Assessing the Benefits of Vegetation Enhancement for Biodiversity: A Draft Framework

A report for
Environment Australia
and the
Biodiversity Benefits Task Group

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Assessing the benefits of vegetation enhancement for biodiversity: A draft framework

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Summary

The Land Water and Biodiversity Committee under the Natural Resources Management Ministerial Council convened a Biodiversity Benefits Task Group to conduct:

> an assessment of the biodiversity benefits of revegetation, and vegetation rehabilitation and protection programs, and an analysis of the most effective program interventions.

This report proposes a methodological framework for assessing the biodiversity benefits of vegetation enhancement activities, many of which have been funded through the Natural Heritage Trust.

The framework is applied in four principal steps, and at three scales (patch, landscape or subcatchment, and region or catchment), as follows:

Step 1. Identify key threats to broad attributes of biodiversity and identify management interventions aimed at reducing the threats.

Step 2. State the desired or predicted response (e.g. improved regeneration) for at least one attribute of biodiversity (e.g. native understorey species) to each vegetation enhancement activity (e.g. fencing) and elucidate the underlying theoretical or conceptual models (e.g. State and Transition) that underpin the expected response to each intervention.

Step 3. Choose or develop methods (such as 'Habitat Hectares' or 'Ecological Benefit Index') to detect change in the chosen biodiversity attributes as a response to the management interventions.

Step 4. Rigorously apply the chosen methods to compare the observed outcomes and the predicted biodiversity response to management interventions.

A preliminary application of this framework has been conducted at regional, landscape and patch scales. There is inadequate information to make any conclusive statements, but we have gained the following insights that require further analysis.

1. Small-scale revegetation interventions can provide occupiable habitat for a remarkable diversity of woodland birds, but as yet there is no evidence that revegetation enhances populations at the landscape scale or species at the regional scale.
2. At the patch scale, habitat values of revegetation will change with time and are dependent on broader landscape characteristics. The effect of changes in habitat values of revegetated patches is not yet known nor even modelled at landscape and regional scales.
3. Large-scale (commercial) *Pinus radiata* plantations provide occupiable habitat for a wide range of birds and some mammals, and unoccupiable habitat for other species particularly insects and native understorey plants.
4. Large-scale *Eucalyptus globulus* plantations in south-western Western Australia provide limited direct habitat value for native vertebrate species and may pose a threat from invasive insect pests. These plantations may, however, provide significant off-plantation benefits by reducing the risks of secondary salinity.
5. There is some evidence from temperate woodlands in eastern and Western Australia that fencing remnant vegetation improves regeneration of native plant species, but on-going management interventions are often required.
6. Methods are being developed to assess the structural response of native vegetation enhancement activities at the patch scale. There is little quantification, so far, of the benefits of vegetation enhancement for any functional attribute of biodiversity, including ecosystem services. However, the detailed studies by the Rural Industries Research and Development Corporation/ Joint Venture Agroforestry Program (RIRDC/ JVAP) shelterbelt program, have shown that

revegetation has value in reducing wind and improving crop productivity in some situations.

7. At the national scale, vegetation enhancement activities have not yet compensated for the rate of clearing of native vegetation. Protection of native vegetation has occurred at a patch scale through fencing incentive programs, but protection of native vegetation from modification by clearing at a regional scale has been inadequate so far.

Our cursory application of the assessment framework has led us to this conclusion: the many thousands of vegetation enhancement activities which have been implemented with significant public and private resources have so far given us a glimpse of the possible biodiversity benefits, but at a small scale.

An adequate assessment of the biodiversity benefits of vegetation enhancement activities will cost money. Natural resource management programs that invest in significant activities aimed at benefiting compositional, structural or functional attributes of biodiversity should put aside at least 1% of the budget for assessing the benefits.

The first priorities for future assessments are the bioregions that have already received significant funding for vegetation enhancement activities and the bioregions that have the best existing data. The data should include details about who did what, and when — this is essential information. There is much to be learned from the many thousands of projects funded by the past decade of natural resource management funding. The application of our generic framework at any scale across any attribute of biodiversity needs to be expanded if we are to learn from past failures and successes.

Future investment in natural resource management should first focus on protecting high quality attributes of biodiversity such as intact expanses of native vegetation. Repair and reconstruction is far more expensive than protection. Analysis of future investment options as a function of landscape stress, as mapped by the Land and Water Resources Audit, is one means of prioritising future funding.

I. Report scope

The Land Water and Biodiversity Committee under the Natural Resources Management Ministerial Council convened a Biodiversity Benefits Task Group to conduct:

> an assessment of the biodiversity benefits of revegetation, and vegetation rehabilitation and protection programs, and an analysis of the most effective program interventions.

The assessment was to focus on the biodiversity benefits of on-ground actions (physical interventions) at range of scales and within a broad range of landscapes.

Environment Australia contracted CSIRO Sustainable Ecosystems to assist in this assessment. The contract had four objectives:

1. Develop a methodological framework to assess the biodiversity benefits of vegetation enhancement activities.
2. Apply this method to a number of case study regions that have received significant Commonwealth and state funding for vegetation enhancement activities.
3. Provide recommendations for further assessment of the biodiversity benefits of vegetation enhancement.
4. Provide recommendations of ways to prioritise future investments in vegetation enhancement.

In outline, this report:

- gives an operational definition and provides a matrix for defining the broad range of attributes of biodiversity at a range of scales;
- describes the various assessment scales that need to be considered across geomorphic, ecological, institutional and management units;
- briefly describes the range of management actions or interventions which are encompassed by the term ‘vegetation enhancement’;
- provides a generic framework for assessing the biodiversity benefits of vegetation enhancement;
- applies this framework in four steps, across a wide range of case studies, most at the patch and landscape scales (see Appendix);
- describes the insights gained from the review of these case studies;
- makes recommendations for further assessment of the biodiversity benefits of vegetation enhancement;
- makes recommendations for prioritising future investments in vegetation enhancement.

II. Definitions and assumptions

The definition of biodiversity adopted by the National Strategy for the Conservation of Australia's Biological Diversity (Commonwealth of Australia1996) is:

> The variety of life forms: the different plants, animals and micro-organisms, the genes they contain, and the ecosystems they form. It is usually considered at three levels: genetic diversity, species diversity and ecosystem diversity.

This definition is consistent with the definition adopted by the International Convention on Biological Diversity in Rio de Janeiro in 1993:

> Biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

The term 'biodiversity' was first widely promulgated by a U.S. National Academy of Science symposium in 1986, which generated remarkably high national and international interest (Takacs 1996). The symposium's papers reported a wide range of views and definitions of biodiversity (Wilson 1988).

The paper by Franklin (1988) in the symposium proceedings noted that the growing concern over *compositional* diversity (e.g. species) was not accompanied by an adequate awareness of *structural* and *functional* diversity. Noss (1990) also recognised the limitations of focusing just on the compositional attributes of biodiversity, and developed a simple conceptual framework for identifying specific and measurable indicators (or attributes) of biodiversity (Fig. 1). Noss (1990) recognised that biodiversity is not simply the number of genes, species or ecosystems in a defined area. Knowing that one area contains 500 species and another contains 50 species does not indicate how these species are arranged (structure) or what they do (function).

For our purposes the following definition is enough (Freudenberger and Stol 2002):

> Biodiversity: the variety of life — what it's made of, how it's arranged and what it does, from microscopic to global perspectives.

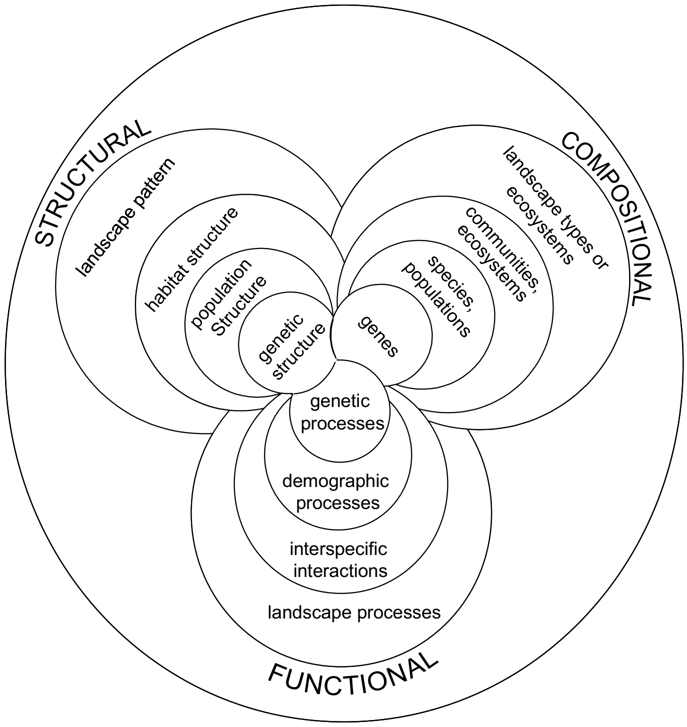
This plain-English definition of biodiversity can itself be shortened to: 'The variety of life, its composition, structure and function, at a range of scales'.

Biodiversity is not a quantity that can be measured in its entirety. Rather biodiversity is a similarity or difference in measurable characteristics or attributes from one place to the next. A biodiverse landscape maintains the composition, structure and functional of attributes of biodiversity, which includes agricultural production. Our abbreviated definition of biodiversity, with its three key attributes (composition, structure, function) forms the basis of this report.

We use the term 'attribute' to mean some measurable characteristic of biodiversity. The role of any attribute as a surrogate or indicator is complex. Vegetation itself is an important attribute of biodiversity and it is assumed that native vegetation is a crude but useful surrogate for some attributes of biodiversity. The relationships between compositional, structural and functional attributes of biodiversity at different scales are many, often complex and mostly unknown.

An extensive scientific literature, including Australian studies, examines the relationships between measures of vegetation and the occurrence of other taxa. McElhinny (2002) and Doherty et al. (2000) have recently reviewed this literature.

The Resource Assessment Commission (RAC 1993) defined a surrogate indicator as: 'a quantity or combination of quantities used



A simple conceptual framework for identifying specific and measurable attributes of biodiversity (adapted from Noss 1990)

to obtain information about the target in lieu of measuring the target more directly'. The RAC referred to the 'target' as an entity about which information is desired, such as a particular species, a community, or a measure of biodiversity. However, in the opinion of the RAC, the use of surrogates is questionable unless the following assumptions hold:

> that there is a model linking the surrogate and the target, that this link is constant or varies in a known way in space and time, and that the surrogate can be measured more readily, easily or cheaply than the target.

Therefore, fundamental to the use of any surrogate indicator of biodiversity is the assumption that a correlation exists between the surrogate and biological diversity (Ferrier and Watson 1996). The link, or correlation, can range from a very simple qualitative model based on biological 'common sense', to a mathematical or statistical model requiring extensive data collection and analysis (RAC 1993).

The lack of such a link probably explains the poor results obtained by Ferrier and Watson (1996) when using ground-dwelling invertebrates to evaluate broad surrogates such as vegetation mapping and species distribution modelling. These authors did not attempt to establish a correlation between ground-dwelling invertebrates and the broad surrogates that were used.

Doherty et al. (2000) reviewed and critically assessed the evidence for a relationship between biodiversity, habitat complexity, habitat quality and ecosystem processes, with the aim of identifying surrogate or 'higher-order' indicators of biodiversity. They concluded that despite the large amount of literature discussing biodiversity, habitat conditions and ecosystem processes, there is scant empirical data to prove more than simple linkages between specific elements. Doherty et al. (2000) found that several past studies of the relationship between biodiversity and ecosystem processes were limited by:

- an assumption of system equilibrium;
- a unifactorial focus;
- too typological an approach without emphasis on variation in time and space;
- being too limited in temporal and spatial scope, restricted to a single study site or a short time span;
- neglect of evolutionary aspects of ecology;
- substitution of correlation for explanation (Willson 1996).

