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MONITORING THE OUTCOMES OF REFORESTATION FOR BIODIVERSITY CONSERVATION

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Introduction

The reforestation of cleared rainforest land is a recent activity in Australia. In the Wet Tropics of north Queensland two major reforestation schemes, the Community Rainforest Revegetation Program (CRRP) and the Wet Tropics Tree Planting Scheme (WTTPS), were established after the listing of the Wet Tropics World Heritage Area in 1988. Since 1997, the Natural Heritage Trust (NHT) has been the main source of funds for conservation-oriented revegetation works in the Wet Tropics region and elsewhere in Australia (Catterall *et al.* 2004; Vize *et al.* 2005).

None of the major reforestation schemes in the Wet Tropics have incorporated a formal monitoring programme to assess their outcomes for biodiversity, even though the stated goals of the schemes included addressing the problems of land degradation (CRRP; Vize *et al.* 2005), environmental repair (WTTPS; Gleed 2002) and restoring habitat (NHT; Australian Government 2006a). Although projects funded by the NHT are required to report on administrative outcomes (e.g. area planted, volunteer hours expended), the monitoring of ecological outcomes is optional. Not surprisingly, few NHT-funded reforestation projects

in the Wet Tropics have conducted quantitative monitoring of vegetation or fauna (Catterall & Harrison 2006) (Box 42.1). Freeman (2004) found that most community groups in the Wet Tropics lacked the time, personnel, resources, motivation and expertise to monitor projects properly. A wider review of NHT projects in the Wet Tropics concluded that 'monitoring and evaluation is carried out randomly and not against set criteria ... [there] is a distinct lack of knowledge regarding monitoring and evaluation methodology and practices, and the lack of capacity (knowledge, time, money) within many groups to undertake such work in the first place' (Greening Australia 2003). In fact, these problems are endemic to the NHT programme. A review of over 13 000 NHT-funded revegetation projects across Australia found that 'only a handful' of projects had monitored the outcomes of revegetation for biodiversity (Freudenberger & Harvey 2003).

A list of revegetation projects in the Wet Tropics that have been monitored for their biodiversity outcomes follows. The community group TREAT (Trees for the Evelyn and Atherton Tablelands), along with researchers from CTR (Centre for Tropical Restoration), a small team within the Queensland Parks and Wildlife Service with close links to TREAT, has monitored

Box 42.1 Documenting reforestation projects in the Wet Tropics 1997–2001

Catterall and Harrison (2006) compiled available records of revegetation projects funded by the Natural Heritage Trust (NHT) in the Wet Tropics between 1997 and 2001. During this period, there were 49 NHT-funded projects focused primarily on the reforestation of cleared land in the Wet Tropics. In aggregate, these projects comprised restoration works (mainly tree-planting) on many sites, with a total area of 644 ha, at a total cost of over Au\$16 million (\$25 600 ha⁻¹), of which 36% was funded by the NHT. Community groups comprised 29 of the 44 different proponents involved in these activities, and volunteer labour contributed around 25% of the total cost of the projects.

Monitoring of project outcomes was a requirement of NHT funding. However, the nature of any monitoring programme was determined entirely by proponents, and the conduct of proposed monitoring activities was not audited by the NHT.

Table 42.1 lists monitoring activities reportedly undertaken within 87 vegetation-related projects that included both reforestation and the protection or repair of existing remnants. The majority of the projects (83%) reported some form of monitoring, with up to four different monitoring activities conducted per project. However, considering just those monitoring activities aimed at assessing vegetation or fauna, 44% of reported activities consisted simply of taking photos, while an additional 31% were unspecified. Fewer than 20% of activities comprised surveys of plants or animals, and these surveys were not necessarily quantitative or robustly designed. This low return of information on the outcomes of previous reforestation works has provided the stimulus for developing a regionally consistent approach to documenting and monitoring of the outcomes of reforestation in the Wet Tropics (Kanowski & Catterall 2007).

