RESEARCH REPORT

doi: 10.1111/j.1442-8903.2008.00386.x

Assessing the biodiversity benefits of plantations: The Plantation Biodiversity Benefits Score

By E. Margaret Cawsey and David Freudenberger

Margaret Cawsey *works at the Australian National Wildlife Collection, CSIRO Sustainable Ecosystems (GPO Box 284, Canberra, ACT 2601, Australia. Tel. +61-2-6242 1628. Fax: +61-2-6242 1565. Email: margaret.cawsey@csiro.au).* ***David Freudenberger*** *is the Director of Science and Major Projects for Greening Australia (PO Box 74, Yarralumla, ACT 2600, Australia. Tel. +61-2-6281 8585. Fax: +61-2-6281 8590. Email: dfreudenberger @greeningaustralia.org.au).*

Summary **All forests, including commercial plantations, provide a range of habitats for conserving and enhancing elements of native biodiversity. However, the biodiversity values of commercial plantations will depend on the management practices adopted on site, as well as the landscape context of the plantation. The present study describes a generic, quantitative method for assessing the potential biodiversity benefits that might be derived from a plantation, depending on the management practices adopted. This method is based on existing ecological design and management principles. The Plantation Biodiversity Benefits Score (PBBS) was designed to be repeatable and practical to apply. The method can be used either as a stand-alone tool or as part of an integrated framework to assess and compare the commercial and environmental benefits that can be derived from different layouts, management practices and locations of plantations anywhere in Australia.**

Key words: *assessment of biodiversity, biodiversity benefits, commercial environmental forestry, forestry, metric, plantations.*

Introduction

There is increasing demand from investors in farm forestry for some 'green' component to their investments. Public and private investors are requiring that plantations demonstrate some measurable environmental benefits, as well as a commercial return (Lindenmayer & Franklin 2002). The positive environmental impacts of commercial forestry can include environmental services such as salinity abatement and reduction of ground water flow (Stirzaker *et al*. 2002) and benefits for native wildlife (Salt *et al*. 2004), more broadly: 'biodiversity benefits'. The Commercial Environmental Forestry Project at Ensis, a joint venture of CSIRO Australia and Scion New Zealand (http://www.ensisjv.com/), required a quantitative method to assess the potential biodiversity benefits of plantations to be included in a Scenario Planning and Investment Framework (SPIF). The biodiversity assessment system needed to:

1. Be based upon an existing method or set of guidelines for the assessment of potential biodiversity benefits.
2. Apply to any plantation in Australia.
3. Provide an objective and repeatable assessment of attributes of a plantation that may lead to biodiversity benefits.
4. Permit comparison between different plantation designs and management practices and between plantations in different geographical locations.
5. Raise awareness in plantation managers of the ecological importance to the native biota of various habitat components, both on-site and at the landscape scale, and of the effects on-site management practices have at both scales.
6. Encourage the adoption of biodiversity-friendly management practices, rather than penalizing the adoption of management practices designed to maximize other plantation benefits, be they economic or other environmental benefits (e.g. salinity abatement, water management).

This paper briefly presents the approach taken to develop the PBBS, then describes the components of the PBBS.

Approach

The PBBS was developed using the following approach:

1. Conduct a literature review of existing approaches to the assessment of the biodiversity benefits of native and/or plantation vegetation and gauge their relevance to the requirements.
2. Develop a draft assessment method based upon one or more of these approaches.
3. Gather feedback on the suitability of the draft assessment method through a 'fit for purpose' assessment by stakeholders and modify the method accordingly, producing a prototype PBBS.
4. Field test the prototype PBBS and modify it on the basis of feedback from the field testing.

A summary of the process is presented here.

Literature review

From the literature review, it was concluded that there were three possible approaches to the assessment of the biodiversity benefits of plantations:

1. The use/adaptation of an existing assessment system developed specifically for native vegetation (both remnants and plantings).
2. The use/adaptation of an existing assessment method for plantations.
3. The development of a new assessment system based on a recent and comprehensive synthesis of the literature (Salt *et al*. 2004) that describes how farm forestry plantings can be designed

© 2008 Ecological Society of Australia

and managed to benefit native biota, while also drawing upon existing systems based upon the assessment of native vegetation (point 1).