McElhinny (2002) considers using forest and woodland structure as a surrogate for various taxa. Forest structure generally implies vegetative cover at various strata on and above the ground. Structural complexity is essentially a measure of the physical layers in a patch of vegetation, and the relative abundance of these layers (Newsome and Catling 1979). Australian studies have associated the relative abundance or richness of different fauna groups with various structural attributes. Most work focuses on a local or stand scale, useful for management of a patch, but not as useful for regional or landscape-scale management. McElhinny (2002) gives the following guidelines for an index of structural complexity:

1. Use a simple mathematical system to construct the index.
2. Start with a comprehensive set of attributes, which can be reduced to a core set by establishing relationships between the attributes.
3. Benchmark attributes against their values in natural stands.
4. Trial different weightings of attributes, adopting those weightings that most clearly distinguish between stands.

The 'Habitat Hectares' approach developed in Victoria (Parkes et al. 2003) and being adapted for NSW (P. Gibbons, pers. comm.) objectively measures the quality of each vegetation remnant in the rural landscape by comparing it to a 'benchmark' for the same vegetation type. A biodiversity index has been constructed, combining current and predicted vegetation quality and conservation significance. The index is being used to quantify on-ground management outcomes as part of a trial of a market-based mechanism for purchasing land management services.

Oliver (2002) has designed a toolkit to quantify the current biodiversity value of a defined area of terrestrial landscape, predict the future biodiversity value after land-use change and incorporate these values into an 'Environmental Benefits Index'. Three broad surrogate measures of biodiversity are assessed: vegetation condition, conservation status and landscape context.

Barnett et al. (1978) developed a structural complexity index by summing values describing small mammal habitat. A habitat complexity score developed by Newsome and Catling (1979) was used by Catling and Burt (1995) to account for the distribution of ground-dwelling mammals in coastal forests. Watson et al. (2001) have modified the Newsome and Catling (1979) complexity score to successfully account for the occurrence of small woodland birds.

All surrogate measures of biodiversity are imperfect. No one surrogate can adequately capture all the compositional, structural and functional attributes of biodiversity. For the purposes of assessing the biodiversity benefits of vegetation enhancement activities, a range of partial measures of biodiversity should be assessed that include compositional, structural and functional attributes of biodiversity.

The term 'biodiversity benefits' is broadly defined as 'quantifiable and *desired* changes in a biodiversity attribute of interest'. To assess benefits due to management interventions such as vegetation enhancement activities, first we must define the sort of change we want in an attribute of interest, and then we must choose an appropriate method to monitor changes in that attribute.

Consideration of scale is essential when assessing the biodiversity benefits of enhancement activities. Table 1 shows the range of scales often found relevant by stakeholders. It also outlines some of the diversity of terms used in relation to scale, and groups them in relation to the descriptive terms for scale we use consistently in this report, namely patch, landscape and region.

Throughout this report, we use the term 'vegetation enhancement' as a catch-all term for those on-ground actions that aim to improve an attribute of biodiversity. It is a more goal-orientated term than 'vegetation management' or 'ecosystem management'.

Defining scale Geomorphic/ Geographic	Biological	Institutional/ Jurisdictional	Management unit	Term used in this report
Micro (μm²–m²)	Genes and individual organisms	Crown (state and Commonwealth) e.g. protected species		
Slope (catena) (1–1000 ha)	Patch or population	Individuals (e.g. farmers) some agencies (e.g. State Forests of NSW)	Paddock, forest coupe	**Patch**
Landscape/ subcatchment (100–1000 ha)	Communities and some ecosystems	Local government, community groups (e.g. Landcare), some state agencies	Farms, forest blocks, national parks	**Landscape (subcatchment)**
Catchment (1000 ha –millions km²)	Biomes, some ecosystems, threatened species	Regional associations (e.g. MDBC**), catchment management groups, local government	Catchment	**Regional (catchment or IBRA* region)**
Continental/ transcontinental	Threatened species	States, Commonwealth Government and international treaties		**National**

*IBRA = Interim Biogeographic Regionalisation for Australia
**MDBC = Murray-Darling Basin Commission

Vegetation enhancement is defined to include:

- protection — e.g. fencing to control grazing, the establishment of off-stream watering points, protection from clearing;
- rehabilitation — e.g. reseeding of understorey, weed removal, stabilisation of dunes, controlled burning and re-establishment of riparian woodland flooding regimes;
- revegetation — dramatically altering plant composition by planting with seedlings or seeds of native species, e.g. planting of woodland species into a pasture dominated by exotic species. For the purposes of this consultancy, revegetation includes agroforestry plantings and commercial plantations.

From our case-study assessment of biodiversity benefits we have omitted a large number of management interventions which are relevant to the enhancement of biodiversity. These interventions, many of them funded by the Natural Heritage Trust, include:

- feral predator control,
- reduction in water pollutants,
- erosion reduction activities (e.g. contour banks and gully stabilisation),
- improvement in aquatic macro-habitats (e.g. addition of snags),
- threatened species recovery projects,
- selection and acquisition of conservation reserves.

Our framework also does not assess the benefits or effectiveness of the social and institutional processes that are required to underpin on-ground actions. These non-physical interventions include planning at a range of scales, facilitation, communication and incentives. These types of activities are being reviewed by other processes (e.g. the Bushcare Monitoring and Evaluation Program).

In assessing the biodiversity benefits of vegetation enhancement we have made the following broad assumptions:

1. Some attributes of biodiversity are threatened.
2. Vegetation enhancement can reduce some threatening processes.
3. It is possible to detect change in the status of some biodiversity attributes after vegetation enhancement.

The following assessment framework is designed to explicitly address and test only these assumptions, because vegetation enhancement cannot benefit every attribute of biodiversity: it cannot directly reduce all threatening processes. For example, vegetation enhancement does not directly alter the impact of feral predation, known to be the major cause of the decline or extinction of many small ground-dwelling marsupials (Short and Calaby 2001). Although vegetation enhancement can act indirectly, by either providing refuge from feral predators or by increasing the habitat for the predator, those sorts of fine-scale interactions are beyond the scope of this report.

III. Assessment framework

The first objective of this report was to develop a framework suitable for assessing the benefits of any vegetation management activity at any scale, across any attribute of biodiversity. We propose a four-step assessment process:

Step 1. Identify the biodiversity attributes of concern and describe their status; identify key threats to these attributes; identify a range of broad vegetation enhancement activities that should reduce these threats.

Step 2. State the changes in biodiversity attributes that are desired or predicted in response to vegetation enhancement activities; think through the conceptual models that underpin these predictions.

Step 3. Choose or develop methods for detecting and monitoring change in biodiversity attributes as a response to vegetation enhancement; take into account the required time-scale and spatial replication needed to confidently detect change.

Step 4. Apply the monitoring methods to detect changes; assess them against the responses predicted.

Applying these four steps makes us consider each cell of the four matrices (Tables 2–5) which are described in detail in the following sub-sections.

As discussed in Section II.A above, three broad attributes of biodiversity should be considered: composition, structure and function at a range of different scales.

At each step of this proposed assessment process we define the scale of interest and key attributes of biodiversity. For simplicity, only three scales are shown in the assessment framework matrices (Tables 2–5): namely, patch, landscape (subcatchment) and region. Other scales such as national or even genetic could be inserted into these matrices. The relationships among these geomorphic scales and ecological, institutional and management scales were defined in Table 1.

It is useful but inadequate to assess the benefits of vegetation enhancement for a few individuals of a few charismatic bird species at the scale of only a few hundred patches of revegetation or fenced remnants. The presence of charismatic birds in individual patches needs to be examined at the landscape and regional scales as well. There are questions which need to be addressed; for example, are occupied patches of enhanced vegetation contributing to viable populations at a landscape scale and is the species persisting throughout its range at a regional scale?

Step 1 Describe the status of biodiversity attributes, identify key threats to them and broad management interventions (e.g. vegetation enhancement) required to reduce the threats

Scale	Status (Expression of threatening processes)			Threatening processes		Management intervention
	Composition	Structure	Function	Modification	Removal	
Patch						
Landscape (subcatchment)						
Region						

Assessing the benefits of vegetation enhancement for a few taxa at a range of scales is clearly a challenge and requires considerable resources. The challenge becomes much greater if a wide range of taxa is examined to quantify their responses to vegetation enhancement.

A complementary approach which is less demanding of resources is to assess the effects of vegetation enhancement on broad categories of habitat structure *at patch scales*. Within enhanced patches of vegetation, components of habitat such as canopy, mid-storey, understorey and ground cover can be rapidly assessed without the expert knowledge needed to identify flora and fauna to species level. Increasing the diversity and heterogeneity of habitats within and between patches of native vegetation is a justifiable objective for vegetation enhancement based on niche theory and the extensive empirical data demonstrating the relationships between habitat structure and the diversity and abundance of a wide range of taxa (McElhinny 2002).

At the landscape scale, quantifying structure can be a useful and rapid means of assessing some of the benefits of vegetation enhancement. Two main questions can be addressed:

(i) have enhancement activities significantly increased the sizes of mean remnant patches of woodlands, forests or grasslands?

(ii) has enhancement decreased landscape fragmentation?

Historical and current sequences of air photos or satellite images can be examined to assess the mosaic of land-cover types and land uses. Changes in cover can be assessed against theoretical and empirically derived benchmarks, such as those reported in McIntyre et al. (2002). They specify that no more than a maximum of 30% of native vegetation should be replaced by intensive land use such as cropping, and that at least 10% of native vegetation should be dedicated to nature conservation. Similarly, land-cover mosaics can be assessed at the regional level to determine if vegetation enhancement activities have significantly changed the distribution of land cover classes.

A comprehensive analysis of the benefits of vegetation enhancement cannot be gained merely by assessing its benefits for species and habitats (composition and structure). Most of the Australian continent is used to provide goods and services for human consumption. These goods and services are derived from patches, landscapes and regions. The following questions could be addressed.

At the patch scale,

a) have vegetation enhancement activities reduced wind and water erosion?

b) has the rehabilitation of riparian vegetation significantly improved bank stabilisation?

At the landscape scale,

c) have enhancement activities significantly reduced deep drainage and the risk of dryland salinity and improved downstream water quality?

At a regional scale, the cumulative effects of vegetation enhancement can be assessed against end-of-catchment water quality targets, whether they be electrical conductivity (salinity) at Morgan, South Australia, or nutrient concentrations in rivers flowing into the Great Barrier Reef Marine Park.

The core of the proposed framework for assessing the biodiversity benefits of vegetation enhancement is simple: three attributes at three scales (Table 2). However, this simple 3 x 3 matrix suggests that there are threatening processes affecting the biodiversity attributes within each cell of the matrix and that these threats are expressed and recognised at each of the three broad scales.

The expression of a threatening process is often referred to as the 'status' of a threatened species, landscape or catchment. The National Land and Water Resources Audit (2002) has made considerable progress in quantifying the status or expression of threatening processes of various attributes of biodiversity at the scale of IBRA subregions. The quantifiable expression of a threatening process is often confused with the threatening process itself. They can be quite different and need to be considered separately. The 'status' columns of our proposed assessment matrix (Table 2) are useful for defining the objectives of vegetation enhancement activities. It is assumed that enhancement activities are aimed at improving the status of biodiversity. However, our review of case studies (below) indicates that many enhancement projects do not articulate which attributes of biodiversity they aim to improve, what the current status of each attribute is, or at what scale the attributes are relevant.