Table 42.1 Monitoring activities reported by vegetation-related projects funded by the NHT in the Wet Tropics 1997–2001

Monitoring activities per project	Projects conducting specified number of monitoring activities	Number of projects that monitored attributes			
		Vegetation	Fauna	Pest species	Water quality
Attributes targeted for monitoring					
0	15	—	—	—	—
1	35	31	0	1	3
2	26	25	9	3	15
3	9	11	7	2	6
4	2	1	4	2	1
Total	87	68	20	8	25
Focus of monitoring activities	Total number of monitoring activities	Type of monitoring activity			
		Photo	Survey	Growth rates	Unspecified
Type of monitoring					
Vegetation	68	39	11	6	12
Fauna	20	0	5	0	15

Source: Catterall and Harrison (2006).

changes in vegetation structure, plant recruitment and assemblages of birds and/or small mammals on a number of revegetated sites (Tucker & Murphy 1997; Tucker 2000, Grundon *et al.* 2002; White *et al.* 2004). Some in addition, a number of these revegetation projects have also been surveyed by universities and other research institutions; for example, Jansen (1997, 2005) monitored leaf litter invertebrates and birds, and Grove and Tucker (2000) surveyed saproxylic beetles, in one corridor site revegetated by TREAT and CTR while Ward *et al.* (2003) monitored rodents in another a revegetated site. The most comprehensive monitoring of revegetation projects in the Wet Tropics to date, at least in terms of number of sites assessed and number of taxa surveyed, has been the collaborative surveys of birds, reptiles, invertebrates, plants and forest structure in different types of reforestation, pasture and rainforest reference sites (Kanowski *et al.* 2003, 2006; Proctor *et al.* 2003; Catterall *et al.* 2004; Tucker *et al.* 2004; Wardell-Johnson *et al.* 2005). While this project has provided robust comparisons of the biodiversity outcomes of different types of revegetation, it is nevertheless a snapshot survey, mostly of young reforested sites. The structure, composition and availability of resources in reforested sites are likely to change considerably as plantings mature (Kanowski *et al.* 2004, 2005a).

Consequences of the lack of monitoring of reforestation projects

Because most reforestation projects in the Wet Tropics have not been monitored, the significant investment in reforestation in the region has resulted in only modest advances in our understanding of the factors affecting the biodiversity value of reforested sites (Catterall *et al.* 2005; Catterall *et al.*, Chapter 41, this volume). The insights that have been obtained have generally been derived from post hoc studies that have often been poorly replicated or confounded across key factors (Catterall *et al.* 2004). Opportunities for examining trade-offs or synergies between biodiversity conservation and other objectives of reforestation (e.g. production, water quality), which are fundamental to rational land-use planning, have simply not been addressed in the design of the major reforestation schemes, such

that consideration of these issues for the Wet Tropics is still mainly speculative (Catterall *et al.* 2005; Kanowski *et al.* 2005b). Of course, this problem is not restricted to the Wet Tropics or even Australia. The failure of many restoration projects worldwide to include a monitoring component has been strongly criticized by ecologists because of lost opportunities for learning about and improving restoration practices (e.g. Block *et al.* 2001; Lake 2001; Gillilan *et al.* 2005). Nevertheless, the problem has been felt particularly keenly by Australian ecologists because the NHT programme does not fund research (Australian Government 2006a). Hence, the significant investment in restoration by the NHT programme has not been matched by a significant increase in knowledge about the consequences of restoration for biodiversity. Thus, Lake (2001) noted that,

in Australia, the practice of undertaking poorly designed restoration projects has been widespread; driven by political pressures to initiate community-based projects without interference from monitoring or research. In terms of ecology, very little of value has been learnt from such projects, and in terms of restoration, design inadequacy has meant that lessons learnt on the sites cannot be reliably evaluated to improve restoration on these sites or elsewhere.

More bluntly, Chapman and Underwood (2000) have stated: 'In Australia, much money and resources are wasted in on-the-ground projects which are poorly designed and seldom evaluated.'