Existing methods for assessing native vegetation

At the time of the project, there existed in Australia three published methods for assessing the condition of native vegetation: 'Habitat Hectares' (Parkes *et al.* 2003), *BioMetric* (Gibbons *et al.* in press) and the Biodiversity Benefits Index of Oliver and Parkes (2003); the latter two are broadly based upon the 'Habitat Hectares' method. These methods are basically additive indices of structural complexity (McElhinny *et al.* 2005), assessed at two or more scales (e.g. site, landscape, regional). Theoretically, these methods should all be capable of assessing the biodiversity benefits of any patch of land, from a paddock, through a plantation, to an area of native vegetation.

Although it would be desirable to employ one of these existing, well-tested methods, the condition 'benchmarks' (e.g. habitat structure and vegetation composition) upon which the existing systems rely are specific to the state in which each system operates. A method based on any of these systems could not be immediately operational across the whole of Australia as comparable benchmark data currently do not exist for the whole of Australia.

Existing method for assessing plantation biodiversity benefits

A single plantation scoring method devised for Australian conditions, specifically South Australia, was found (New & England 2002). This is also basically an additive index, scoring points for the positive features of a farm forestry design. However, it also penalizes negative features by deducting points. This made it unsuited to the purpose as the requirement for the present project was to develop a system that generally did not penalize designs or management practices, instead being as positive as possible to reduce barriers to adoption. Also, the deduction of points adds complexity to the mathematical framework of the score, making it less easy 'to visualize the output from the index' (McElhinny *et al.* 2005).

Furthermore, more than a third of the New and England (2002) biodiversity score is derived from assessment of the condition of remnant native vegetation associated with a farm forestry design. Although it is acknowledged that remnant vegetation contributes to the biodiversity benefits of a plantation, several states have legislated, or are in process of legislating, their own methods (e.g. Parkes *et al.* 2003 in Victoria, Gibbons *et al.* in press in NSW) to assess the condition of remnant native vegetation against relevant state benchmarks. If a plantation estate also manages blocks of remnant vegetation, the condition of these remnants should be assessed using the relevant state system, while the biodiversity benefits of the plantation components of the estate should be assessed using a generic method focused upon the plantations, including their landscape context.

A new system based on existing guidelines

Salt *et al.* (2004) reviewed and synthesized the Australian and overseas scientific literature on the biodiversity benefits provided by farm forestry. They describe ecological design themes and principles for farm forestry and present a prescriptive approach, providing broad guidelines for farm forestry management practices, at both stand (site) and landscape scales, which would be expected to enhance the biodiversity benefits of farm forestry plantations.

Salt *et al.* (2004) contend that a plantation is a category of forest and have devised a list of management guidelines which should position any planting in Australia (regardless of composition or structure), along a continuum of increasing habitat structural complexity, from a monoculture of exotic species to the 'ideal' habitat complexity exhibited by an 'unmodified native forest'. Where a plantation is placed in this continuum would define its relative biodiversity benefits in comparison to a notional native forest benchmark.

It was concluded that the ecological design principles and management guidelines of Salt *et al.* (2004) could provide the basis for a generic method for rapid assessment of the biodiversity benefits of plantations.

Development of the PBBS

On the basis of the conclusions from the literature review, the PBBS Version 1 was designed (Cawsey & Freudenberger 2005: Appendix 1). The ecological design themes and principles of Salt *et al.* (2004) were allocated to a scale, either site scale (Table 1) or landscape scale (Table 2).

