each site. The workbook can also store data from bird surveys in up to four forest and four pasture (or whatever habitat represents the pre-restoration environment) reference sites, to enable evaluation of the performance of the revegetation project. If reference sites are surveyed, the workbook will automatically compare values for bird species attributes in revegetated sites with values for reference sites. If only the revegetated site is surveyed the workbook will simply calculate its progress across different years.

Using the bird species composition workbook

This workbook consists of a series of different spreadsheets (worksheets). Some of these worksheets are designed to receive the survey data (as recorded in the field data sheet) while others have been set up to calculate and display summaries of the survey results. Each worksheet has a pre-set name which is referenced to in the descriptions below. Note that these instructions assume that you have a basic familiarity with Microsoft Excel. If you have more advanced knowledge of Excel you will find that with a little trial and error you can customise these spreadsheets to further suit your own monitoring needs.

Which worksheet should I start with?

- If you are entering **forest or pasture reference site data**, use the appropriate reference site worksheet.
- If you have **baseline data** for your revegetation site, enter it in the Revegetation Site - Baseline worksheet.
- For the **current year of monitoring**, enter data in the <u>Revegetation Site – Current Yr</u> worksheet. If you also have additional data previously collected in an appropriate format from earlier years of monitoring, enter these data in the appropriate <u>Revegetation Site – Yr *x*</u> worksheet(s) (where *x* = 1 to 10) which correspond with the number of years for which you have been monitoring.

Important points to note:

- Before you begin entering data, make a copy of the worksheet you are about to use so that you have a template saved as a back-up.
- **N.B. Do not delete or alter the name of any of the worksheets** – If you do so, the automatic calculations will no longer work properly because formulas in the report are linked to them.

Where do I enter the data in a worksheet?

Once you have chosen the appropriate worksheet, transfer the data recorded on the field data sheets into the cells which are shaded grey in Sections A and B1 in the worksheet (see Figure 8.2).

Fill in Section A: General Information

In Section A you need to change ‘n’ in the cell next to ‘Region’ to ‘WT’ (Wet Tropics) or ‘ST’ (Sub-tropics) as appropriate in order for the automatic calculations to retrieve information on species (if this is not done the data can still be usefully entered but the ‘Report’ worksheet will not calculate properly). Transcribe the information for date of survey, start time, observer(s) and weather conditions from the field data sheets into the corresponding columns. Record the survey start time in 24 hour clock format, e.g. 4.30pm is entered as 16:30.

Fill in Section B1: Bird Data

In Section B1 enter a code for each species recorded at the site into the column headed ‘Species code (C&B 2008)’. Look up these codes in the Species Information worksheet; it would be useful to print these out before beginning to enter the data to help with the process of locating the right code number for each species. When a species code number is entered in Section B1, first the common name will be generated automatically in the column to its left, and species information will be generated automatically in Section B2: Calculations to its right (i.e. Family, scientific and common names, habitat grouping, and whether the species is a seed disperser or not).

For each species recorded at the site in that year, enter the total number of individuals (added up across all the records for that species in each plot during each visit) in the columns to the right of the species code. These columns are headed ‘Visit 1 Plot 1’, etc. If a species was not recorded on a particular plot or visit, enter 0 (zero) in that column (do not leave as ‘n’). Enter off-site records in the off-site column, noting the visit in which the observation was made. The toolkit workbook also contains a Data Entry Demo worksheet. This is simply a copy of the basic worksheet in which sample data have been entered as an aid to understanding how the data entry and summary sections work.

What about unidentified or partially identified birds?

Enter the code ‘**999**’ for unidentified birds that are definitely a different species from anything else recorded. Enter the code ‘**ZZZ**’ to record unidentified birds that could belong to a species previously recorded during this or other visits to the site.

Observations with a 999 code are counted in the calculation of the number of species at the site, whereas those with a ZZZ code are not. As their habitat group and seed dispersal capabilities are unknown, the worksheet also generates a ZZ code in those columns.

The 999 and ZZZ codes can be entered in the species code column more than once if appropriate.

Important points to note

- Use only the Species codes (C&B 2008) and ignore all other codes in the Species Information worksheet.
- If less than four visits are entered, the worksheet will not perform calculations.
- Each bird species must be entered only once in Section B1.
- Do not enter data in cells used for calculations (Sections B2 and C).
- Retain ‘n’ in any cell where it occurs unless you are replacing it with information or data.

Section A: General information

Region:	WT	(WT or ST)								
Site name:	Cleminson Creek					Age (in years) at *end* of this completed year of surveys - change x to a number.				
Site no./code:	TA-RE-09		No. of visits this year:		4	Age of revegetation:				9 yrs
Notes:	easiest entry point is now by fifth fence post. Grassy patch within reveg. site is approx 2x2m.									

Visit No.	Year	Month	Day	Start time	Observer initials	Temp	Rain	Cloud	Wind	Other notes:
Visit 1:	2008	1	2	7:30	AB	24	0	3	0	brief drizzle stopped survey for five minutes
Visit 2:	2008	4	15	8:00	AB	21	0	2	1	
Visit 3:	2008	8	14	7:45	AB, AC	18	0	1	1	AC came along for training
Visit 4:	2008	12	9	8:50	AB	26	0	2	0	see Fig 7.2 of the Toolkit for model field data for this visit
Visit 5:										
Visit 6:										

Temperature (Temp) : in ^{0}C or 0=cold, 1= mild, 3= warm, 4= hot. Rain: 0=nil; 1=drizzle; 2=rainy. Cloud: 0=clear; 1=1/4 cover; 2=1/2 cover; 3=3/4 cover; 4= total cover.
Wind: 0=calm; 1=leaves rustle; 2=branches move; 3=large branches move.