Effective monitoring of community-based restoration projects

There is extensive recent literature on the monitoring of biodiversity in forests and other ecological communities (Boyle & Boontawee 1995; Stork & Samways 1995; Jermy *et al.* 1996; Krebs 1999; Noss 1999; Henderson & Southwood 2000; Elzinga *et al.* 2001; Downes *et al.* 2002; Nakashizuka & Stork 2002; Kitching *et al.* 2005; Magnusson *et al.* 2005; Spellerberg 2005), and the monitoring of restoration projects in particular (Michener 1997; Block *et al.* 2001; Holl & Cairns 2002; Society for Ecological Restoration 2002; Wardell-Johnson *et al.* 2002; Catterall *et al.* 2004). Readers seeking information on the design, implementation and

analysis of monitoring programmes are referred to this literature.

Here we wish to address two issues pertinent to effective monitoring of community-based restoration projects, the prevailing type of restoration in the Wet Tropics and, indeed, much of Australia. These issues are to do with the specification of performance criteria for evaluating the success of restoration projects, and the rigour with which restoration projects should be monitored.

Specifying performance criteria for restoration projects

Monitoring can be defined as the repeated survey of target variables and their assessment against performance criteria (Stork & Samways 1995; Spellerberg 2005). Performance criteria for ecological restoration projects are typically derived from comparisons with a reference system; for example, remnant forest similar to the type that existed on a site prior to clearing (Society for Ecological Restoration 2002). A fundamental problem with assessing the success of rainforest restoration projects is that, in Australia at least, most reforested sites are young (years to decades), whereas it is likely to take decades to centuries for many of the attributes of restored sites to converge on mature rainforest (Hopkins 1990; Guariguata & Ostertag 2001).

An alternative to judging young restored sites against mature reference systems would be to assess changes in restored sites against a target trajectory, using criteria appropriate for particular states in that trajectory (Society for Ecological Restoration 2002; Walker & del Moral 2003). Unfortunately, knowledge of succession in reforested rainforest, and how succession might be affected by the particular characteristics of a site or deflected by various disturbances, is currently insufficient to assess whether restoration is on track or not (Hopkins 1990; Kooyman 1996). A large number of case studies of restored sites, covering a wide variety of ecological situations (e.g. size, composition, proximity to remnant forest), would need to be documented for restoration practitioners to be able confidently to assess sites against an ideal restoration trajectory (Catterall *et al.* 2004). Such data are available for few ecosystems. One exception is the jarrah (*Eucalyptus marginata*) forests that were mined for bauxite in Western Australia. Data collected over 15 years

from more than 400 plots were used by Grant (2006) to develop a model of successional trajectories in rehabilitated jarrah forests and to identify deviations from the target trajectory. This study demonstrates the scale of the effort required to determine successional trajectories even when, as in the jarrah forest, the course of succession is largely dependent on the initial plant species composition of the rehabilitated site. A greater effort may be required to document successional trajectories in rainforests, because succession in rainforest is not only strongly dependent on the dispersal of seeds to disturbed sites, a process that is spatially and temporally variable, but also influenced by a series of complex interactions between animals and plants (Hopkins 1990; Catterall *et al.* 2004; Kanowski *et al.* 2004).

Even if successional trajectories can be identified, performance criteria will need to be tailored to specific revegetation models. For example, *ex situ* recruitment is likely to be a critical measure of success in the so-called Framework Species model, where pioneer species are planted to provide rapid canopy closure and conditions suitable for the recruitment of mature phase species (Goosem & Tucker 1995; Kooyman 1996). In contrast, recruitment is likely to be less important, at least initially, in a Maximum Diversity model, where a wide range of species are planted at a site. In this case, survival and *in situ* recruitment may be a more informative measure of success during the early stages of restoration. Suitable performance criteria would also need to be developed for rainforest fauna and ecological processes, such as seed predation and decomposition, in reforested sites (Catterall *et al.* 2004). At present, the responses of animals to rainforest succession are poorly understood, even for well known taxa such as birds in well studied landscapes such as the Wet Tropics (Crome 1990), while basic data on rates of ecological processes in restored rainforest are almost entirely lacking.

How rigorously should restoration projects be monitored?