The broad structure of the 'Habitat Hectares' score (Parkes *et al.* 2003) was adopted, attributing 75% of the score at the site scale (Table 1) and 25% at the landscape scale (Table 2). This appeared to be a useful division of points because, although landscape scale issues are highly important ecologically, 12 of the 13 Salt *et al.* (2004) management guidelines operate at the site scale and because plantation managers have more control over practices at the site scale. The next step was to allocate the Salt *et al.* (2004) guidelines for improving the biodiversity value of a plantation to themes and design principles at both scales (Tables 1 and 2). The final process was to define and quantify explicit performance criteria, for each management guideline, with reference to relevant literature justifying the relative importance of the weightings for each management guideline and its components where applicable (Tables 3–17). At the site scale, the management guidelines were weighted in proportion to the time required for the desired biodiversity benefits to develop.

This PBBS Version 1 was subjected to a process of stakeholder and scientific peer review. On the basis of the feedback from the review process (Cawsey & Freudenberger 2005, Chapter 4), the scores, criteria and weightings were modified to produce the Prototype PBBS (Cawsey & Freudenberger 2005, Chapter 5). The Prototype PBBS was then subjected to wider stakeholder review and field testing of its practicality. The latter entailed site visits to small-scale farm forestry developments in the Bega Valley, NSW and large Radiata Pine (*Pinus radiata*) plantations in the Bombala District, NSW. On the basis of this feedback (Cawsey & Freudenberger 2006, Appendix 3), the prototype was modified to produce the PBBS (Version 2) described here.

© 2008 Ecological Society of Australia

Table 1. Site scale management guidelines and weightings of the PBBS, organized by the design themes and principles for 12 management guidelines of Salt *et al*. (2004)

Theme	Design principle	Management guideline	Score Name	Max weighting (percentage)
Complexity	Structure	1. Incorporate paddock trees	Paddock Tree Score	10
		2. Site preparation	Site Preparation Score	8
		3. Preserving biological legacies	Biological Legacy Score	9
		4. Install artificial hollows (nest boxes)	Artificial Hollows Score	3
		5. Thinning and pruning	Thinning and Pruning Score	5
	Time and age	6. Rotation times	Rotation Score	5
	Patchiness	7. Mosaics: mixed age stands	Mosaics Score	5
Composition	Mix of species	8. Mixed plantings	Mixed Planting Score	5
	Local species	9. Planting with local species	Local Species Score	5
Ecological Management	Weed control	10. Control escapees	Control Escapees Score	5
		11. Control weeds	Control Weeds Score	5
		12. Control pest animals and livestock	Control Pest Animal Score	10
Total Plantation Biodiversity Score at the site scale				75

Table 2. Landscape scale scores and weightings for the PBBS, organized under the design themes and principles for the Salt *et al*. (2004) 'site location' management guideline

Theme	Design principle	Score name	Max weighting (percentage)
Location	Adjacency	Landscape connectivity	15
	Connectivity		
	Landscape context		
Configuration	Size		
	Shape	Plantation width	10
Total Plantation Biodiversity Score at the landscape scale			25

Table 3. Criteria and scores for the incorporate paddock trees management guideline

Criteria	Paddock Tree Score
≥ 4 paddock trees/hectare† (alive or dead) within the plantation	10
2–3 paddock trees/hectare† (alive or dead) within the plantation	8
1 paddock tree/hectare† (alive or dead) within the plantation	5
no paddock trees (alive or dead) within the plantation	0

†Tree density is defined as the mean number of trees for the whole area of the plantation, only including trees surrounded by plantation trees.

Table 4. Criteria and component scores for the site preparation management guideline

Component	Criteria	Tree Protection Score
Protection of paddock trees	Site Preparation to ensure that there is no deep ripping or plantation trees established within a buffer area of 1.5 × tree height from a paddock tree	4
	No buffer around paddock trees	0
		Watercourse Protection Score
Protection of watercourses	Retain, encourage or plant local native vegetation buffers ≥20 m wide and ≥100 m long along watercourses to protect the riparian zone	4
	Retain, encourage or plant local native vegetation buffers ≥20 m wide and <100 m long along watercourses to protect the riparian zone	2
	No protection measures or buffers <20 m wide	0
Site Preparation Score = Tree Protection Score + Watercourse Protection Score = 8 (maximum)		

The Plantation Biodiversity Benefits Score

Appendix 1 provides a Glossary of terms used in the description of the scoring system.