Section B1: Bird data

enter species code only once for each species encountered and retain "n" in empty rows. In rows where a species is recorded, enter 0 for visits/plots when it is not observed.

Species name	Species code (2008)	Visit 1 Plot 1	Visit 1 Plot 2	Visit 2 Plot 1	Visit 2 Plot 2	Visit 3 Plot 1	Visit 3 Plot 2	Visit 4 Plot 1	Visit 4 Plot 2	Visit 5 Plot 1	Visit 5 Plot 2	Visit 6 Plot 1	Visit 6 Plot 2	Off-plot (note visit)	Other comments (eg breeding, note visit)
Bar-shouldered Dove	**74**	1	0	1	0	1	0	1	0	n	n	n	n		
Spangled Drongo	**725**	1	1	1	1	1	1	1	1	n	n	n	n		
Silvereye	**798**	2	2	2	2	2	2	2	2	n	n	n	n		
Tawny Grassbird	**790**	1	0	1	0	1	0	1	0	n	n	n	n		in reveg tree on fenceline (visit 4)
Red-browed Finch	**838**	0	1	0	1	0	1	0	1	n	n	n	n		in grassy patch
Brown Gerygone	**568**	0	1	0	1	0	1	0	1	n	n	n	n		
Lewin's Honeyeater	**600**	0	1	0	1	0	1	0	1	n	n	n	n		
Black-faced Monarch	**748**	0	2	0	2	0	2	0	2	n	n	n	n		
Orange-footed Scrubfowl	**8**	0	1	0	1	0	1	0	1	n	n	n	n		
Australian Brush-turkey	**6**	0	1	0	1	0	1	0	1	n	n	n	n		digging on mound (visit 4)
Brown Cuckoo-Dove	**61**	0	0	0	0	0	0	0	0	n	n	n	n	1(visit 4)	
Unident. & diff. from other birds	**999**	0	0	0	0	0	0	0	1	n	n	n	n		
Unident. but could be species recorded on site	**ZZZ**	0	0	0	0	0	0	0	1	n	n	n	n		
#N/A	**n**	n	n	n	n	n	n	n	n	n	n	n	n		

Figure 8.2. Example of data entry into Sections A and B1 of the Data Entry Demo worksheet contained in ‘Monitoring toolkit bird species composition.xls’.

What are all the worksheets for?

Field Data Sheet	This data sheet is ready to print and use for bird surveys.
Data Entry Demo	This worksheet contains data from the sample field data sheet as shown in Figure 8.2 of the toolkit to demonstrate data entry.
Forest Reference Sites 1-4	These worksheets are for data collected in forest reference sites. One to four different reference sites can be used. Four to six visits (or surveys) can be entered for each site.
Pasture Reference Sites 1-4	These worksheets are for data collected in pasture reference sites (assuming that pasture represents the pre-restoration habitat). One to four different reference sites can be used. Four to six visits (or surveys) can be entered for each site.
Revegetation Site – Baseline	Enter data from a baseline (pre-restoration) survey of the revegetated site (if conducted) into this worksheet. Four to six visits (or surveys) can be entered.
Revegetation Site – Current Yr	Enter data for the current year of survey at the revegetated site in this worksheet. When the current year's surveys are complete, copy Sections A and B1 from the Revegetation Site - Current Yr worksheet into the Revegetation Site - Yr *x* worksheet (where *x*=1 to 10) that corresponds with the number of years of monitoring you have completed. Also copy notes from Section D into the relevant Revegetation Site - Yr *x* worksheet. Once the report has been generated (see below) delete your data from the Revegetation Site - Current Yr worksheet ready for the next year's data entry.
Revegetation Site – Yr *x*	(where *x*=1 to 10): These worksheets are for long-term storage of data collected in the revegetated site up to and including the current year of monitoring. Enter data from completed years of monitoring into the appropriate sheet with the first year of monitoring going into Revegetation Site - Yr 1, as described above.
Report	**This worksheet automatically generates a report comparing numbers of rainforest (RF), grassland/wetland (GW) and seed disperser species in the revegetated site and reference sites.** Do not enter data in the report worksheet**.**

A copy of the Report may be printed direct from the worksheet onto an A4 page. **To save a permanent e-copy of the Report**, use the following procedure before deleting the year's data from the 'Revegetation Site – Current Yr' worksheet: (1) Open a new Excel workbook or Word document; (2) Copy the whole report from the 'Revegetation Site – Current Yr' worksheet; (3) Use 'paste special' to paste this as a picture into the new workbook or document; (4) Save the new workbook with a suitable name.

Species information:

This worksheet contains background information about species, and ecological information used to interpret the monitoring results in the Report, including their names, taxonomic status, habitat groupings and seed disperser classifications.

All Australian bird species are listed in this worksheet, however habitat groupings and seed disperser classification have been provided for only a subset of these species (the species most likely to occur in pasture, rainforest or restored rainforest sites in the Australian Wet Tropics and subtropics based on research findings by the Toolkit authors). The full species list is provided to accommodate the occurrence of uncategorised species on sites surveyed by users of this toolkit. If desired, users may add habitat groupings based on their own judgement for these additional species, by modifying the Species Information worksheet.

The rows in the Species Information worksheet have been sorted from top to bottom according to the numerical value of the Species code (C&B 2008) in column 1. **It is essential that this order is maintained**. If the species order is changed then the 'Lookup' functions for species names will no longer work properly; incorrect species names will appear in the data entry worksheets and the Report will be incorrect. Species codes used in this worksheet are derived from the order in which species are listed in Christidis and Boles (2008), and the 2008 common and scientific names are used. The first column of this worksheet shows the species codes to enter in the data entry worksheets. It is useful to refer to a hard copy printout of these codes when entering data.