The absence of a species of interest from a patch of remnant forest defines the status of that patch in terms of a compositional attribute of the patch. The absence of tree hollows and fallen timber from the patch affects its structural status. The existence of surface erosion affects the functional status of the patch.

The presence or absence of threatened species affects the status of compositional attributes of biodiversity at a regional scale. The percentage remaining of woody cover across a catchment is the status of one structural attribute at a regional scale. The mapped distribution of dryland salinity across a subcatchment is the status of one functional attribute of biodiversity at a landscape scale.

Recognising and quantifying the status of each of various attributes of biodiversity at a range of scales is much easier than understanding the underlying causes (threatening processes) leading to a loss of status for that particular attribute at that scale. For example, the absence of individuals of various species is often fairly easy to document (e.g. the disappearance of birds and plants), although even this can be difficult due to the cryptic nature of many native species. Even more difficult is the elucidation of the underlying reasons why expected species are missing from a patch of vegetation.

Reasons for a species' absence could be loss of habitat (e.g. nest hollows), inadequate habitat (e.g. insufficient fallen timber), pressure from exotic predators (e.g. foxes and cats) or competition from weeds, or competition from superabundant native species (e.g. noisy miners and kangaroos), or a combination of threatening processes. Caughley and Gunn (1996) strongly argue that the immediate (proximal) as well as the ultimate threatening processes need to be understood. Fox predation may be the immediate cause for the disappearance of a ground-dwelling marsupial, for example, but the ultimate cause may actually be loss of refuge habitat due to intensive grazing which has suppressed recruitment of juveniles into the adult population to the point where foxes have a major impact.

A plethora of vegetation enhancement activities are consciously or unconsciously aimed at reducing processes that threaten compositional, structural or functional attributes of biodiversity. We have included a threatening processes column within the proposed assessment framework (Table 2) as a trigger for assessing whether a vegetation enhancement activity could possibly reduce that threat, or whether the threatening process affecting some attributes of biodiversity was even recognised or known.

We have adopted the broad approach of McIntyre and Hobbs (1997) which classifies landscapes by their responses to two groups of threatening processes: habitat modification and habitat removal. We suggest that all vegetation enhancement activities can be similarly classified, as aiming to reduce threats that result from either habitat modification or habitat removal. For example, fencing of remnant vegetation may potentially reduce the many threats that result from habitat modification due to intensive grazing by livestock. In contrast, revegetation activities may reduce some of the threats due to habitat removal (e.g. clearing).

The final column in this first matrix (Table 2) is there simply to match a particular vegetation enhancement activity at a defined scale against a particular attribute of biodiversity, its status, and the underlying threatening processes which the enhancement activity is intended to reduce. For example, revegetation in the form of strips (e.g. shelter belts) can be matched at the patch scale against a functional attribute such as wind erosion or crop productivity. Alternatively, the same revegetation activity or project can be matched at the landscape scale against the structural attribute of remnant patch isolation in a landscape with a highly fragmented status. In this second situation, the underlying threatening process is assumed to be a species' loss of 'room to move', leading to reduced population viability for that species. If this same strip of revegetation is part of a much larger project to link up widely distributed remnants, then at a regional scale it could be matched against some statistic of fragmentation.

The matrix for Step 2 (Table 3) follows directly from the first matrix (Table 2). The management intervention column is from the previous matrix.

We do not know for certain that vegetation enhancement activities reduce threatening processes and improve the status of some attributes of biodiversity. As scientists we are still struggling with the concept of biodiversity, let alone being able to define how it actually responds to vegetation management. The best we can do, whether scientists or land managers, is to predict what vegetation enhancement might do for some attributes of biodiversity, biased by our preference for managing and researching at the patch scale.

In Table 3 we have a framework in which to match a particular management intervention with the responses we expect or predict from a given attribute of biodiversity, at a given scale, and within the context of the specific threatening process affecting that attribute. For example, tree and shrub regeneration at the patch scale is one predicted response to fencing for one narrow attribute of biodiversity (trees and shrubs).

Any predicted response, often expressed as a desired response, is based on some sort of model. These models are often nothing more than wishful thinking, but even this is usually based on some sort of conceptual understanding of how a vegetation ecosystem works. In column 3 of Table 3, we can identify our conceptual model(s) instead of ignoring them. Models are a useful and essential means of simplifying the complexity of ecosystem processes across time and space. An assessment of the benefits of vegetation enhancement activities needs to be based on available models and should aim to improve these models.

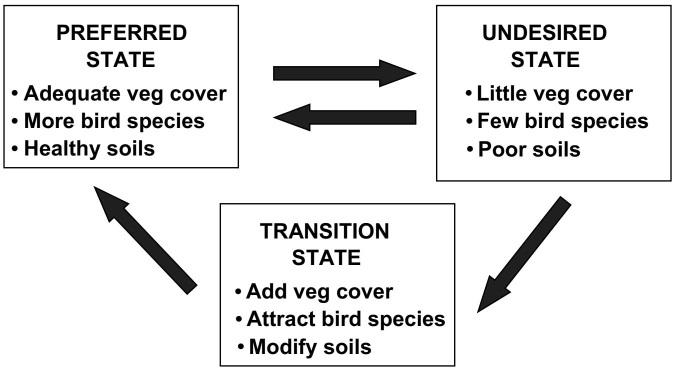
The State and Transition model (Westoby et al. 1989; Fig. 2) probably underpins many people's understanding of what vegetation enhancement might accomplish. Most of us have at least a mental model of what we perceive as an 'undesired state' and have some sort of an idea of a 'preferred state'. The rationale for vegetation enhancement activities is to assist in the 'transition' from the undesired state to the preferred state. Application of the State and Transition model helps clarify exactly what a land manager or policy maker intends to achieve, by defining attributes or characteristics of the preferred state compared to the undesired state.

Healthy trees, trees with hollows, woodlands with diverse understorey structure, landscapes that leak less water and nutrients are attributes of many people's preferred state. Others may have a preferred state called 'pre-1750', though the attributes of this state are largely unknown and lead to a lot of debate and angst (Benson and Redpath 1997). The biodiversity benefits of vegetation enhancement ought to be assessed against the attributes of stakeholders' preferred states.

The predicted-responses columns of our assessment framework (Table 3) should include attributes of the preferred state. The State and Transition model can help us understand the range of possible enhancement activities which

Step 2: State the desired or predicted response to vegetation enhancement activities

Scale	Management intervention	Model	Predicted biodiversity responses		
			Composition	Structure	Function
Patch					
Landscape (subcatchment)					
Region					



State and Transition Model
(after Westoby et al. 1989)

may be required for the transition from the undesired state to the preferred state. If better water use (less percolation to the water table) and profitable farm enterprises are the only major attributes of a stakeholder's preferred state, then expanding the cover of a deep-rooted perennial pasture plant such as lucerne may be the only vegetation management technique required for the transition to that preferred state. However, if stakeholders also want to have diverse native wildlife within the landscape of concern, then transition to the preferred state may require fencing of remnant vegetation and replanting of a number of native species to recreate a complex habitat structure.

CSIRO could have expended all the resources it committed to this consultancy just on reviewing the many field and remote sensing methods that can be used to assess attributes of biodiversity that might respond to vegetation enhancement. However, in our proposed assessment framework (Tables 3 and 4), the choice of method depends on the assessments in all the other columns and rows.

The choice of methods for detecting change depends on:

- scale,
- biodiversity attributes of interest,
- type of management intervention,
- the expected response to the intervention, and
- the model that underlies the desired response.

Methods suitable for monitoring and assessment at the patch scale can include wildlife surveys, if that sort of compositional attribute of biodiversity is of interest. Piezometers that detect changes in the shallow water table may be all the technology required for assessing the effects of an agroforestry block on drainage of water below the rooting zone. The 'Habitat Hectares' scoring system developed by Natural Resources and Environment (NRE) Victoria, is useful for the rapid measurement of (mostly) structural attributes of biodiversity at the patch

Step 3: Choose or develop methods for detecting and monitoring change in biodiversity attributes as a response to vegetation enhancement

Scale	Method appropriate for each attribute at each scale			Required time scale	Required spatial replication
	Composition	Structure	Function		
Patch Landscape (subcatchment) Region					

scale, within the context of some structural attributes of biodiversity at the landscape scale (Parkes et al. 2003). The ‘Ecological Benefits Index’ being developed by NSW Department of Land and Water Conservation (DLWC) specifically assesses the potential benefits of vegetation enhancement activities, again mostly at a patch scale (Oliver 2002). NSW National Parks and Wildlife Service (NPWS) is developing ‘Biodiversity Benchmarks’ with the aim of quantifying mainly structural attributes of biodiversity that are found in relatively intact patches of remnant native vegetation (P. Gibbons pers. comm.).

Our four-step assessment framework provides a broad context for patch-scale methods that rapidly and repeatably assess the benefits of enhancement activities for some important structural attributes of biodiversity.

At the landscape scale, repeat aerial surveys once every five years may be all that is needed if increases in the patch sizes of remnant woodland and the density of riparian vegetation are the expected responses to fencing at the scale of a subcatchment. An analysis of relatively inexpensive Landsat TM satellite data over a ten year time series may be all that is needed to assess cumulative changes in woody vegetation cover at a catchment scale, if woody cover is the structural attribute of interest.

The technical application of these relatively simple methods should not be underestimated. Even something as apparently simple as surveys of woodland birds is fraught with assumptions, errors and compromises (Recher 1988, Mac Nally and Horrocks 2002). Analysis of remotely sensed data requires careful scene rectification, well stratified ground truthing and sophisticated statistical algorithms to reduce sampling and interpretation errors over a time sequence of many scenes.

We suggest that our assessment framework is a useful starting point from which to engage community stakeholders, ecologists and statisticians in developing detailed monitoring procedures and methods, but only after the other elements of this framework have been addressed: scale, attribute, threat, intervention, response and model.

In the final step of our assessment process we apply the monitoring methods of choice, focused at the critical scale of interest and on the biodiversity attributes of greatest concern. This step is for assessing measured *outcomes* against expectations. Before assessing outcomes, we can also use the matrix (Table 5) to assess whether *inputs* such as fencing and revegetation have actually been carried out as planned. This part of the matrix easily accommodates the current Bushcare Monitoring and Evaluation Program, which is assessing whether planned enhancement activities have been substantially implemented.

Table 5, the final matrix, encapsulates all the key features of the assessment framework. It forces the user to consider scale, and choose ideally at least three biodiversity indicators that include attributes of composition, structure and function. The final matrix also requests the user to articulate the predicted or desired outcomes of the various planned and implemented enhancement activities.

Step 4: Apply the monitoring methods to detect changes; assess them against the responses predicted

Scale	Inputs		Observed response (outcomes)			Predicted response		
	Planned activities	Actual activities	Composition	Structure	Function	Composition	Structure	Function
Patch								
Landscape								
Region								

Many vegetation enhancement projects are simply too recent to have their outcomes assessed. As mentioned above, the final matrix also allows biodiversity benefits to be predicted from *inputs* if they (on-ground activities) have been mapped and if appropriate predictive models are available to assess on-ground outputs. This predictive approach to assessing biodiversity benefits is further developed as a recommendation in Section VI of this report.

The simple 3 x 3 matrix of biodiversity attributes by scale (Table 2) has grown to become a complex multi-dimensional series of matrices. We do not expect that the framework could ever be fully applied at any scale, never mind a range of scales. The framework clearly shows that assessing the biodiversity benefits of vegetation enhancement is not a trivial process. To assess these benefits with scientific rigour, across a range of scales and including attributes of composition, structure and function, is perhaps an impossible task. We have little understanding of how biodiversity works at anything larger than the scale of a few hectares. A superficial application of this framework to 44 case studies, (see Appendix) has provided considerable insight and should prompt further discussion and research.