The PBBS makes no assessment of the value of pre-existing native vegetation on the site of the proposed plantation. It assumes that all state-regulated requirements (e.g. codes of practice, clearing assessments, trade-off agreements) have been fulfilled.The PBBS does not assess the desirability of placing a plantation into a landscape, but does assess where in the landscape the plantation is placed. Once a plantation site has been selected, the PBBS provides a tool to assess the likely biodiversity benefits of the plantation, with the concomitant intention to decrease the biodiversity disadvantages for any surrounding native habitat.

Site scale management guidelines

Incorporate paddock trees

The retention of native paddock trees, whether alive or dead (but still standing) contributes more than any other component to the biodiversity potential of any planting (note: living trees should be retained alive and not killed).These trees provide residual habitat for a variety of invertebrate and vertebrate species. Nearly 300 different species of invertebrates have been associated with the bark of a single paddock tree

© 2008 Ecological Society of Australia

Table 5. Criteria and component scores for the preserving biological legacies management guideline

Component	Criteria	Tree Retention Score
Tree retention at harvesting	Retention of all mature native trees (alive or dead) at time of harvesting	3
	No retention of mature native trees (alive or dead) at time of harvesting	0
		Tree Environment Score
Tree Environment Score	Enhancement of environment around paddock trees with the planting of local native shrubs	3
	No enhancement of the environment around the mature (e.g. Paddock) trees	0
		Dead Wood Score
Retain dead wood and rocks at harvesting	≥80% of boulders and fallen logs retained at time of harvesting	3
	≥50% and <80% of boulders and fallen logs retained at time of harvesting	2
	≥20% and <50% of boulders and fallen logs retained at time of harvesting	1
	<20% of boulders and fallen logs retained at time of harvesting	0
Biological Legacy Score = Tree Retention Score + Tree Environment Score + Dead Wood Score = 9 (maximum)		

Table 6. Criteria and scores for the artificial hollows management guideline

Criteria	Artificial Hollows Score
Some nest boxes installed, with appropriate monitoring for and exclusion of pest species	3
No nest boxes installed OR no monitoring of nest boxes	0

Table 7. Criteria and component scores for the thinning and pruning management guideline

Component	Criteria	Thinning Score
Thinning	Variable density thinning at some stage	2
	Standard thinning only	1
	No thinning	0
		Deformed Tree Score
Deformed trees	Some ringbarking/poisoning of deformed plantation trees	1
	No ringbarking/poisoning of deformed plantation trees	0
		Pruning Score
Pruning	Prunings, natural branch fall and/or felled dead trees left on the ground	2
	No prunings, natural branch fall or felled dead trees left on the ground	0
Thinning and Pruning Score = Thinning Score + Deformed Tree Score + Pruning Score = 5 (maximum)		

Table 8. Criteria and scores for the rotation times management guideline

Criteria	Rotation Time Score
Rotation times ≥25 years	5
Rotation times ≥15 years and <25 years	3
Rotation time <15 years	0

Table 9. Criteria and scores for the mosaics of mixed-age stands management guideline

Criteria	Mosaic Score
Establish or harvest to ensure a mosaic† of stands (coupes) of more than 2 different ages‡	5
Establish or harvest to ensure a mosaic of stands (coupes) of 2 different ages	3
All stands (coupes) of one age	0

†'Mosaic' requires that the second age class be > 20% of the plantation area; ‡'different' age is defined as > 25% of the rotation length.

(Recher *et al*. 1996). In addition, paddock trees are often the only available source in the landscape of hollows, which take over 100 years to develop and are used by over 300 wildlife species (Gibbons & Lindenmayer 2002). Therefore, the PBBS strongly weights (10) the incorporation of paddock trees within a plantation (Table 3). The large value (5) for incorporation of a single paddock tree was designed to encourage the retention of any large trees.