Species code 08 and **Species code 94**: These worksheets list Australian bird species alphabetically with their Christidis and Boles (1994) common names and their Christidis and Boles (2008) and (1994) numbers respectively. This workbook uses the 2008 numbers. The 1994 numbers are supplied for further information only.

What does the Report information mean?

Bird species most likely to occur in rainforest landscapes of the Australian Wet Tropics and subtropics were classified into functional 'habitat' groups based on their use of uncleared vegetation types within these regions. Categories are based on independently-published descriptions (such as Crome *et al.* 1994 and Higgins and others 1996-2006; see also Catterall *et al.* 2004). If this toolkit is used in other regions, users will need to modify the Species Information worksheet accordingly (this requires some expertise in *Excel*).

- ***Rainforest-dependent* (RF)** species are largely confined to, or dependent on, rainforest.
- ***Mixed Forest* (MF)** species occur mainly in a wider range of forested habitats spanning both rainforest and the more open-canopied eucalypt forests and woodlands.
- ***Eucalypt Forest* (EF)** species are typically found in eucalypt forest or woodland, and only occasionally occur in denser forest (including rainforest), or more open habitats.
- ***Grassland/Wetland* (GW)** species occur mainly in grassland, wetland or water, although they may also occur within lightly-timbered open habitat, or be dependent on dense swampy vegetation; includes aerial feeding species.
- ***Non-native* (XX)** species are exotic species which have established free-living populations since European settlement.

The numbers of RF and GW species are used in the Report worksheet to provide information about progress in the bird community in the context of rainforest restoration: progress is indicated by increases in RF species and/or reductions in GW species. Other habitat groups (MF, EF, XX above) are not used in the Report.

The number of seed disperser species is also calculated in the Report worksheet to provide insight into the potential for rainforest seed to be dispersed into the site. Each bird species was categorised as either a seed-disperser or not, based on published information about feeding habits and diets. Species were considered to be seed-dispersers if they had been recorded eating fruits on a regular basis (even if fruits were not their main food source), as long as they were not seed 'crushers' (seed predators such as parrots which chew into seeds or some pigeons which grind seeds in their crops). Seeds may sometimes be dispersed by these crushers, and by many other species which eat fruit on rare occasions, but here we are only interested in identifying species that have a higher potential for seed dispersal (see Moran *et al*. 2004 and Moran & Catterall 2010 for further information).

There is a section in the data entry worksheet for each site, headed *Section C Bird Community Overview for this year* (see Figure 8.3), which shows the number of species and individuals of all birds, and the numbers of RF species, GW species and seed disperser species. The important data used for comparisons between sites and times are in the section headed 'on-plot records', in particular the numbers in the 'All visits total' row. In the right hand column (headed 'Total species' the numbers include all species recorded whether on or off plot, to provide an overview of how many bird species were recorded both in and near the transect and what proportion of these species are RF or GW birds, although this is not useful for quantitative comparisons.

Section C: Bird community overview for this year

Note that the information in the section below is generated automatically - do not enter data.

	On-plot records						Total species	
	No. of birds	No. of species	No. of RF species	No. of GW species	No. of seed disperser species	Seed disperser abundance	All species	12
Visit 1:	15	10	4	1	2	5	No. of RF species	5
Visit 2:	15	10	4	1	2	5		
Visit 3:	15	10	4	1	2	5		
Visit 4:	17	11	4	1	2	5	No. of GW species	1
Visit 5:	n	n	n	n	n	n		
Visit 6:	n	n	n	n	n	n		
All visits total:	**62**	**11**	**4**	**1**	**2**	**20**	No. of seed disperser species	2
All visits average:	**15.50**	**10.25**	**4.00**	**1.00**	**2.00**	**5.00**		

Figure 8.3. Example of results generated in the data worksheets by entering data into the 'Monitoring toolkit bird species composition' Excel spreadsheet.

The Report worksheet provides a comparison between the bird species composition for the current year of monitoring and previous years of monitoring at the revegetated site and reference sites (if reference data have been collected).

Figure 8.4 shows an example of a report generated from using the toolkit to store and analyse data for a ten year old revegetated site at Cleminson Creek in the Wet Tropics, with monitoring in 2008 and 2009 when the site was aged nine and ten years respectively; but with no baseline monitoring data or monitoring in earlier years.

Data were entered into the following worksheets*:*

- Forest Reference Site 1;
- Forest Reference Site 2;
- Pasture Reference Site 1;
- Pasture Reference Site 2;
- Revegetation Site – Current year,
- Revegetation Site – Yr 1; and
- Revegetation Site – Yr 2.

In this report (Figure 8.4), survey plots in pasture reference sites had on average two species of GW birds and no RF or seed disperser species. The forest reference plots had an average of 14.5 RF species and no GW birds. Forest plots also contained on average six species of birds with potential to disperse seeds (Figure 8.4). Results from the two years of monitoring at the revegetated site show that GW birds were recorded in 2008 but were absent in 2009 and both the number of RF species and seed disperser species increased.

As a revegetated site develops a vegetation structure and floristic composition with greater similarity to that of forest reference sites, it may be expected that the site's bird species composition would also progress towards that of intact forest (see Figure 7.1). The results so far from the monitoring in the Cleminson Creek example above suggest a trend towards the forest reference sites. However more monitoring over time would be needed to assess whether this trend continues. The increase in the number of species capable of dispersing seeds to and from the site also suggests that the site is increasing in potential for the regeneration of rainforest plant species, especially if there is nearby forest to act as a seed source.