The framework takes some thought when it is being filled in. Once completed, the framework facilitates detailed assessment across an unlimited number of attributes of biodiversity across all any scales of interest. Alternatively, the framework can be used to assess a single vegetation enhancement activity at a single patch focusing on individuals of a single species. The framework allows an assessor of a single patch to place the assessment in a much broader context. It allows the assessor to think about status, threatening processes, predicted responses to management interventions and the underlying conceptual or theoretical models.

In the following sections we outline insights gained from an initial application of this framework at national and regional scales.

IV. National application of assessment framework

We have applied our four-step assessment framework at a national scale to examine some potential biodiversity benefits of Commonwealth, state and private vegetation enhancement activities.

The Land and Water Resources Audit has recently completed a national analysis of threatening processes (LWRA 2001). The LWRA report provides a summary statistic for 'landscape stress' at the scale of IBRA sub-regions. The audit calculated stress on the following threats and attributes of biodiversity:

- extent of native vegetation cover, and cover protected by conservation reserves (structure),
- degree of connectivity (structure)
- extent of changed soil conditions (function),
- degree of changes in hydrological conditions (function),
- distributions of feral plants and animals (composition),
- threatened ecological communities and species (composition),
- current rates of clearing of native vegetation (threatening process),
- trends in dryland salinity (threat),
- inappropriate fires regimes (threat).

In a separate report to Environment Australia, Harvey and Freudenberger (2003) assessed whether the broad management interventions funded by the Commonwealth match levels of 'landscape stress' amalgamated up to the scale of IBRA regions. The report shows that more funding per hectare was generally invested in regions with high stress and less funding per hectare in regions with lower stress levels.

Unfortunately, there are very few data sets that can be used to assess whether the benefits of vegetation enhancement funded by the NHT or previous programs have reduced any of the landscape stresses (threatening processes) documented by the audit. The best data set reveals changes in vegetation cover, due to the availability of time-sequence satellite imagery. The further application of our assessment framework at the national scale focuses exclusively on change in cover due to clearing. This is recognised as a major threatening process, with the greatest losses occurring in agriculturally productive regions of Australia (Australian State of the Environment Committee 2001). About half of Australia's woody cover (92.5 million ha) has been cleared since European settlement, and that estimate does not include cleared grasslands, heathlands and sparse woodlands (BRS 2002).

Among other objectives, the Natural Heritage Trust vegetation enhancement activities were intended to prevent any net loss of native vegetation across Australia. This broad objective has underpinned many vegetation enhancement activities including protection of existing native vegetation.

A number of land-cover change projects over the past few years have been assessed by a combination of satellite imagery, aerial photos and ground surveys (Department of Natural Resources 2000; Bedward et al. 2001; Cox et al. 2001; ERIC 2001; Queensland Herbarium 2001).

The survey methods of Step 3 above were applied to land cover in NSW and Queensland. During the period 1997–1999, approximately 446,000 ha/yr of remnant vegetation was cleared in Queensland (Queensland Herbarium 2001). This does not include the 142,000 ha/year of regrowth vegetation that was cleared during this period, as estimated by the Statewide Landcover and Trees Study (Department of Natural Resources 2000). In NSW, during the period 1997–2001, approximately 60,000 ha/year were cleared (Bedward et al. 2001; Benson 2001; Cox et al. 2001).

Less detailed analysis of land-cover change by the Bureau of Rural Sciences (BRS) during 1990–1995, for all of Australia, included both decreases in cover due to clearing and increases in cover due to on-farm tree planting and plantations. Estimated annual rates of decrease in woody cover resulting from clearing for agriculture and grazing was 292,000 ha/year, offset by only 83,000 ha/year of plantings. These clearing rates contribute to more land being cleared in the past 50 years than were cleared in the previous 150 years (Australian State of the Environment Committee 2001).

Clearing of native plant species destroys habitat for thousands of other species. For example, 1000–2000 birds permanently lose their habitat for every 100 ha of woodland that is cleared. The clearing of mallee kills on average more than 85% of the resident reptiles and more than 2000 individual reptiles per hectare (Australian State of the Environment Committee 2001).

Clearly, the vast scatter of vegetation enhancement activities implemented across Australia during the past ten years has not stopped the clearing, nor have rates of revegetation substantially offset rates of loss. Two centuries of gross habitat loss due to replacement of native vegetation with crops, pastures, roads and cities has yet to be halted. The consequences are on-going loss of viable populations of many species, and functional losses resulting in erosion, declining water quality and expanding areas of dryland salinity (Australian State of the Environment Committee 2001).

V. Regional assessment: case studies

We have applied our assessment framework within a diverse sample of regions across Australia (see Appendix). To do that, we have made an extensive search of the published literature; we have conducted email and phone interviews of selected regional Bushcare Facilitators and managers of large NHT-funded projects; and we have examined a selection of Bushcare Monitoring and Evaluation reports.

Step 1 (threats and interventions) was simple to apply to most projects. The broad threatening processes and on-ground actions needed to reduce these threats are widely known. Similarly, Step 2 (desired responses) was easy to apply, although predicted responses based on statistical models or application of regionally specific guidelines were rarely available. Few projects have developed and applied methods to monitor outcomes (Step 3), and few have assessed them against predicted benefits (Step 4). Very few projects have adequate documentation of outputs, or of the activities that have actually been implemented on the ground. Of the over-13,000 projects funded by the NHT, only a few appear to have adequate baseline data from which to make any rigorous assessment of the predicted benefits or the actual outcomes for biodiversity. Nor could we find many projects that have assessed the benefits from previous programs such as pre-NHT Landcare and One Billion Trees.

Only a handful of projects have assessed outcomes of vegetation enhancement activities, and they have mostly been small research projects, many of them conducted by honours students or volunteers. The investment by the Commonwealth and the states in assessing the biodiversity benefits of vegetation enhancement is minimal with the exception of some research projects managed by the Rural and Industries Research and Development Corporation (RIRDC) and Land and Water Australia (LWA).

The 44 case studies outlined in the Appendix have shown us that some of the information is anecdotal and time-consuming to track down. The studies provide too little data to permit any conclusive statements to be made about the biodiversity benefits of vegetation enhancement, particularly at scales larger than a small catchment. We have gained some insights from this review of project-based data which provide a starting point for further discussion, development and testing. The insights are presented below, organised within the assessment framework.

Insight 1. *Small-scale revegetation projects can provide occupiable habitat for a remarkable diversity of woodland and forest birds.*

There is evidence from a mere six case studies that mixed species plantings of native trees and shrubs provide occupiable habitat for some birds which are showing regional declines in eastern and southern Australia (case studies 8, 9, 11,17, 38 and 44). We do not know whether revegetation is providing habitat adequate to support viable populations of woodland birds, or only a sink for dispersing juvenile birds with high mortality rates because they are occupying suboptimal habitat.

Insight 2. *The habitat values of revegetation will change with time and are dependent on broader landscape characteristics.*

It may take decades to detect biodiversity benefits that result from protecting remnant vegetation from continuous livestock grazing. Recruitment of trees and shrubs appears to be episodic and driven by climatic variability. The habitat value of revegetated patches will change rapidly as trees and shrubs grow from planted seeds and seedlings. The habitat values of the revegetation will change for centuries, as today's seedlings eventually grow old enough to support hollows for the wide range of hollow-dependent vertebrates and invertebrates. Today's small and isolated patches of revegetation may some day become centres in a connected network of corridors and enlarged remnants, as the slow but cumulative effects of small individual efforts merge into significantly altered landscape patterns.

Insight 3. *Large-scale (commercial) plantations (native and exotic trees) provide occupiable habitat for a wide range of birds and some mammals and unoccupiable habitat for other species, particularly native understorey plants.*

Ironically, we know more about the habitat values of plantations than we do about small scale NHT-funded vegetation enhancement activities. The research of David Lindenmayer and his numerous colleagues (case study 30) provides a detailed and comprehensive examination of the habitat values of pine plantations in the region of Tumut, NSW, in comparison to patches of native forests of various sizes. A similar study has been conducted within the pine matrix and remnant patches along the coastal escarpment of southern NSW (case study 29). Both these studies have showed that although some taxa (birds, mammals and insects) found in eucalypt forests have colonised the matrix of pines that replace the eucalypts, other taxa have been lost from remaining small eucalypt patches and are only now found in relatively intact expanses of eucalypt forest.

In contrast, large scale *Eucalyptus globulus* plantations in south-western Western Australia offer limited habitat value for native vertebrate species and may pose a threat to native vegetation by introducing an invertebrate pest species of *E. globulus* not normally found in WA (case study 41). The *E. globulus* plantations provided little habitat structure because of their very simplified understorey. However, these *E. globulus* plantations may yield significant off-site benefits by reducing the risk of secondary dryland salinity. Other plantation studies have also shown the importance of internal block patchiness and diversity of plantings (case studies 31, 34, 35, 39). A current study is examining the habitat values in subtropical planted and naturally regenerating forests in south-eastern Queensland (case studies 32, 33).

Insight 4. *There is some evidence from temperate woodlands in eastern and Western Australia that fencing remnant vegetation improves the regeneration capacity of native plant species.*

Considering the many millions of dollars spent on fencing incentive programs to protect remnant vegetation from continuous livestock grazing, there is little demonstrated benefit of this fencing (case studies 18, 20, 44). There is an expectation that regeneration of native trees, shrubs, grasses and forbs will occur, but rigorous evidence to support this expectation is generally lacking. Some studies have shown that fencing is not enough on its own, although it is an essential condition. Additional management interventions are required, such as understorey sowing or radical disturbance such as small-scale topsoil removal (case studies 20, 44).

Insight 5. *There is little quantifiable evidence, so far, that vegetation enhancement activities such as fencing and sowing of understorey species have a significant impact on increasing patch structure (i.e. habitat complexity).*

Many on-ground works such as fencing and sowing of understorey (a relatively new practice) have begun too recently for there to be enough data to quantify their benefits. There are project proposals to model changes in habitat structure over time (J. Langridge pers. comm), but few monitoring programs actually measure changes over time and space. The innovative Habitat Hectares assessment method can rapidly assess the current structure against benchmarks and estimate relative predicted benefits (Parkes et al. 2003), but actual structural changes have not been quantified.

Insight 6. *Few studies so far have demonstrated any functional benefits of vegetation enhancement at the patch scale except for wind reduction.*

Vegetation enhancement activities have the potential to intercept rainfall before it percolates to the water-table, reduce the risk of dryland salinity, improve pollination, increase soil fertility and enhance other ecosystem services. One comprehensive demonstration of the functional benefits of on-farm woody vegetation is its ability to reduce wind velocity (Cleugh et al. 2002). However, the reduction in wind is only weakly linked to improved crop productivity except in those environments where blasting by wind-driven sand can cause significant crop losses. The benefits of woody vegetation to crops is offset by competitive interaction, for water for example. The functional benefit of native vegetation is an area of active field research and modelling.

Insight 7. *There is limited evidence, so far, that vegetation enhancement activities have improved the population viability of locally or regionally threatened species.*

There is potential to use the databases of the National Bird Atlases I and II (1981, 2001) to assess changes in bird occurrences in subcatchments in which native vegetation has increased in condition and extent. This has not been done so far. The benefit of vegetation enhancement activities in conserving threatened flora requires further investigation.