For simplicity, paddock trees (Appendix 1) were recognized regardless of diameter at breast height (d.b.h.). Specification of large d.b.h. values would exclude some species, for example, Mallee species that are used in some commercial environmental forestry plantations in low rainfall regions in Australia. Even if smaller paddock trees do not yet contain hollows, if they are retained (see under Biological legacies below) they have the potential to develop them. They also provide significant habitat other than that related strictly to hollows (Carruthers & Paton 2005).

Site preparation

Site preparation for a plantation is crucial in preserving and maintaining biodiversity benefits. It is important to prepare the site

© 2008 Ecological Society of Australia

to preserve as much habitat complexity as possible, minimizing the damage to existing native vegetation, logs and rocks, and to minimize erosion to prevent damage to aquatic ecosystems (Salt *et al*. 2004). Therefore, the Site Preparation Score has two components: the Tree Protection Score and the Watercourse Protection Score.

It is difficult to quantify, over all possible sites, a scoring method to take account of all levels of coarse woody debris, rocks and other components of habitat complexity. Therefore the Tree Protection Score focuses on the paddock trees retained within the precincts of a plantation, weighted heavily for management practices that protect them from damage.

A practical measure for the protection of paddock trees during site preparation and plantation establishment is to leave an undisturbed area around each tree to buffer it from the disturbance e.g. ripping. The PBBS recommends a buffer width of 1.5 times the height of the paddock tree in question. Stakeholder feedback suggests that plantation trees within this distance suffer a severe decline in plantation growth (Cawsey & Freudenberger 2006: Appendix 3). Buffers of this dimension require surprisingly little space. For example, four 6-m high paddock trees/hectare only require 113 m^2/ha. This area amounts to 1.1% of the total plantation area, assuming the trees are not closer to each other than 9 m, in which case the area will be less. With buffers related to tree height, even four trees/ha of 10 m in height only reduce the plantation area by 1.9%.

Protection of watercourses by planting out buffer zones with permanent native vegetation contributes to biodiversity benefits, both on plantation and in neighbouring native vegetation and aquatic ecosystems.

The Site Preparation Score (Table 4) is the sum of the scores from the two components. This management guideline is weighted heavily (8) in its contribution to the PBBS.

Biological legacy

The biodiversity value of plantations can be enhanced by the preservation of 'biological legacies', that is, any natural elements of the landscape that existed before the plantation. These include paddock trees (alive or dead), fallen wood and boulders. It is important that these legacies remain in good condition during the lifetime of the plantation and are retained at harvest to contribute biodiversity benefits into the future (Salt *et al*. 2004).

The first component of the Biological Legacy Score (Tree Retention) assesses the retention of paddock trees at harvest

Table 10. Criteria and scores for the mixed plantings management guideline

Criteria	Mixed Planting Score
>2 species in the plantation; 2nd and 3rd species comprise a minimum of 20% of plantation area	5
2 species in the plantation; 2nd species comprises a minimum 20% of plantation area	3
1 plantation species in the plantation	0

Table 11. Criteria and scores for the local species management guideline

Criteria	Local Species Score
>1 local species comprising at least 20% of the plantation	5
1 local species comprising at least 20% of the plantation	3
No local species	0

Table 12. Criteria and component scores for the controlling escapees management guideline

Component	Criteria	Wildlings Score
Wildlings	Monitor and eliminate wildlings	2.5
	No monitoring and control of wildlings	0
		Non-Hybrid Score
Non-Hybrid	All plantation species are non-hybridizing	2.5
	Plantation species can hybridize with local species	0
Control Escapees Score = Wildlings Score + Non-Hybrid Score = 5 (maximum)		

Table 13. Criteria and component scores for the controlling weeds management guideline

Criteria	Control Weeds Score
No environmental weeds present AND/OR programme to *eradicate*/maintain the absence of weeds throughout the life of the plantation	5
Environmental weeds present AND programme to *control* weeds before/during plantation establishment	3
Environmental weeds present AND no weed control	0