REPORT **Cleminson Creek** **TA-RE-09** **June 28, 2010**

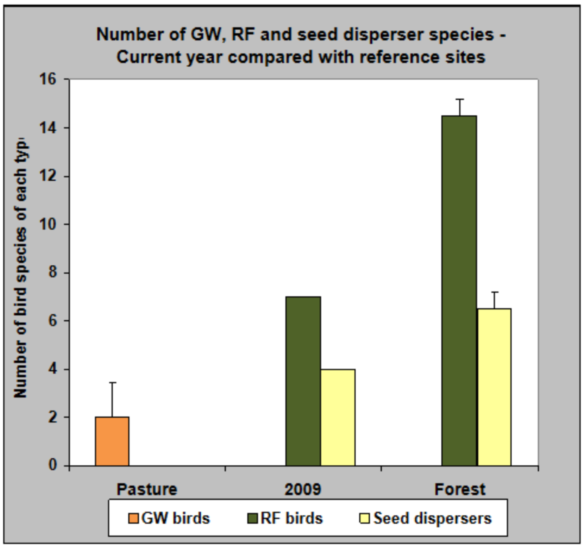
Number of GW, RF and seed disperser species - Current year compared with reference sites

Sites	Data used	GW birds	GW (Std Dev)	RF birds	RF (Std Dev)	Seed dispersers	Seed dispersers (Std Dev)
Pasture	*Average of site totals*	2.0	1.4	0.0	0.0	0.0	0.0
2009	*Current year's total*	0.0		7.0		4.0	
Forest	*Average of site totals*	0.0	0.0	14.5	0.7	6.5	0.7

In 2009 at ten years old, this revegetation site no longe had GW (grassland/wetland) species present and numbers of rainforest bird species and seed-dispersin species had increased compared to the previous year.

Number of GW, RF and seed disperser species - Compared with reference sites through time

Sites	Year	Reveg. age	Data used	GW birds	RF birds	Seed dispersers
Pasture			*Average of site totals*	2.0	0.0	0.0
Baseline			*Average of site totals*	n	n	n
Monit. Yr 1	2008	9 yrs	*Total for year*	1.0	4.0	2.0
Monit. Yr 2	2009	10 yrs	*Total for year*	0.0	7.0	4.0
Monit. Yr 3	x	x yrs	*Total for year*	n	n	n
Monit. Yr 4	x	x yrs	*Total for year*	n	n	n
Monit. Yr 5	x	x yrs	*Total for year*	n	n	n
Monit. Yr 6	x	x yrs	*Total for year*	n	n	n
Monit. Yr 7	x	x yrs	*Total for year*	n	n	n
Monit. Yr 8	x	x yrs	*Total for year*	n	n	n
Monit. Yr 9	x	x yrs	*Total for year*	n	n	n
Monit. Yr 10	x	x yrs	*Total for year*	n	n	n
Forest			*Average of site totals*	0.0	14.5	6.5



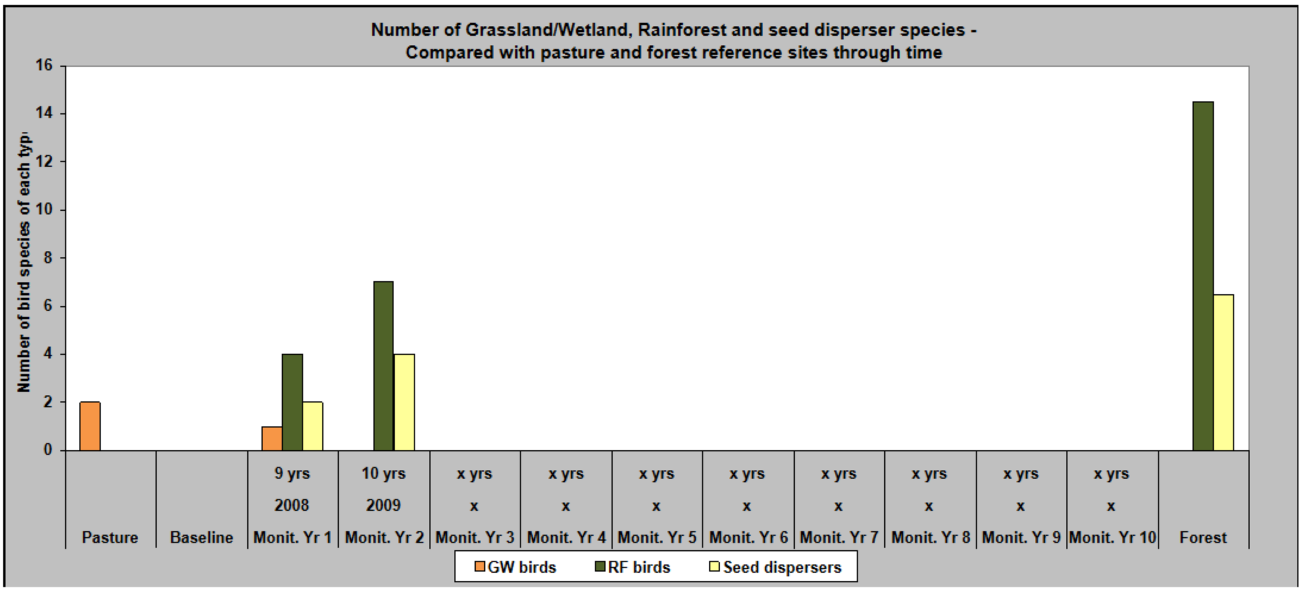


Figure 8.4. Example of report generated by entering data into the 'Monitoring toolkit bird species composition' Excel spreadsheet.