Insight 8. *There is little evidence, so far, that vegetation enhancement activities have significantly increased the sizes of remnant vegetation patches, or decreased their isolation at the scale of a subcatchment.*

We are not aware of any studies that have mapped increases in native vegetation cover and connectivity over the last decade or so. Such mapping could be done relatively easily with aerial photography or satellite imagery. The only documented large increases in woody vegetation cover are in areas where commercial plantations have significantly expanded into former farming country (in south-western WA, for instance). These could be good baseline data on which to base further assessments.

Insight 9. *There are few data, so far, to demonstrate the biodiversity benefits of constructed vegetation corridors.*

A large proportion of NHT-supported projects have been involved in constructing corridors or shelter-belts. For example, there were 34 Bushcare projects with the word ‘corridor’ in the project title in NSW alone during 1999–2000. Constructed corridors have the potential to both benefit and diminish a wide range of biodiversity attributes (Bennett 1999). We only found three studies (case studies 11,14, 44) that examined occupancy of constructed corridors by vertebrates. Two of these studies only considered birds. No studies have demonstrated the *need* for corridors, but some studies have found that various taxa *use* corridors, although no distinction has been made between permanent occupation and temporary use.

Insight 10. *There is no evidence, so far, that vegetation enhancement has significantly improved functional attributes such as water quality and nutrient retention, or led to reduction in dryland salinity.*

The potential functional benefits of vegetation enhancement activities can be modelled, but so far have not been demonstrated. For example, Herron et al. (2002) modelled the effect of a 10% increase in tree cover intended to reduce salinity in the headwaters of the Macquarie River, and predicted a 17% reduction in inflows to Burrendong Dam.

In many cases the opportunity to demonstrate the functional benefits of revegetation has been lost because too few data have been collected before vegetation enhancement, against which to assess changes after enhancement. The best that can be done is to monitor subcatchment function and assess it against modelled (predicted) subcatchment behaviour. The CSIRO Heartlands Initiative aims to assess changes in the function of subcatchments, both from prevegetation conditions and from modelled behaviour (www.clw.csiro.au/heartlands).

Insight 11. *There is no evidence, so far, that vegetation enhancement has significantly improved the status of regionally threatened species.*

We are unaware of any 'de-listing' of regionally threatened species anywhere in Australia except for the estuarine crocodile in northern Australia. The National Bird Atlases I and II (1981, 2001) could be examined to see whether any of the reported increases in species between the two sampling periods might be related to increases in native vegetation protection.

Insight 12. *There is no evidence, so far, that significant increases in woody cover have occurred except in regions with commercial forests planted in previously cleared agricultural landscapes.*

As noted in our national scale assessment in Section IV, there has been a net decrease in the national cover of woody vegetation. We are unaware of any studies that have comprehensively documented changes in woody cover across all bioregions. In bioregions which show some increases in woody cover, most is probably due to commercial forestry, which is dependent on just a few exotic and native species of trees.

Insight 13. *There is no evidence, so far, that vegetation enhancement has contributed significantly to achieving catchment-scale targets for water quality (with respect to salinity levels).*

In the past decade, the reduced rate of increase in water salinity levels at Morgan, South Australia, have been attributed to engineering works (such as salt interception schemes) rather than to vegetation enhancement activities such as revegetation. End-of-catchment salinity levels in the Murray-Darling Basin are expected to rise unless large-scale revegetation occurs over the next few decades (MDBC 1999).

Most knowledge and active assessment of the biodiversity benefits of vegetation enhancement is at the patch scale and focuses on a few taxa within the broad compositional attributes of biodiversity. The few data that are available are promising.

- At the patch scale, some vegetation enhancement activities can improve the probability of natural regeneration and provide occupiable habitat for an increased diversity of woodland birds and some other taxa.
- At the patch scale, the benefits of vegetation enhancement are dependent on the variety and scale of activities such as revegetation as well as proximity to existing remnant vegetation.

We need to remind ourselves that any complex process has some simple elements. We need to remember that native vegetation is a critical element of biodiversity and that 10–20 years of vegetation enhancement activities in many parts of Australia have provided some important information that was not known 20 years ago:

- Native trees and shrubs can be established and grow rapidly in highly modified landscapes. The previous paradigm was that only exotic tree species such as pines could be established in highly altered landscapes such as exotic pastures. The survival and growth rates of native trees and shrubs have surprised a lot of landholders and policy-makers.
- Quite species-diverse plantings of native vegetation can be successfully established at least at the scale of a few hundred hectares. Direct seeding techniques for native species have been developed after many difficulties and with limited budgets, and they are major innovations. This is remarkable progress when compared to the massive resources put into establishment technologies for plants like wheat and lucerne.

It is still very early days. At a regional scale, the investment in vegetation enhancement is still only a few dollars per hectare. Too little vegetation enhancement has hit the ground to make a detectable difference at the regional scale. Even so, some positive responses are being detected at the patch scale. Some attributes of biodiversity are responding to vegetation enhancement in a way desired by a wide range of interested people.

The past 20 years of vegetation enhancement activities are beginning to show what is possible. If nothing else, some vegetation enhancement projects provide tangible visions for the future, rather than fuzzy words such as 'ecological sustainability' or abstract targets such as '30% cover of native vegetation'.

Much has been learned. The first Natural Heritage Trust (NHT1) has supported over 10,000 projects involving hundreds of thousands of people. The cumulative benefit to biodiversity is still low at present, but the cumulative experience gained from this expenditure is enormous. The challenge is to convert this cumulative experience into collective knowledge. The assessment framework presented in this report may help develop this collective knowledge if the framework is applied over sufficiently varied patches, landscapes and regions.

VI. Recommendations

The following subsections recommend ways to further this preliminary and cursory assessment of the biodiversity benefits of vegetation enhancement. We also make recommendations regarding future investments in natural resource management in the light of the lessons learned from previous investments.

The majority of vegetation enhancement activities are still too recent to have had a profound impact on biodiversity. The benefits of these activities may not be detected for decades or even centuries. It will take at least 100 years before hollow-nesting animals can find hollows in the millions of eucalypts that have been planted over the past decade. It takes that long for trees to become old enough and damaged enough to support hollows (Gibbons and Lindenmayer 2002).

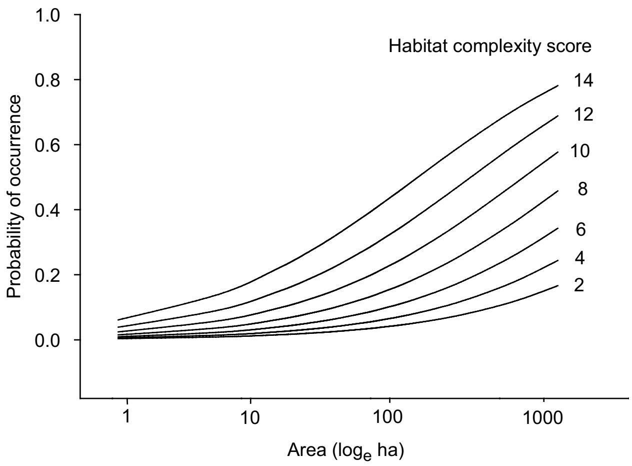
It will take considerably more planting and time before significant increases in woody cover can be detected at a regional scale from satellite images, with the exception of commercial plantations. It is thus not surprising that we found only a few case studies where the benefits of vegetation enhancement have been examined, because there are only a few areas where the enhancement activities are old enough to be assessed.

In the meantime, our assessment framework allows for the analysis of predicted benefits. Step 2 makes explicit the responses desired from vegetation enhancement activities. For some attributes of biodiversity, in some regions, there is a reasonable scientific understanding of what can be expected from enhancement activities such as revegetation, and it is possible to assess the potential benefits of vegetation enhancement inputs. At the patch and landscape scales, enhancement inputs such as fencing of remnants and revegetation can be assessed against best practice guidelines and predictions such as:

- remnants should be enlarged to at least 10 ha in area (Watson et al. 2001);
- shelterbelts and riparian corridors should be at least 30 m wide (Kinross 2000);
- woodland-dependent birds are 12% more diverse in broad strips of native vegetation than in narrow strips (<50 m) (Barrett 2000);
- 10% of a landscape should be dedicated to conservation (McIntyre et al. 2002);
- remnants at least 10 ha in size should not be more than 1 km from other sizeable patches (Freudenberger 2001);
- for every 10% increase in tree cover, bird diversity increases by 7%, exotic birds decrease by 21% (Barrett 2000);
- bird diversity will be re-established 15 years after the removal of stock from heavily grazed remnants, reaching a maximum diversity after 25 years (Barrett 2000);
- a well vegetated river or creekline will provide a 21% increase in woodland dependent birds (Barrett 2000);
- in rangelands, land is needed that is greater than 8 km from the nearest permanent watering point in order to conserve the species sensitive to grazing and proximity to water (James et al. 1999).

These kinds of regionally specific guidelines have been developed from analysis of empirical data or developed from theoretical models of processes such as fragmentation. Example ouptut from an empirically derived model is shown in Figure 3. Similar models are being developed for groups of woodland birds found in revegetated patches of woodland varying in age from 3 to 10 years (J. Reid, pers. comm. based on data from Taws 2002).

The potential benefits of vegetation enhancement activities can be predicted if the following spatially explicit input data are available:



The probability of occurrence of the brown treecreeper as a function of patch size and habitat structural complexity (condition) in mature woodland remnants in the northern ACT and surrounding NSW (Watson et al. 2001).

1. vegetation cover and composition prior to on-ground works, mapped at a fine resolution (at least 100 m^2) and available over the entire subcatchment landscape;
2. all on-ground works (e.g. fencing and revegetation) accurately mapped as a GIS overlay of the prior vegetation cover and composition maps;
3. explicit details of the management interventions within each mapped polygon of enhanced vegetation (e.g. species composition of overstorey and understorey plantings, weed control or fire).

The potential benefits of these inputs can then be assessed against such parameters as:

- increase in native vegetation patch size,
- decrease in isolation,
- potential increase in vegetation condition due to fencing, weed control and understorey enhancement.

The input (actions) documented in the NHT administrative database, including new data being obtained by the Bushcare Monitoring and Evaluation Program, are inadequate for use in predicting biodiversity benefits. Input statistics such as kilometres of fencing or total area of revegetation need to be spatially explicit. Twenty kilometres of fencing and 10 ha of revegetation for corridors will probably have a very different biodiversity benefit than same amount of fencing and revegetation to protect and enhance existing remnant vegetation. Similarly, simple statistics such as the total hectares of remnant vegetation protected are not very informative. The information needed is the configuration and size of each protected remnant. Prediction of the biodiversity benefits of vegetation enhancement activities is not a trivial exercise: it requires good quality input data.

With spatially explicit input data, the potential benefits can be assessed against the known habitat requirements of those few charismatic species, such as woodland birds, for which there is some knowledge in some regions (e.g. Barrett 2000). This type of predictive assessment of biodiversity benefits is most likely to be useful in those regions where there have been concentrated and coordinated on-ground efforts across an entire catchment. There is also potential to assess on-ground actions against functional models of biodiversity such as subcatchment hydrological models where the potential benefits of revegetation for reducing salinity could be assessed in those few subcatchments with appropriate hydrological models. The benefit of tree revegetation could also be assessed against models that simulate the effects of trees on wind and agricultural productivity (Carberry et al. 2002).

Find or commission maps *after* on-ground works in IBRA regions which have received significant funding and have detailed vegetation maps which were made shortly before on-ground works commenced.

Outcomes of the predictive assessment could include:

- predicted benefits for biota such as woodland birds (compositional benefits),

- predicted changes in subcatchment vegetative cover (structural benefits),
- predicted benefits for subcatchment hydrology (functional benefits),
- predicted benefits for agricultural productivity (functional benefits).