Table 14. Criteria and component scores for the controlling pest animals and livestock management guideline

Component	Criteria	Feral Herbivores Score
Feral herbivores	Ongoing control of feral herbivores	2.5
	No feral herbivore control	0
		Exotic Predators Score
Exotic predators	Ongoing control of exotic predators	2.5
	No exotic predator control	0
		Exclude Livestock Score
Exclusion of livestock	Livestock excluded for the life of the plantation	5
	Livestock grazing not excluded from plantation	0
Control Pest Animal Score = Feral Herbivores Score + Exotic Predators Score + Exclude Livestock Score = 10 (maximum)		

 © 2008 Ecological Society of Australia

Table 15. Neighbourhood sizes, criteria and scores for the Landscape Cover Score

Neighbourhood Size	Criteria	Plantation Margin Score
100 m	Existing vegetation cover ≥30%	7
	Existing vegetation cover between 10 and 30%	4
	Existing vegetation cover <10%	0
		Neighbourhood 1-km Score
1 km	Existing vegetation cover between 10 and 30%	4
	Existing vegetation cover <10%	2
	Existing vegetation cover ≥30%	0
		Neighbourhood 5-km Score
5 km	Existing vegetation cover between 10 and 30%	4
	Existing vegetation cover <10%	2
	Existing vegetation cover ≥30%	0
Landscape Cover Score = Σ(Score Values for the three neighbourhood sizes)		

Table 16. Criteria and scores for the Planting Area Weighting and calculation of the final Landscape Connectivity Score

Criteria	Planting Area Weighting
Combined area of new plantings in the plantation proposal ≥50 ha	1
Combined area of new plantings in the plantation proposal between 10–50 ha	0.8
Combined area of new plantings in the plantation proposal ≤10 ha	0.6
Landscape Connectivity Score = Landscape Cover Score × Planting AreaWeighting = value of the Landscape Cover Score	

(Table 5). The second component (Tree Environment) scores the biodiversity benefits from enhancing the environment around these trees, e.g. with the planting of local native shrubs, to encourage their persistence and enhance native diversity. The third component (Dead Wood) is designed to encourage the retention of coarse woody debris and rocks on site, rather than burning/removing them. The Biological Legacy Score is the sum of the scores from the three components. The importance of biological legacies for biodiversity is reflected in the value (9) of the Biological Legacy Score (Table 5).

Artificial hollows

The installation of artificial hollows (nest boxes) is a strategy designed to increase the biodiversity value of a plantation. Plantation trees usually are harvested before they develop hollows or are species that rarely develop them (e.g. pines).

However, nest boxes are not a quick fix or a cheap solution. They must be properly designed and carefully monitored because they can provide refuge for undesirable pest species, for example, European Bees, which must then be removed (Salt *et al*. 2004).

Although artificial hollows are unlikely to have a significant long-term role in improving biodiversity in commercial tree plantations, the Artificial Hollows Score has been maintained in the PBBS in order to follow the management guideline structure of Salt *et al*. (2004), but given a small weighting (Table 6).

Thinning and pruning

The Thinning and Pruning Score has three components; the Thinning Score, the Deformed Tree Score and the Pruning Score (Table 7). Thinnings and prunings can play a role in improving the biodiversity value of a plantation by increasing the structural complexity and diversity of the habitat (Salt *et al*. 2004). Variable density thinning can introduce structural complexity, that is, more like the tree spacing in natural vegetation. Killing deformed trees and leaving them *in situ* can provide diversity and habitat. Branches that fall naturally and prunings left on the ground can provide shelter and habitat. The values for the component scores are summed to give the final Thinning and Pruning Score (Table 7).

Rotation times

The biodiversity benefits of a plantation increase with the age of the trees. Older trees confer more biodiversity value to a stand (Salt *et al*. 2004). The thresholds used in the criteria (Table 8) concur with observations showing that birds such as Treecreepers (*Cormobates leucophaeus* (Latham 1802) and *Climacteris erythrops* (Gould 1841)) do not arrive until a stand is at least 15 years old (Loyn 1980, 1985). The Rotation Time Score is described in Table 8.