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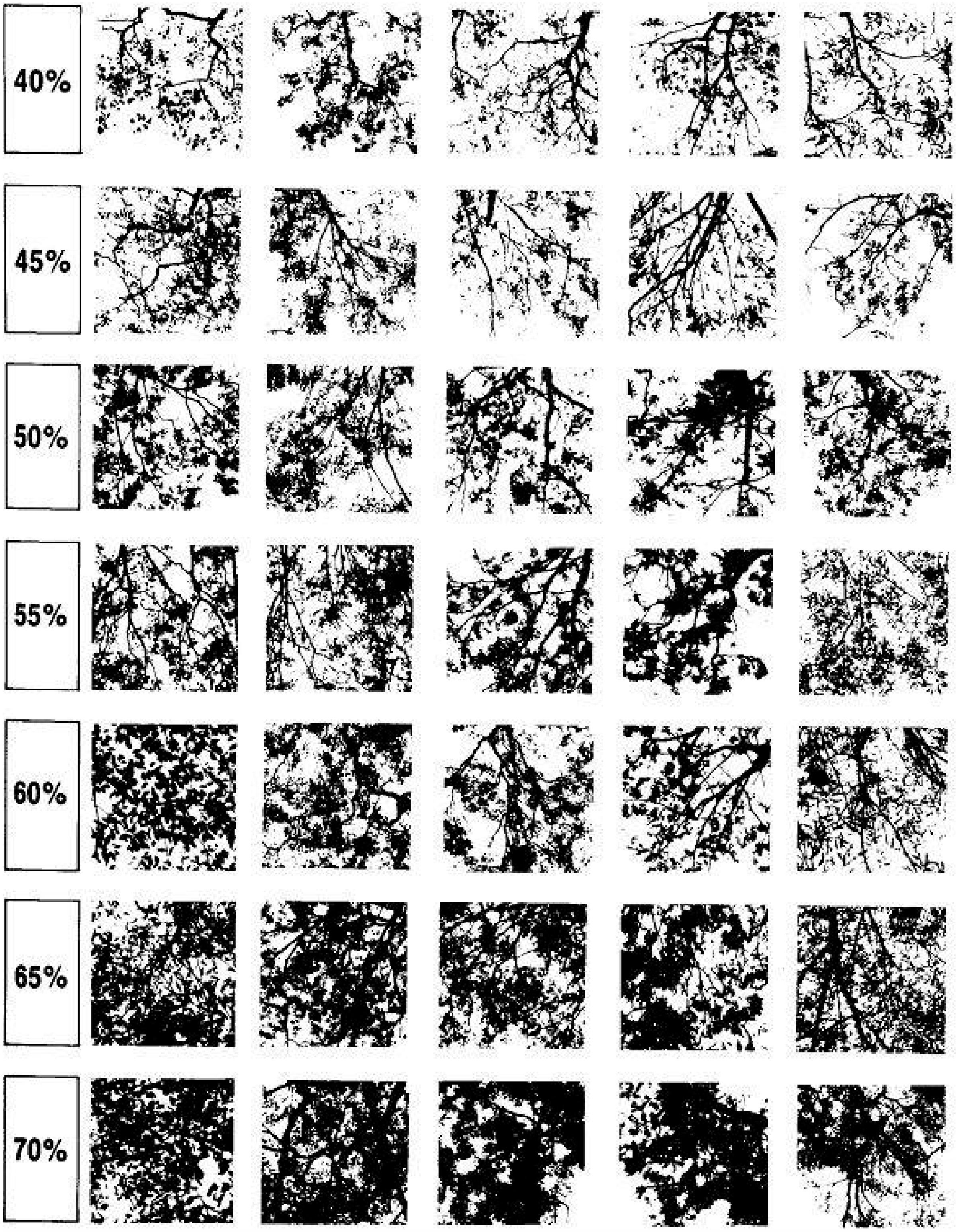
Appendix 1

Reference photographs of canopy cover



Source: Walker and Hopkins (1990). Note: canopy cover in rainforest may often exceed 70%.

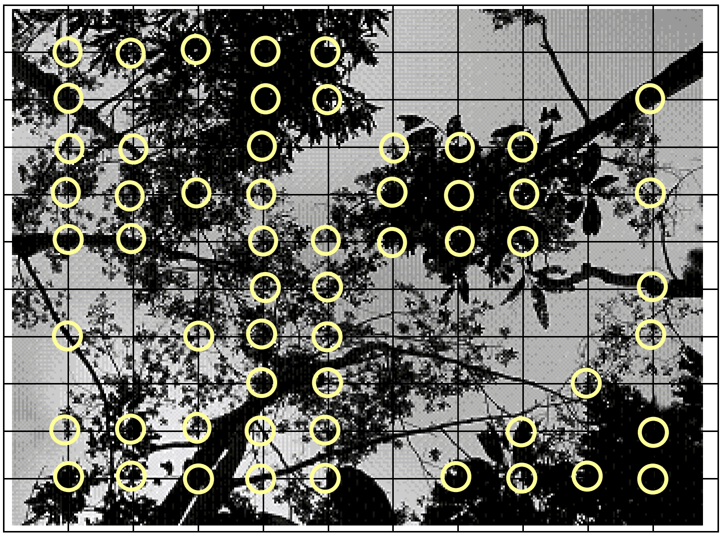
Appendix 2

Calculating canopy cover from digital photographs

Visual estimates of canopy cover can be very subjective. A more objective method uses photographs. This method has the 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 images imported into Microsoft Word. It is based on superimposing a 10x10 grid (the internal gridline intersections of an 11x11 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).

The method assumes you have some familiarity with manipulating images and tables in Microsoft Word.



Instructions

1. Open a new document in Microsoft Word.
2. Create an 11x11 table with closely spaced (e.g. 0.7 cm) columns and rows.
3. Insert the image of the canopy into the document.
4. Format the layout of the picture so that it sits behind the text.
5. Move the picture so that it is located just inside the top left edges of the table.
6. Resize the 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 (distribute columns and rows evenly within the table).
8. Count the number of grid intersections with vegetation to calculate the percentage of canopy cover (see example, above).
9. Alternatively, count intersections with the sky, and subtract from 100 to determine canopy cover.