However, there are all too few predictive models that are useful for assessing the potential benefits of vegetation enhancement. New models, which need to be regionally tested, will be expensive and time-consuming to develop. Strategic investment in the development of new models is required, with priority placed upon developing assessment models for IBRA regions which have received considerable funding (e.g. Tasmanian Midlands). Funding should be a joint initiative of Environment Australia, AFFA, Land and Water Australia, CSIRO and relevant state agencies.

Support is needed for developing better predictive models for assessing the biodiversity benefits of vegetation enhancement activities.

One of the lessons learned from this consultancy is that spatially and temporally explicit data are absolutely essential. The biodiversity benefits of vegetation enhancement are entirely dependent on spatial context. The benefits of fencing remnant vegetation or the construction of corridors can only be assessed by knowing how large the fenced remnants are, how wide the corridors are, and what they connect to. Assessment of benefits is also time-dependent. When the fence went in or when the trees were planted is just as important as what they were and where they were positioned. The biodiversity benefits of revegetation activities will change with time; thus basic data such as the commencement and completion dates of on-ground activities are essential.

Future government co-investments in on-ground works should support a mapping component for all large projects.

Maps should include GIS (geographic information system) layers of pre-investment vegetation cover and layers of past, current and projected vegetation enhancement activities. Every mapped polygon of on-ground works should be linked to a database that documents when the activity took place and what occurred.

GIS software and mapping technology such as GPS (global positioning systems) are now inexpensive enough to be considered essential infrastructure for any large project; just as essential as a computer, fax and vehicle. Every large project, including devolved grant schemes with over $100,000 in government support, should include a mapping and database component.

Our review of case studies which have effectively demonstrated the biodiversity benefits of vegetation enhancements at a patch and landscape scale (see Appendix) indicates that assessment of outcomes is essentially a research process. Community volunteers including landholders can and should be involved in assessing benefits, but it needs to be done with input from professional researchers. The Australian Bureau of Meteorology provides a case in point. It relies on community members in remote locations to monitor temperature and rainfall, but a large staff of professional meteorologists then assesses and prescribes exactly how equipment is installed and read, i.e. the methods. These basic data are used to create sophisticated weather forecasts using complex computer models. Monitoring and assessing something as apparently simple as rainfall, temperature and pressure is in practice a highly complex and sophisticated process. Monitoring and assessing changes in native vegetation cover and composition is an even more complex process that requires substantial resources.

At least 1% of natural resource management funding should be allocated to assessment of the returns on investment. Returns consist of beneficial changes in the compositional, structural and functional attributes of biodiversity.

The Commonwealth Government has committed $5 billion for NHT2 over another five-year period (www.nht.gov.au/overview.html). A 1% allocation from this pool of funding would be $10 million ($2 million/yr). At this level of funding approximately 20 monitoring and assessment research projects could be funded at $100,000 per year (a minimal cost to conduct significant field-based research). These projects should be conducted in the ten IBRA regions which have received the greatest amount of natural resource management funding over the past decade (funding per IBRA region is summarised in Harvey and Freudenberger 2003). High-investment regions should receive high levels of monitoring and assessment in order to determine the outcomes of vegetation enhancement activities. The number of research projects could be substantially increased with co-investment from the states.

Our assessment framework can be used for designing the broad features of any research project set up to assess biodiversity outcomes of vegetation enhancement. The framework explicitly relies on the participation of land managers to, at minimum, identify management interventions and desired outcomes. When applying our assessment framework, participants need to identify the main scales and attributes of biodiversity of interest as well as apparent threats to those attributes. Effective assessment of biodiversity benefits is an inclusive process that depends on both professional research input and participatory input from land managers.

The Land and Water Resources Audit process should be repeated at regular intervals to assess the benefits of natural resource management interventions at regional and national scales.

At the regional scale, assessing biodiversity outcomes from vegetation enhancement activities is easier than assessing benefits at the patch and landscape scale. Indicators at the regional scale are simpler, e.g. native vegetation cover and broad configuration. The Land and Water Resources Audit has provided a trans-regional assessment of biodiversity and landscape health as of about the year 2000. The Audit's measures of biodiversity and landscape health ought to be repeated in about a decade. It is likely to take that long for the cumulative benefits of the many thousands of on-ground activities to emerge as significant changes at the scale of IBRA sub-regions.

Future investments in natural resource management through programs such as NHT2 ought to build on the lessons learned from previous initiatives. So what has been learned?

- Protection is cheaper than repair (PMSEIC paper by Possingham et al. 2002). It is far cheaper to protect native vegetation from the destruction of clearing, continuous grazing and weeds than to attempt reconstruction of native vegetation. Reconstruction not only requires control of grazing and weeds, but also requires the conversion of land that has much higher agricultural values than intact native vegetation.
- Australia's economy has ceased to be dependent on the expansion of agriculture. Australia can now afford to protect the native vegetation that is left rather than continually destroy it in favour of marginal gains in agricultural productivity that the economy does not need. The failure to halt the net loss of native vegetation in clearing was a significant weakness of NHT1.

Future investments should first focus on protecting Australia's native vegetation from further net loss.

In a related but separate report by Harvey and Freudenberger (2003), past Commonwealth investments in natural resources management were assessed by examining the relationship between levels of funding and the amount of landscape stressed (defined by the Land and Water Resources Audit at the scale of sub-IBRA regions). It was found that more funding per hectare was spent in highly stressed landscapes which required considerable repair. An alternative model is to spend more per hectare in moderately stressed bioregions that require less repair, but more protection.

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Appendix: Case study assessments of the biodiversity benefits of vegetation enhancement activities

We have found and briefly summarised 44 case studies from around Australia that demonstrate, or have good potential to demonstrate, the biodiversity benefits of vegetation enhancements. We reviewed and assessed these case studies using the broad assessment framework developed for this report.

The case studies were extracted from the formal published literature, reports and conference proceedings. We also conducted extensive email and phone interviews with Bushcare Facilitators and the managers of NHT-funded projects. Many of the interviews were prompted by Bushcare Monitoring and Evaluation reports, although in themselves the reports provided little information from which to assess observed or predict potential benefits.

The majority of these case studies which most rigorously measured biodiversity benefits were participatory research projects. They involved professional research scientists, community volunteers and landholders. The contribution of amateur ornithologists was particularly important.

Few of the studies have data collected before the vegetation enhancement. Thus it has to be assumed that the conditions and taxa surveyed in cleared landscapes are representative of conditions prior to revegetation. Few studies have followed changes through time: most have only provided snap-shots of conditions and taxa.

Insights gained from the review of the case studies are provided in Section V in the main body of this report.

Drought Landcare project (1995–96)
Northern Midlands, Tasmania
Hassell and Associates Pty Ltd (1998)
Patches in a region

Increasing land degradation and acceleration of this process by drought

28 km conventional and electric fencing,
26000 seedlings,
4000 grass transplants,
35 kg seed direct seeded,
400 ha of remnant bush fenced

Reduced land degradation

Before and after photographs (not from a permanently marked photo point)

Three rare flora species regenerated naturally

Not known, follow up surveys offer sufficient opportunities for assessing benefits

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Midlands Bushweb
Northern Midlands, Tasmania
Louise Gilfedder (personal communication)
Region

Loss, degradation and fragmentation of native vegetation

Fencing, weed control, provision of off-stream watering systems

Rehabilitation of bush in poor condition which would encourage the return of small birds and mammals, and enhancement of the value of farm plantings for wildlife

Vegetation monitoring plots were established at 15 sites which had been involved in the Bushweb project. These have been permanently marked and will serve as long-term monitoring sites in the region. Numerous flora surveys were undertaken, and bird surveys at a number of sites.

Whilst there has been considerable inventory and survey in the region there is still no real sense of the biodiversity benefits of the project.

Too early to tell — we can only assume there have been benefits but they haven't been measured or reported.

East Coast drought Landcare project (Swansea and Triabunna)
1995–97 (61 projects over 47 properties)
Tasmania South East
Final Evaluation Report (1997) (not sighted)
Hassell and Associates Pty Ltd (1998)
The Natural Heritage Trust Evaluation Team (2001)
Regional

Land degradation, weeds (gorse and willow), and dune erosion on grazing land

Fencing of 110 ha of remnants, planting of shelterbelts, 14,000 tree seedlings,
90 kg tree and shrub seed sown, strategic weed control

Enhanced native vegetation

School children involved in some of the monitoring. Before and after photos and observations

60% of gorse and 90% of crack willow killed and 85% tree seedling survival (no time lapse data available). Negative effect on bandicoot population of gorse clearing (1997).

1998 — Better water quality through better erosion control
2001— Observed on ground works were mostly successful; stabilisation and regrowth was evident in riparian areas; shelterbelts and remnants have remained fenced, exhibiting some regrowth; dunes have become stabilised; gorse and willows have been successfully removed.

Bushcare technical extension (BTE)
All of Tasmania
Kelman, J. (2002)
State

Lack of knowledge

Form a technical team of ecologists and botanists to help plan projects,
provide advice to and educate Bushcare groups

Better-integrated and more effective implementation of Bushcare

Document the many and varied ways BTE has aided the implementation Bushcare.

The dissemination of information has led to adoption of improved management principles at different levels throughout the community. The unique skills provided by the team have seen many projects reach fruition.

Not known or measured. A good group to follow up to obtain baseline data for further monitoring.

Blackwood biodiversity project, Blackwood Basin Group NHT Package
Jarrah Forest, Warren, Avon Wheatbelt
Blackwood Basin Group, M&E Officer Erica Shedley (pers. comm.), Bushcare M&E report NHT#983226
Upper catchment

Loss of (riparian) habitat, competition from weeds

3209 ha of remnants fenced, 56 ha revegetated,
46,000 seedlings established, 25 kg seed supplied

Improved habitat and water quality

Baseline photos taken by contracted assessors. Formal vegetation quadrats are present in 20% of sites (WA Wildflower Society and Green Corps). Birds Australia have sites in 20% of sites. Log book and diary observations by landholders in 5% of sites. Plans to revisit.

Quadrats and permanently marked sites but to date they have not been revisited.

Too soon for significant changes, baseline data exist.
Anecdotal notes on site evaluation report: “natural regeneration of reeds is occurring”, “good success rate”, “would impact on water quality on drain”.

Assessment of Landcare and other programs
Sydney Basin
Keith, D. (2002)
Region

Loss and degradation of temperate grassy woodlands

10 years of tree planting through Landcare and other programs

Natural regeneration of understorey

Compare restored vegetation with untreated pasture (control) and remnant vegetation (reference) in an expensive, well-resourced project

Outputs in terms of kilometres fenced and numbers of trees planted are reported but ecological audits are conspicuously rare. Diversity of plantings is poor. Understorey is dominated by weeds. Results suggest either a failure of ecological convergence or century-scale lags in the recovery process.

Full benefit will not be known for decades

Assessment of a large restoration project involving Landcare and other programs

Sydney Basin

Lomov, B. (2002)

Region

Loss and degradation of temperate grassy woodlands

Revegetation on the Cumberland Plains

Invertebrate fauna of revegetated sites become less similar to untreated pasture and more similar to the fauna of remnant bush

Invertebrate surveys, manipulated experiments to describe ecological processes such as pollination, seed dispersal, herbivory, predation and parasitism (research project)

Research in progress

Not known yet

Bringing back the birds

South Eastern Highlands

Taws (2002); Reid (2000a,b)

Regional: 55 properties and 15 reserves

Habitat loss, fragmentation and simplification

Planted plots ranging in age from 14 months to 15 years.
62 sites established by direct seeding and 40 by tubestock planting; 30 are control sites ranging from remnant woodlands to farm paddocks.