There is widespread agreement in the scientific literature, cited above, that ideally the monitoring of restoration projects should be conducted with similar rigour as ecological research, that is, with clearly defined objectives, adequate sampling and replication, appropriate control and reference sites, and valid

statistical analysis. Some authors are adamant that this is the only worthwhile approach to restoration (Chapman & Underwood 2000), while others draw a distinction between what may be a successful restoration and what may be a successful monitoring programme (Palmer *et al.* 2005). Regardless of this distinction, it is widely agreed that there are very few examples of restoration projects where monitoring has met the ideal scientific criteria. The reasons for this are both technical (i.e. difficult experimental conditions, such as a lack of suitable replicate treatment, control or reference sites) and social/political/economic, whereby proponents may not have the resources or skills necessary for monitoring, or may simply lack interest in conducting monitoring, particularly if projects do not have to demonstrate success against ecological objectives.

These constraints are especially acute in the monitoring of community-based restoration projects. Community groups are largely reliant on volunteers and few have the expertise to design, implement and interpret a scientific monitoring programme (Freudenberger & Harvey 2003). According to Freeman (2004), volunteers in environmentally focused community groups in the Wet Tropics are typically motivated to do something for the environment and may not perceive monitoring activities to be as valuable as growing or planting trees. The high turnover of volunteers in community groups also militates against the long-term commitment necessary for tracking the progress of revegetation. Some quotes from representatives of community groups interviewed by Freeman (2004) illustrate these issues: 'We don't have time to monitor', 'We don't know what to do', 'Our funding is stretched as it is', 'Our membership changes through time', 'We can see the trees growing and funding agencies aren't enforcing monitoring anyway', 'Community groups don't know where these results are going' and 'Monitoring is not necessary'.

According to Freeman (2004), the provision of specific funding for monitoring activities, training in survey techniques for volunteers and the availability of simple, standardized and relevant monitoring protocols would overcome a number of the obstacles that currently prevent most community groups from monitoring their revegetation projects. However, these measures may not address fundamental concerns held by community groups about the value of monitoring

or the lack of interest in monitoring by volunteers. Freeman (2004) argued that funding bodies may need to engage professional ecologists to monitor restoration projects established by community groups. Similar conclusions were reached by Greening Australia (2003) in their review of NHT projects in the Wet Tropics and by Freudenberger and Harvey (2003) in their review of the entire NHT programme.

Recent developments in the monitoring and evaluation of reforestation projects in the Wet Tropics

An important recent development in the planning and funding of reforestation projects in Australia has been the establishment of regional Natural Resource Management organizations, partly funded by NHT funds, that are responsible for managing investment in regional restoration projects over the medium to long term (Australian Government 2006b). These institutional arrangements are far more conducive to the development of monitoring and evaluation programs than the short-term, insecure funding associated with previous reforestation schemes. In the Wet Tropics, Far North Queensland Natural Resource Management Ltd (FNQ NRM) has funded a number of monitoring and evaluation projects (FNQ NRM Ltd & Rainforest CRC 2004).

Monitoring and evaluation of revegetation works

One of the projects funded by FNQ NRM specifically targets the monitoring of community-based reforestation works. The project aims to develop a toolkit to help community groups to document, monitor and report on their revegetation works. The initial version of the toolkit includes protocols for documenting on-ground works (establishment statistics) and for monitoring vegetation condition in revegetation projects (basic indicators) (Kanowski & Catterall 2007). Subsequent versions are planned to address the monitoring of more specialized targets (advanced indicators).

This project addresses many of the concerns raised by Freeman (2004) in relation to the effective

monitoring of community-based revegetation projects. First, rather than placing the unrealistic obligation of developing scientifically credible monitoring protocols on to community groups, the project has been contracted to ecologists with specific expertise in biodiversity surveys in reforested sites, including in the Wet Tropics. Second, the project is being developed with the assistance of revegetation practitioners and staff from FNQ NRM and the community groups themselves. This collaboration has the dual purpose of exposing the ecologists responsible for developing the project to the ideas, skills and constraints of the revegetation practitioners and community groups responsible for the on-ground works, and of promoting the value of monitoring among practitioners and community groups. Third, the timeframe of the project allows testing of the protocols by their intended users and subsequent revision of the protocols. The major components of the toolkit are discussed below.