To more accurately determine whether the grid intersects with vegetation or the sky, view the document at 200% zoom.

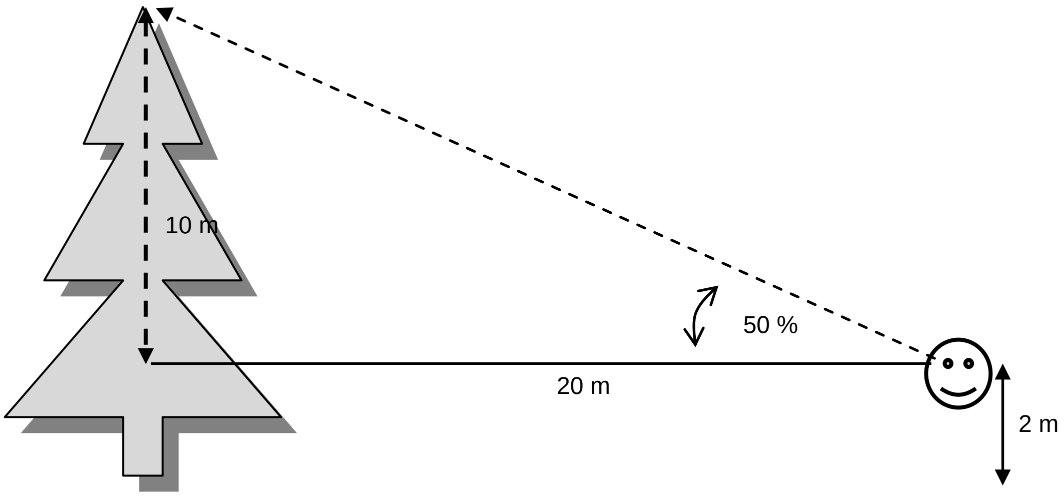
A similar method could be used to estimate canopy cover from photos taken with print film, if necessary, by using a 10 x 10 grid drawn on clear plastic.

Appendix 3

Estimating tree height

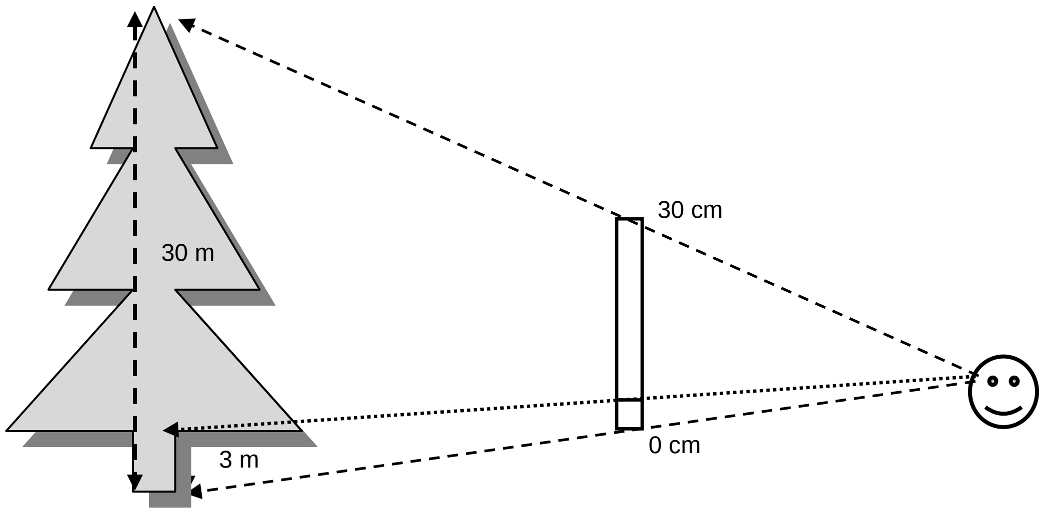
1. Using a clinometer

Stand on the same contour as the base of the tree, and measure the angle from the horizontal to the top of a tree with a clinometer. The value of this angle in percent (e.g. a 45° angle = 100% slope), multiplied by the horizontal distance from the observer to the tree, gives the height of the tree above the observer. In the example below, the top of the tree is 10 m above the observer (i.e. 50% of 20 m). Add the height of the observer above the base of the tree to get the total tree height. In the example below, the tree is 12 m high, i.e. 10 m + 2 m.



2. Using a stick

A stick or ruler is marked at a point 10% along its length: e.g. for a 30 cm ruler, at 3 cm. Holding the stick vertically at arm's length, walk away from the tree until the top and bottom of the stick line up with the top and bottom of the tree. (There is no need to stay on the same contour as the tree). Note the point on the tree which corresponds to the 10% mark on the stick (easier if you have a helper at the tree). Measure the height of this point above the base of the tree. The height of the tree is ten times this value. In the example, the 10% mark on the tree is 3 m above the base, so the tree is 30 m high (i.e. 10 x 3 m).