Birds will come back

Canberra Ornithologists Group (COG) looked at sites quarterly in 2000. Vegetation survey (height, number of plant species, size and shape of patch and surrounding land usage) conducted at each site.

A total of 104 different bird species were found to be using the revegetated sites including 13 species of regionally declining woodland birds

Birds were returning. Excellent survey which could be repeated at a later date.
Further modelling of data in progress (J. Reid pers. comm.).

Renaissance on ‘Lanark’ (Victoria, Western District)
Murray Darling Depression
O’Neill (1999)
Farm

Habitat loss and degradation

Patchwork of farm forestry blocks and shelterbelts
80,000 trees planted since 1967

Increase bird diversity and abundance

Observations by land owners with historical data

75 species including 15 woodland birds and many new wetland birds

Significant benefit to farm productivity and profitability. Long term benefits being realised.

Vegetation Investment Project
South Eastern Highlands
Greening Australia ACT and SE NSW; Freudenberger (1999)
Region

Habitat loss, fragmentation and simplification

Guidelines to buffer, link and revitalise patches of remnant vegetation.
Fencing of remnants and extensive revegetation.

Integrated and effective planning and implementation of vegetation enhancement works

Extensive baseline data collected on woodland birds and development of predictive models

Plantings and remnant protection too recent

Potential to model benefits if on-ground works mapped to the existing GIS

Birds on Farms

Barrett (2000)
National and Regional

Habitat loss

Fencing and planting guidelines

Native bird communities can be restored by vegetation enhancement activities

Bird surveys

430 bird species recorded over 330 farms in SW and SE Australia

Detailed predictive models of the benefits of vegetation enhancement for native birds

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Saltshaker
NSW South Western Slopes.
Freudenberger (2001)
Catchment (Boorowa)

Habitat loss, isolation and degradation

Guidelines to improve the native biodiversity through efficient enhancement of remnant vegetation. Fencing and revegetation implemented.

Declining woodland birds recover

Bird surveys and habitat assessments carried out by CSIRO prior to vegetation enhancement activities. All vegetation enhancement mapped.

Too soon to tell. Habitat values of older revegetation assessed by Taws (2002).

Predicted benefits to be assessed early 2003 by CSIRO

Boomey Landcare wildlife corridor (NE Orange), 1994–95 Drought Landcare project
South Western Slopes
Hassell and Associates Pty Ltd (1998)
18 km corridor

Loss of habitat, isolation of remnants

Planting and fencing 3 km per year

Encourage biodiversity, encourage wildlife movement and provide shelter

Continuing monitoring, e.g. echidna scrapings and birds. Before and after photographs.

Not stated

Re-establishment of bird and fauna habitats, provision of predators for insect control, a reduction in wind erosion. Opportunities for follow up of assessment surveys.

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a) Vegetation recruitment in a restored habitat linkage in tropical north Queensland (Donaghy's Corridor along Tooheys Ck)
b) Rainforest restoration along Tooheys Ck linking rainforest fragments on the Atherton Tablelands: use by birds
Einasleigh Uplands
a) Tucker and Simmons (in press); Simmons and Tucker (2002)
b) Jansen (2002)
1.5 km corridor

Loss and isolation of habitat

Planting over four years, weed control

Natural regeneration, use and colonisation by mammals of the corridor

Vegetation transects post-planting. Mammal mark and recapture. Bird surveys.

In as little as two years after completing the forest linkage there was colonisation by a range of small mammals and birds recognised as forest obligates.

Demonstrated utility of the linkage for small mammals and birds. Project can claim success in attempting to address fragmentation and isolation issues.

Weddin Landcare Corridor Links
NSW South Western Slopes
Jenny Schabel (Bushcare Facilitator); Weddin Landcare Steering Committee (pers. comm.); Freudenberger and Drew (2001)
Catchment

Fragmentation of habitat

Recreating dense corridors from scratch, in cleared farming landscapes, lots of fencing. Laborious site preparation, maintenance of tree guards and weeds. Mainly straight rows of tube-stock or direct seeding. Some (but minor) assisted natural regeneration in revegetated areas.

Better habitat connectivity in narrow corridors. Shrubby thickets for small birds.
Some erosion control, water-quality benefits in riparian areas.

CSIRO bird survey closely linked with project LA0348.98 and is repeatable. Some Bird Atlas and Field Naturalist bird monitoring activities have occurred or are planned in some areas. Some photopoints, and diary recordings by landholders. Monitoring and evaluation activities written in the application have not been achieved yet. Bushcare monitoring and evaluation site visits.

To early to tell

Assessment possible once all on-ground works are mapped; a detailed GIS exists for the area.

The utility to birds and mammals of remnant riparian vegetation and associated windbreaks in the tropical Queensland uplands
Einasleigh Uplands
Crome et al. (1994)
Farm

Habitat fragmentation, wind

Planting of native and exotic trees and shrubs in windbreak strips, 0.5 ha (20–25 years in age)

Birds would use windbreaks

Bird and mammal surveys

37 species of birds recorded, 14 in one windbreak.
No mammals recorded in the windbreaks.

Few birds typical of rainforest habitats were recorded in windbreaks despite the presence of many rainforest-dependent species in small rainforest remnants (<1 ha) along a nearby creek.

The potential of revegetation programs to encourage invertebrates and insectivorous birds
Avon wheatbelt
Majer et al. (2001)
Several patches

Habitat loss and degradation

Trees planted along roads as part of the Ribbons of Green program

Increased habitat for birds and insects

Bird surveys of plantings compared with use of remnant vegetation.
Invertebrates sampled by spraying canopies with pesticide.

26 birds recorded, 3 only in remnants and 6 only in the replanted areas.
Local trees planted along roads were being used by birds and providing habitat for invertebrates.

Recommend use of a variety of tree and shrub species from within the region. Herbs, logs and coarse woody debris should also be added.

The short term effects of stock exclusion in remnant grassy woodlands
Riverina
Spooner et al. (2002)
Landscape or Region: 24000 sq km

Grazing

Fencing

Tree and shrub recruitment will be enhanced when remnants are fenced off from grazing stock

Vegetation and soil surveys at 47 sites of paired fenced and unfenced sections of remnants

Tree recruitment in 59% of fenced sites compared to 13% of unfenced sites. Fenced sites also had a greater cover of native grasses. Tree recruitment was better where there was a greater cover of perennial native grasses.

Fencing arrested the decline of biodiversity in grassy woodlands. It is an important first step in the conservation of this vegetation community.
Recruitment response quite rapid after fencing (1–2 years).

Lachlan Remnant Vegetation Management Incentives
NSW South Western Slopes
Jenny Schabel (Bushcare Facilitator)
Greening Australia / Lachlan Catchment Management Board
Catchment

Degradation and loss of habitat

Fencing. Crash grazing once a year at max. in specific seasons was a condition of funding.

Better habitat through retention of woody debris, understorey regeneration, protection from continuous overgrazing

Landholder at a minimum to collect yearly photopoints and keep a diary of events.
Save the Bush toolkit (Charles Sturt Uni) distributed. Other monitoring options recommended.
Initial flora survey information provided.
There are approximately 260 sites for this project. Some may have adequate baseline data.
Many sites have been grazed this year due to drought (simulated disturbance event). The break of the drought should set off a significant regeneration event.

Too soon for a significant response

In Jenny's opinion this project has delivered many environmental benefits. Remnant protection must continue to be a priority. This project design could be easily modified to suit Catchment Blueprint implementation.

Arnhem Land Fire Abatement Program
Arnhem Land, Central Arnhem
Bill Panton (Jeremy Russel Smith and Peter Cook)
Region

Large scale wildfire

Controlled fires, implemented from aircraft

More patchy landscape, with a greater range of habitat types and ages. Fewer wildfires.

Satellite mapping fires; intensity size and frequencies.
Survey of Aboriginal food sources repeated after 27 years (John Altman CRES).

Little change in the food sources. Fewer wildfires.

More varied habitat

Effects of restoration treatments on the establishment of perennial shrub and tree species in degraded *Eucalyptus salmonophloia* (salmon gum) remnants

Avon wheatbelt

Yates et al. (2000)

Patch

Grazing, weeds

Fencing, various soil preparation techniques. In addition to the exclusion of livestock and the management of weeds and reintroduction of plant species, restoration of plant species diversity will require techniques which mimic large scale disturbances, reduce soil compaction and restore soil water infiltration.

Improved regeneration of *Eucalyptus salmonophloia*

Seedlings were planted into areas that differed with respect to grazing, tree canopy cover, and soil compaction. Growth was monitored seven times between July 1996 and 1998.

Exclusion of rabbits had no effect. Absence of tree canopy had a positive effect. Deep ripping aided both tree and shrub survival.

Increasing levels of intervention will increase the chances of successful restoration of tree and understory species diversity in degraded *E. salmonophloia* woodlands

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Four Hill Farm restoration project

NSW South-western Slopes

Bauer and Goldney (1998)

Farm

Habitat degradation

Destocking

Enhanced habitat

Vegetation mapping, flora and bird surveys

“Efforts are too much chance-directed to be meaningful and cost effective.”

Natural regeneration

Conservation and sustainable management of native grasslands in the mid-north

Flinders Lofty Block

Millie Nicholls (pers. comm.)

Lewis Kahn (pers. comm.)

Patch

Grazing

Fencing small areas (10 ha) and subdividing larger paddocks to implement rotational grazing

Increase in diversity of the vegetation in the grazed and ungrazed areas

Used 50 m transects to measure species presence/absence, richness, cover and dry weight in comparing four different grazing regimes at one site. Monitored annually.

27 sites, 100 m transect, with twenty 50x50 m quadrats: changes in pasture composition. Monitored annually but needs more money to continue. Simple transects set up on all funded sites but not revisited.

“Excellent information”

Research in progress

Vegetation restoration and landscape design for enhanced biodiversity conservation

Riverina

Lindenmeyer — current Land & Water Australia project www.lwa.gov.au/nativevegetation/p2_vege_restore.asp

Farm and landscape

Loss, fragmentation and degradation of native vegetation

Planting and fencing implemented.

Provision of guidelines.

Fauna will be using planted areas on farms

Bird and other animal surveys over three years comparing farms with plantings with farms without. Comparison of vertebrate abundance across a wide range of vegetation types within different landscapes and farm units.

Too soon to tell (Project running July 2001–July 2005)

Too soon to tell (Project running July 2001–July 2005)

Landscape planning for biodiversity conservation in agricultural regions:
Living Landscapes
Avon wheatbelt
Lambeck (1999)
Region

Habitat loss, fragmentation and destruction, predation by feral animals, weed invasion and inappropriate fire regimes

Planting and fencing

Retain biodiversity in agricultural landscapes

Application of the focal species approach based on bird surveys, to develop guidelines

Specifications of patch types, sizes and configuration

Guidelines in the process of being implemented

Enhancing biodiversity values in agricultural lands
Avon wheatbelt
Brooker et al. (2001a,b)
Subcatchment

Habitat loss, fragmentation and destruction

Planting and fencing

Habitat reconstruction guidelines bases on the focal species approach

Detailed vegetation maps of remnants.
Bird surveys.

On-ground works yet to implemented.
Excellent baseline data.

Too soon to tell

Bush for biodiversity: Reversing multiple bird species decline
Kanmanto
Andrew West, Bushcare Facilitator, Northern agricultural district (pers.comm.)
Regional

Loss, fragmentation and simplification of habitat

Fencing and planting

Restored bird habitat will reverse the decline in native bird species

Project in planning stage. Designing revegetation with specific goals in mind.