Establishment statistics

Interpreting the results of a monitoring programme generally requires knowledge of the condition of sites prior to the on-ground works, as well as detailed information on the on-ground works themselves (Society for Ecological Restoration 2002). Unfortunately, many revegetation projects in Australia have been poorly documented. The review by Freudenberger and Harvey (2003) of NHT-funded revegetation projects across Australia found that very few had adequately documented the on-ground works and that only a few appeared to have collected baseline data. Furthermore, data reported by NHT-funded projects are not readily accessible by the public.

The monitoring and evaluation toolkit being developed for FNQ NRM specifies the collection of a range of establishment statistics to enable subsequent monitoring of projects for biodiversity. Some of these statistics are already required for projects funded by the NHT (e.g. site location, area planted, number of stems planted, budget, timeline), while other statistics have been included to provide the background data needed to interpret the monitoring results, including a basic ecological description of the site (soils, rainfall, landscape context), a description of the revegetation approach used in a project (e.g. framework species, maximum diversity) and the identification of suitable

control and reference sites, if relevant. It is intended that information collected on revegetation projects will be maintained by FNQ NRM and made more accessible to interested parties.

Basic indicators

The selection of target variables is an important element of a monitoring programme. Criteria used to select target variables include relevance to project objectives, sensitivity to management practices, the feasibility and cost-effectiveness of surveys and whether variables can act as surrogates for other components of the ecosystem (Stork & Samways 1995; Holl & Cairns 2002). Ideally a diverse range of variables relating to habitat structure, biota and ecological processes would be surveyed to assess biodiversity, but community groups are limited in their ecological expertise (Freeman 2004; Spellerberg 2005). Hence, monitoring protocols intended for use by community groups need to identify target variables that can be easily and rapidly assessed in the field, given the available expertise. Details of the approach used to identify these target variables, termed basic indicators, in the monitoring toolkit that is being developed for FNQ NRM, are given in Box 42.2.

Advanced indicators

In some cases, it may be better to monitor directly the value of revegetation projects for various components of biodiversity than to rely on surrogates. For example, evaluation of the success of a reforestation project aimed at conserving the cassowary (*Casuarius casuarius*) would probably require surveys of the use of the reforested sites by cassowaries, rather than an assessment of vegetation structure or condition. Although community groups could commission local naturalists to survey such advanced indicators, they might still need guidance on appropriate survey methodologies, particularly if the naturalists have little training in survey design (Spellerberg 2005).

Monitoring the different stages of revegetation

Regardless of whether basic or advanced indicators are used to monitor revegetation projects, it is important that target variables are relevant to the stage of development of the revegetation. A key distinction is between the establishment phase of revegetation (the period

Box 42.2 Selection of basic indicators for monitoring reforestation projects

The development of a monitoring toolkit to help community groups to monitor reforested sites (Kanowski & Catterall 2007) required the identification of target variables, or basic indicators, that would:

- 1 provide information on the development of revegetated sites;
- 2 be correlated with the use of revegetated sites by rainforest wildlife;
- 3 be readily applied in the field by non-specialists.

Potential indicators were selected from the literature on the vegetation structure of rainforests (Webb *et al.* 1976), revegetated rainforest sites (Kooyman 1996; Kanowski *et al.* 2003) and Australian forests and woodlands (McElhinny 2002; Parkes *et al.* 2003; Gibbons *et al.* 2005).

The potential for these attributes to act as surrogates for rainforest fauna was examined using data from reforested sites in eastern Australia (see Catterall *et al.* 2004 for overview of sites and methods). For these analyses, rainforest birds and reptiles were identified from natural history observations. The habitat affinities of mites were determined from analysis of the relative occurrence of mite taxa in pasture and rainforest reference sites, while the affinities of beetles were derived from the similarity of assemblages in revegetated sites to reference rainforests. The results of these analyses (Table 42.2) show that nearly all the structural attributes assessed were potentially useful surrogates of rainforest fauna when the full set of reforested sites was considered. However, a much smaller subset of variables was correlated with rainforest taxa when analyses were restricted to young replanted sites. In young sites, six of thirteen structural attributes assessed were correlated with rainforest bird richness, but only two were correlated with the richness of rainforest reptiles and beetles, and none with mites.