Appendix 4

Recording cyclone damage to trees

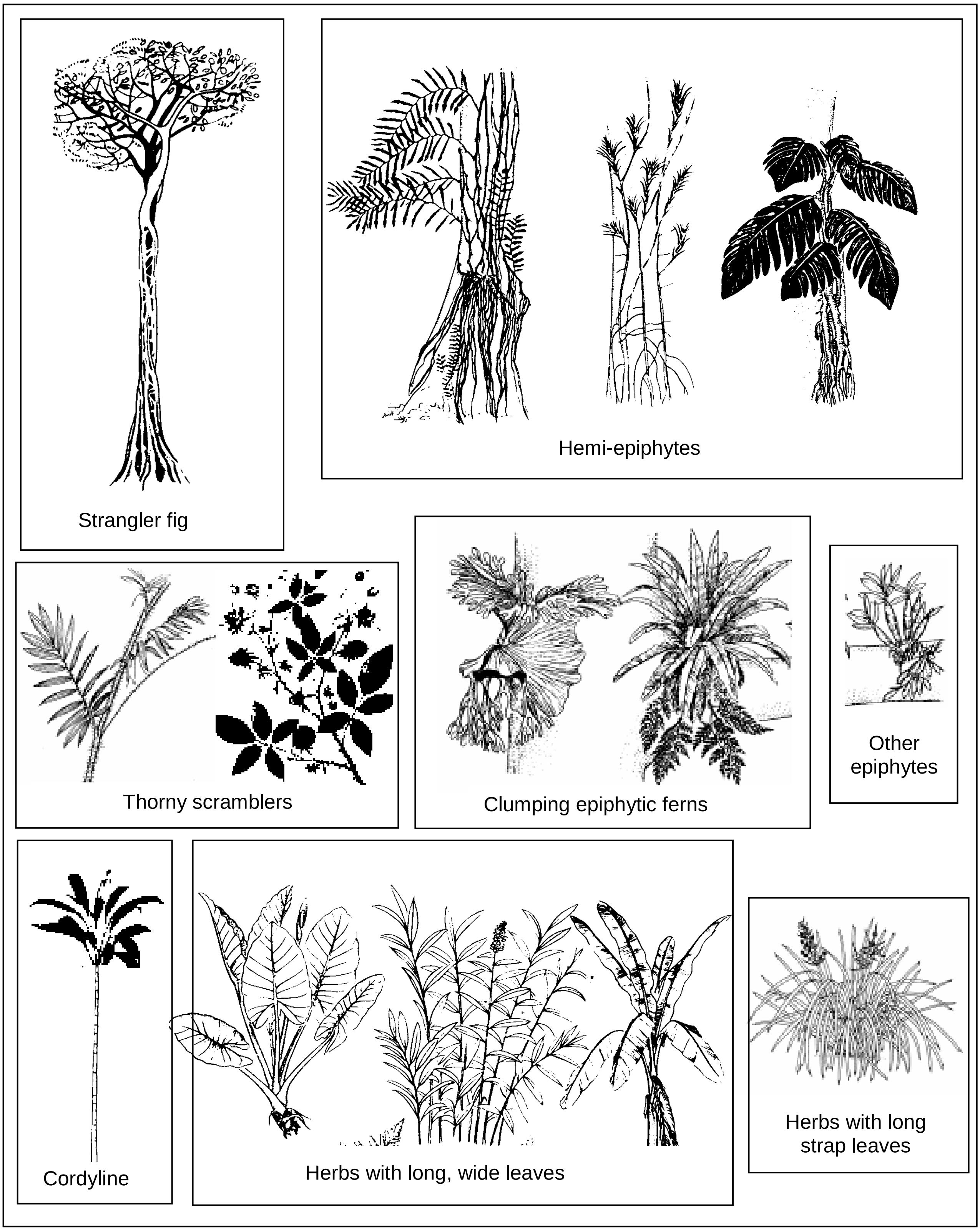
Optional: Proforma for recording CYCLONE / STORM DAMAGE to trees: Tally the number of **damaged** live trees by dbh class and damage class. 1 = defoliation, minor branches broken; 2 = larger branches broken; 3 = trunk snapped; 4 = tree uprooted. **Note:** minor damage may be difficult to assess after the event.

PLOT 1	**Trees, shrubs and saplings (>1 m high). Tally stems by damage class and dbh class (cm).**									
Damage class	<2.5 cm	2.5-5 cm	5-10 cm	10-20	20-30	30-40	40-50	50-75	75-100	>100
Class 1 defoliation, minor branches broken										
Class 2 larger branches broken										
Class 3 trunk snapped										
Class 4 tree uprooted										

PLOT 2	**Trees, shrubs and saplings (>1 m high). Tally damaged stems by dbh class (cm).**									
Damage class	<2.5 cm	2.5-5 cm	5-10 cm	10-20	20-30	30-40	40-50	50-75	75-100	>100
Class 1 defoliation, minor branches broken										
Class 2 larger branches broken										
Class 3 trunk snapped										
Class 4 tree uprooted										

Appendix 5

Reference illustrations of special life forms



Illustrations mostly from Webb *et al.* (1976).

Appendix 6

Supporting information for bird identification

Field Guides (books)

Morcombe, M. (2004) *Michael Morcombe's Pocket Field Guide to Australian Birds*. Complete Compact Edition. Steve Parish Publishing.

Pizzey, G and Knight, F. (2007) *The Field Guide to the Birds of Australia*. Eighth Edition. Harper Collins.

Simpson, K and Day, N. (2004) *Field Guide to the Birds of Australia*. Seventh Edition. Penguin.

Slater, P., Slater, P. and Slater, R. (2009) *The Slater Field Guide to Australian Birds*. Second edition. New Holland Publishing.

Sound Guides (CDs)

A Field Guide to Australian Birdsong. CD Series by Bird Observation & Conservation Australia (BOCA) (http://www.thebirdingshop.com/audio_visual_field_guide_to_australian_birdsong_cd.htm)

Australian Bird Calls: Subtropical East by David Stewart (http://www.naturesound.com.au/cd_subtropical_east.htm)

Australian Bird Calls: Tropical North-east by David Stewart (http://www.naturesound.com.au/cd_tropical_north_east.htm)

Australian Bird Call Series. Bird Calls of Far NE Queensland. Vol 3, CD1-3 by Fred van Gessel. Available by contacting: fvangessel@optusnet.com.au, Phone (+61) (2) 4343 1283.