Too early to tell

Benefits will be easier to measure against specific goals rather than the general NHT goals of the past

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Pelican Point Revegetation
Einasleigh Uplands
Grundon et al. (2002)
Patch (20 ha) and landscape

Vegetation clearance for agriculture

Planting to recreate rainforest, tall wet sclerophyll forest, open woodland and swamp forest. Plantings in 1991, 1994, 1995 and 1996. Areas of grasslands left as well.

Enhanced biodiversity

Bird surveys (regularly since 1991) and small mammal surveys (every 3 months since 1996). Tree growth (initially assessed from 8 photo monitoring sites since 1994).
More detailed assessment carried out between 1998 and 2001 included vegetation plots, phenology, mammal trapping and bird counts. (NHT Project $15000 plus in-kind $23000)

Establishment and growth of trees good. There are now more forest species of birds, more native and fewer exotic species of mammals.

The area now attracts many different species of birds, mammals and other fauna. A good example of NHT funding for monitoring. A clear demonstration of the biodiversity benefits of species-rich revegetation.

Pine plantation/eucalypt remnant research at Wog Wog.
South East Corner.
Margules (1992)
Davies and Margules (2000)
Landscape

Habitat fragmentation

Sampled invertebrates before and after creating fragments of old eucalypt forest by clearing followed by planting of pines

Habitat fragmentation reduces biodiversity and reduction in biodiversity is dependent on fragment size. Detailed predictive graphs were drawn up for five groups of invertebrates over three sizes of fragments.

144 permanent plots in three fragment sizes replicated six times with stratification into slopes, drainage lines and inner and outer zones. Major invertebrate groups and vegetation sampled.

After seven years of sampling the many data should be able to provide an insight into beetle responses to fragmentation. Beetle species turnover was reduced in fragments.

Pine matrix appeared to have the potential to influence some species by allowing some species to become more abundant.

A large scale experiment to examine the effects of landscape context and habitat fragmentation on mammals and birds
South Eastern Highlands
Lindenmayer et al. (1999, 2002, 2003)
Patches and landscape

Habitat fragmentation within pine forest

Plantations (pine)

Loss of species from small eucalypt remnants

Surveys of mammals and birds in 40 sites in large contiguous areas of *Eucalyptus* forest, 40 sites in areas dominated by radiata pine plantations, and 86 sites in fragments of eucalypt forest surrounded by extensive pine plantation

Fragments of native forest within pine forests are occupied by several species of native mammals even where they have been isolated from the main native forests for years. Many species of birds use the pine matrix and small remnants. A few birds are more abundant in pines.

Fragments of native forest within pine forests should not be cleared

Birds, mammals, reptiles and amphibians in eucalypt plantations near Albury-Wodonga: A pilot study of variables influencing biodiversity

South Eastern highlands, Riverina

Kavanagh et al. (2001)

Kavanagh and Turner (1994)

Regional

Habitat loss

Plantations of eucalypt species

Plantation size, age, diversity and proximity to native vegetation influence bird species diversity

Bird, mammal, reptile and frog surveys

Plantation size, age, diversity and proximity to native vegetation *do* influence bird species diversity

The juxtaposition of remnant vegetation strongly influences the habitat values of plantations. Multi-species plantations have far greater habitat values than single-species plantings.

Biodiversity values of reforestation projects in tropical and subtropical Australia

Einasleigh Uplands

Kanowski et al. (2002)

Patch

Loss and fragmentation of habitat

Unassisted regrowth, timber plantations, and diverse “restoration plantings”

More species in regrowth and plantings

Transect-level surveys of plants, vertebrates and invertebrates plus various special metrics integrated into a “biodiversity value”

Research in progress

Research in progress

Rehabilitation of degraded tropical forests (NHT plantings)
Wet tropics
Eskine, P. (2002)
Patch and landscape

Vegetation degradation and clearing

Diverse plantings, direct seeding, plantings of a mixture of high value rainforest timbers (farm forestry)

Diverse plantings would accelerate the rate of biodiversity restoration

Monitoring some of the ecological and functional outcomes of diverse plantings for biodiversity with farm forestry planted for timber production and biodiversity

The more interventionist the method the more expensive it will be

Research in progress

Revegetation; its biodiversity conservation effectiveness
Kanmanto
Wendy Harris (1999)
20,600 ha = Landscape

Loss and fragmentation of habitat

Agroforestry (*Eucalyptus leucoxylon*, *E. cladocalyx*, *Allocasuarina verticillata*, *A. muelleriana*, *Melaleuca uncinata*) plantations, revegetation (planting and fencing)

There would be more plant and bird species in native habitats than planted habitats

Vegetation and birds surveys were carried out to compare agroforestry plantations, revegetation with natural regeneration, remnant vegetation and roadside vegetation

In planted habitats, plant species diversity was low, tree density high and there was little species diversity of shrubs and groundcover. Patches need to be linked to facilitate colonisation by birds. Differences in bird usage correlated with structural and floristic factors.

Overall planted habitats were found to be far less species-diverse in native plants and birds than ‘natural’ habitats. Another example of the value of follow-up surveys and assessment.

An ecological assessment of the Monarto Revegetation Program
Kanmanto
Dale Leary (1995)
Landscape, 80 sq km

Vegetation clearing

Planting of local and non-local tree species between 1974 and 1979

Native bird communities can be restored by revegetation programs

Compared bird usage of plantations, remnant vegetation and agricultural lands. Transects (15) visited three times in 1995. Floristic, habitat resources and food resources were assessed.

More birds preferred the plantations and native vegetation to the cleared agricultural land. Structural features of the vegetation are influential at a regional scale. Birds prefer the spatial patchiness provided by native vegetation.

Plantations need to better emulate natural areas with patchy distribution of trees supplemented by a diverse planting of understorey.
Good example of value of assessment surveys.

Best practice guidelines for establishing shelterbelts on King Is.
King
Jonathon Duddles, Greening Australia Hobart (pers. comm.)
Russell Warman, King Island
Landscape

Wind erosion

Planting and fencing of mainly local native trees and shrubs

Provision of shelter for stock and habitat for wildlife

Observations and some quadrats (GPS marked) of plantings up to 10 yrs old

Local species doing well, eucalypts only just staring to produce seed after 10 yrs.
Some bird usage.

Potential for further analysis

Revegetation to combat rural tree decline in the Midlands of Tasmania
Northern Midlands
Dugald Close and Neil Davidson CRC Sustainable Production Forestry.
Close and Davidson, N.J. (2002). Midlands Tree Committee.
Landscape

Agricultural landuse and super-abundant native species

Sprayed out weeds, cultivated and ripped and mounded, fenced with wire netting and electric wire to deter possums, sprayed with residual, 2 months before planting (August 2002), planted.

Provide wind shelter, habitat for birds and native insects, which are set up within the regional Bushcare strategy that aims to link native bush remnants.

Assessment of survival and growth of seedlings at all sites half yearly. Future projects may investigate the physiology of different species with a view to identifying species best suited to the environment.

At this early stage survival has been excellent, about 95%; possum browsing has been a problem although at this stage they seem to be targeting *Eucalyptus nitens*, *E. globulus* and *E. camaldulensis* and otherwise eating clover that is growing between rows.

Adequate site preparation and post-planting weed control essential.
Potential for assessing habitat values.

The utilisation of natural and planted linear habitats
by birds in northern Victoria
South Eastern Highlands.
Ryan (1993, 1999)
Patches in a landscape

Habitat loss, fragmentation and degradation

Planting of mainly eucalypt species to reduce rising groundwater

Birds would be more diverse in remnants. Bird species diversity and abundance increased with age of revegetated habitats. Compare findings with Biddiscombe (1985).

Birds sampled in 0.5 ha transects in 24 revegetated linear strips (0.5–10 ha, 5–30 yrs of age) and five roadside remnant woodland patches

53 species recorded, 25 from revegetated sited only and 25 in both revegetated
and remnant sites

Bird species diversity and abundance increased with age of revegetated habitats

A comparison of the avifaunal diversity in native hardwood plantation and pastureland

South Eastern Highlands

Klomp and Graham (2002) in north-eastern Victoria, Johnstone Centre report no. 163 Charles Sturt University

Farms (3)

Habitat loss and degradation

Plantations of hardwoods

Hardwood plantations offer better habitat for birds than pasture

Bird surveys to compare plantations, adjacent pastureland and remnants in four study areas. Surveys carried out over 2 days every 6 weeks from Aug 1999 to July 2001.

Birds prefer native remnants due to the structural complexity. Plantations and edge areas support greater species diversity than pastureland. Within plantations, previously applied management practices influence bird diversity.

Permanently marked points can be used for further monitoring of biodiversity changes in the plantations. Biodiversity of existing plantations could be enhanced by increasing their size and width, connecting them to other nearby areas of vegetation, increasing the diversity of habitat structure and resources by planting local understorey and ground cover species and by planting trees at intervals to ensure a variety of age classes.

Bird populations of farm plantations in the Hotham River Valley , WA

Avon wheatbelt

Biddiscombe, E.F. (1985), Biddiscombe et al. (1985)

Farm

Habitat loss, salinity

Eucalypts planted under saline conditions

Birds would use plantings

Seven years of monitoring tree survival and growth rates from the time of planting. Birds observed from transects and incidental observations.

61 species of birds observed. Distinct seasonal fluctuation in species diversity and abundance. 14 species observed breeding in the planted vegetation.

Increasing bird diversity and abundance was associated with the developing structure of the planted vegetation, foliage cover and tree height. After three years, the vegetation had developed sufficient structure to provide habitat for a wide range of species. A good project to revisit.

Faunal use of blue gum plantations
Jarrah forest
Hobbs et al. (in press)
Cunningham, S.A. (2002)
Landscape

Loss of habitat

Commercial plantations (*Eucalyptus globulus*)

Species richness higher in native forest.
Plantations near forests support more species of fauna than isolated plantations.

Comparative vegetation quadrats, bird surveys and invertebrate sampling within and between remnant vegetation, plantations and pasture sites

Plantations near remnants were important, edges were important. Plantations were dominated by more individuals of fewer species. A weed weevil appears to have recently migrated from plantations to native forest and may become a pest.

Plantations contained a small overlap of species found in native forests. Plantations adjacent to remnant vegetation may act to buffer the remnant. Pest invasion a significant risk.

Impacts of willow invasion on riparian birds
South Eastern Highlands.
Holland Clift (2002)
Patch — river corridor

Weed invasion

Clearing woody weeds (mainly willows)

Bird usage would differ between native vegetation, areas infested with willows and areas cleared of willows

Bird usage, invertebrate abundance and vegetation structure were compared between areas of native vegetation, areas infested with willows and areas cleared of willows

Native sections of the river corridor had more bird species and a greater diversity of foraging guild than either the cleared or willow invaded sections

Willow invasion directly into riparian zone is likely to markedly reduce the abundance and variety of birds and its spread into previously cleared sections is unlikely to facilitate many woodland dependent birds. Clear willows and revegetate with native riparian vegetation.

Grassy box woodland
New England Tablelands
Windsor, D.M. (1998)
Patch

Lack of 'triggers' for natural regeneration

Various disturbance regimes with fenced remnants including herbicides, fires, ripping and scalping (top soil removal)

Enhanced natural regeneration

Detailed vegetation surveys in well replicated sites

Little regeneration in fenced remnants without disturbance.
Ripping and scalping had the greater benefit.

Post-fencing disturbance is likely to be required to stimulate regeneration in weed infested sites.

Birds in shelter belts
New England Tablelands
Kinross (2000)
Patch

Loss of habitat

Revegetation in shelterbelts and small agroforestry blocks

Habitat for birds

Repeated bird surveys in revegetation strips of different widths

More bird species in corridor shelterbelts. Some nesting in shelterbelts.

Narrow (<25 m wide) shelterbelts provide little habitat for declining woodland birds