Table 42.2 Correlation (r_s) of structural attributes with the richness of rainforest birds, reptiles and mites, and the assemblage composition of beetles, in reforested sites in tropical Australia. Reforested sites included young monoculture plantations, young cabinet timber plantations, young ecological restoration plantings, old monoculture plantations and regrowth

Attribute	Birds	Reptiles	Beetles	Mites
All reforested sites ($n = 35$)				
Tree species richness	0.71*	0.66*	0.65*	0.52*
Canopy cover	0.75*	0.71*	0.68*	0.49*
Canopy height	0.57*	0.54*	0.52*	0.53*
Tree density	0.54*	0.56*	0.51*	0.34*
Large tree density	0.61*	0.60*	0.48*	0.59*
Basal area	0.68*	0.69*	0.54*	0.48*
Tree height diversity	0.52*	0.51*	0.41*	0.54*
Tree diameter diversity	0.43*	0.44*	0.26	0.29
Special life forms	0.59*	0.51*	0.44*	0.59*
Shrub density	0.63*	0.53*	0.51*	0.49*
Woody debris	0.46*	0.50*	0.50*	0.52*
Leaf litter	-0.05	0.02	0.01	0.06
Grass cover	-0.71*	-0.64*	-0.56*	-0.56*
Young replanted sites only ($n = 20$)				
Tree species richness	0.75*	0.58*	0.57*	0.32
Canopy cover	0.59*	0.70*	0.32	0.04
Canopy height	0.03	-0.12	-0.07	0.01
Tree density	0.46*	0.43	0.16	-0.01
Large tree density	-0.06	0.26	-0.04	-0.19
Basal area	0.49*	0.40	0.08	-0.16
Tree height diversity	-0.06	0.01	-0.25	-0.22
Tree diameter diversity	-0.07	0.01	-0.35	-0.34
Special life forms	0.26	0.30	0.31	0.15
Shrub density	0.65*	0.39	0.58*	0.18
Woody debris	0.07	-0.10	0.18	0.14
Leaf litter	-0.20	-0.20	-0.06	-0.10
Grass cover	-0.47*	-0.33	-0.31	-0.10

* $P < 0.05$.

Sources: Kanowski *et al.* (2003, 2006), Proctor *et al.* (2003), Catterall *et al.* (2004), Wardell-Johnson *et al.* (2005), Grimbacher *et al.* (submitted 2007).

of several years following planting until trees form a relatively closed canopy that suppress grasses) and the subsequent building and maintenance phases (Catterall *et al.*, Chapter 41, this volume). Appropriate targets to monitor during the establishment phase would include the survival and growth of planted trees, the development of canopy closure and the proportion of the ground covered by grasses and weeds that might suppress the recruitment of rainforest plants. Such targets would be directly related to site capture and their assessment could provide useful feedback on the maintenance requirements of a site. In the subsequent building and maintenance phases, a typical objective for restoration projects might be the development of a floristically and structurally diverse forest that provides habitat for native wildlife. Appropriate monitoring targets during these phases would include vegetation structure, floristic composition, the recruitment of plants and the use of reforested sites by wildlife.

Summary

- With some important exceptions, most reforestation projects in the Wet Tropics of north Queensland have not been monitored for their outcomes for biodiversity. Consequently, despite a large investment of public funds, the value of reforestation projects for biodiversity remains poorly known.
- The monitoring and evaluation of reforestation projects requires the development of performance criteria that are appropriate for particular stages and models of reforestation.
- Developing suitable criteria will require data from a large number of reforested sites, representing a range of ecological situations.
- The effective monitoring of reforestation projects poses significant challenges for community groups. Volunteer members of community groups typically lack sufficient training in survey design and evaluation, and may not perceive the value of information obtained from monitoring.
- A monitoring and evaluation programme involving collaboration between ecologists, revegetation practitioners and community groups has recently been instigated in the Wet Tropics region. The project has the potential to improve our knowledge of the

biodiversity outcomes of reforestation, although it will require long-term commitment to realize its potential.

- Rapid advances in knowledge of the outcomes of reforestation for biodiversity and other objectives are likely to require the incorporation of experimental research and monitoring programmes within reforestation projects.

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