Voices of Subtropical Rainforests by David Stewart (http://www.naturesound.com.au/cd_rainforests.htm)

Organisations

Birds Australia
For Regional Group contacts: http://www.birdsaustralia.com.au/

Bird Observation and Conservation Australia (BOCA)
For Branch contacts: http://www.boca.org.au/

Birds Queensland, Queensland Ornithological Society Inc.
For Contacts: http://www.birdsqueensland.org.au/

Appendix 7

Consideration of survey effort required for monitoring bird species composition

Below we explore the results of bird survey data, collected using very similar methods to those described in this toolkit, to demonstrate the basis of the recommendation that four surveys is a reasonable effort to yield repeatable results and to reflect the difference in rainforest-dependent birds between revegetated sites and forest reference sites.

Figure A7.1 shows that if you count the number of rainforest-dependent bird species found during four thirty-minute bird surveys at any site, the results will be very similar to the number obtained from an independent set of four different surveys. Fewer surveys do not produce sufficiently repeatable results.

Figure A7.2 shows how the number of rainforest-dependent bird species increases if you increase the number of repeat surveys at a site. It takes many surveys, certainly more than the eight shown in this graph, to record close to the full complement of species occurring in a forest site, and the level of effort required to do so would be too onerous for a revegetation monitoring program. What is important, however, is not the number of species recorded *per se* but that the survey effort is sufficient to reflect the amount of **difference** between revegetated and forest sites in the factor being measured (i.e. in the number of rainforest bird species). Figure A7.2 shows that with less than four surveys, the cumulative number of rainforest bird species recorded can vary so much that there is overlap between forest and revegetated sites. With four or more surveys, the relative difference between revegetated sites and forest reference sites in rainforest species richness is apparent. Four surveys therefore provide a reasonable compromise between sufficiency and effort but five or six surveys will provide more reliable data. With less than four surveys there is a large risk that misleading results will be obtained.

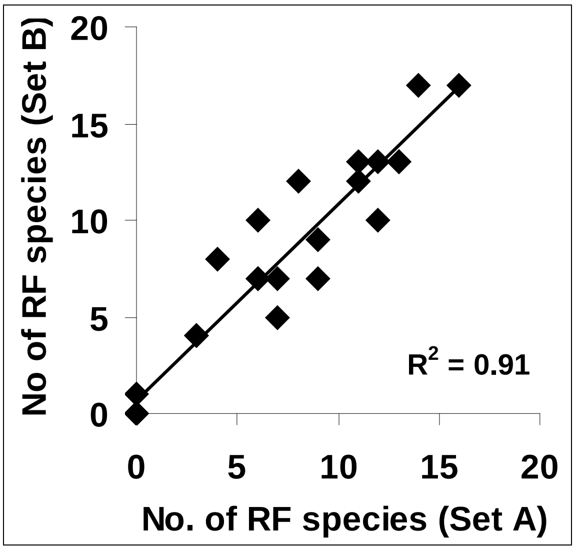


Figure A7.1. Will four repeat surveys using the toolkit method give informative results? This graph shows the level of agreement in the total number of rainforest-dependent (RF) bird species recorded at two independent sets (A and B) of four repeat surveys. Each point in the graph represents a different site (with five in pasture, ten in revegetated sites about ten years old, and ten sites in rainforest), although some points are on top of each other. There is a high level of consistency in the results from Set A and Set B, indicating that four repeat surveys gives a reasonably-reliable indication of the amount of difference in the number of rainforest species between different sites. The data were collected from 30-minute surveys of 0.3 ha transects in North Queensland (as described in Catterall *et al*. 2004).

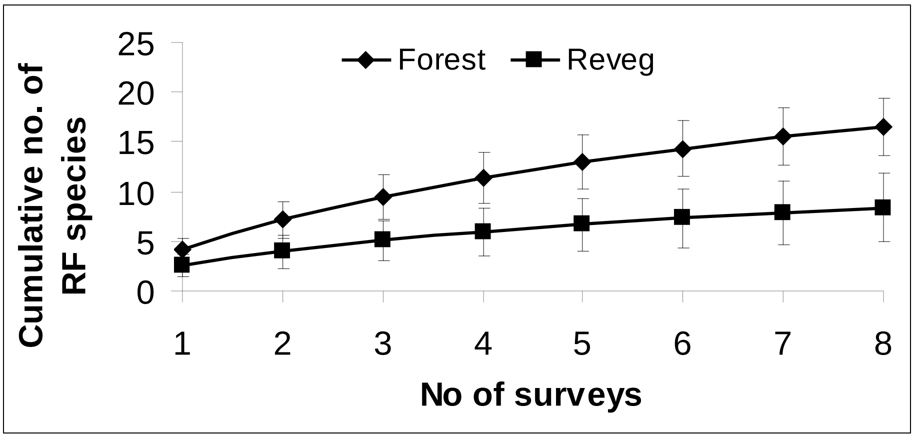


Figure A7.2. How the total number of rainforest-dependent (RF) bird species increases as more repeat surveys are conducted at a site. The bars show the upper and lower limits within which 99% of possible values should lie (based on data from ten different sites of each type). This example uses data collected from thirty-minute surveys of 0.3 ha transects in rainforest and revegetated sites aged around ten years in North Queensland, using a similar method to that presented in this toolkit (described in Catterall *et al*. 2004). Numbers were calculated using the Mao Tau process in '*EstimateS*' (Version 8.2, R.K. Colwell, http://purl.oclc.org/estimates).

Further Information

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