Mosaics; mixed age stands

Mosaics of different-aged stands (or 'coupes') increase the diversity of the landscape, which in turn allows a greater diversity of use by wildlife because different species use stands of different ages in different ways (Loyn 2004; Salt *et al*. 2004). Young stands can provide cover and habitat for species that live and move near the ground. Older stands can provide cover and habitat for species that operate in upper forest strata. A mix of different aged stands may therefore support greater native species richness than single-aged stands.

The diversity of the landscape, in terms of an age mosaic, can be viewed at both the site (i.e. single plantation) scale and the landscape scale. The PBBS scores it at the site scale because landowners cannot commit their neighbours to establish plantations at different times or harvest at particular life stages in order to create a

© 2008 Ecological Society of Australia

mosaic of different-aged stands across property boundaries. The Mosaic Score is described in Table 9.

Mixed plantings

In a similar manner to a mosaic of different-aged stands, plantations with a diversity of tree species, whether they are exotic or local natives, tend to increase the diversity and abundance of native wildlife (Salt *et al.* 2004) in a way that monocultures do not (Kavanagh *et al.* 2005). One potentially cost-effective way of increasing this diversity is by planting a variety of species, for example, mixing eucalypts with nitrogen fixing species such as acacias, which also have the potential to increase productivity (Forrester *et al.* 2006). Ideally, additional species should also have different growth forms to achieve better biodiversity benefits, for example, smooth bark *vs.* rough bark, eucalypt *vs.* acacia *vs.* exotic pine, different growth rates, flowering times, rates of branch fall, etc., but for simplicity, the PBBS does not address such criteria.

The Mixed Planting Score is described in Table 10. There is a large increment in the score for the use of two species in a plantation to encourage any mixed planting.

Local species

The PBBS provides incremental rewards for increasing the use and area of local species (Table 11).

Local species of trees, particularly genotypes of local provenance, have been widely regarded as those best adapted to local conditions (Salt *et al.* 2004). They also preserve local genetic resources (Harwood 1990). However, recent literature questions the importance of provenance, suggesting that species of strictly local provenance may also be more vulnerable to the effects of local insect pests, climate change, etc. (Harwood 1990), so the selection of provenance may require some consideration. For this reason, provenance is not emphasized in the Local Species Score (Appendix 1). Ideally, the species mix should also include different growth forms to achieve better biodiversity benefits; however, for simplicity, the PBBS does not specifically address such criteria.

Controlling escapees

Most plantations consist of exotic species, many of which have the potential to become environmental weeds, displacing nearby native vegetation (Salt *et al.* 2004). For this reason it is important to control the escape of wildlings. It is also important to recognize the potential for the escape of genes, that is, genetic pollution through hybridization of plantation species with remnant native species. One suggested strategy is to physically separate the plantation from patches of native vegetation. This is at odds with recommendations for increasing the connectivity in the landscape (Salt *et al.* 2004) and pollination agents can travel quite long distances. It may be possible to choose non-hybridizing genotypes when selecting plantation species.

The Control Escapees Score has two components; the Wildlings Score and the Non-Hybrid Score. The values for the component scores are summed to give the final Control Escapees Score (Table 12).

Controlling weeds

Plantations may become a major source of environmental weeds (Appendix 1) which may invade native vegetation from outside sources, displacing native species and reducing the biodiversity value of both plantations and native remnants alike (Salt *et al.* 2004). The Control Weeds Score is described in Table 13.

Controlling pest animals and livestock

Feral vertebrate herbivores (e.g. rabbits, hares, deer, goats) have the potential to harm both plantations and native biodiversity (Salt *et al.* 2004). Plantations can provide shelter for feral predators (e.g. cats and foxes) that prey upon native wildlife. Livestock grazing can also reduce the biodiversity values of plantations; even a few livestock can have detrimental effects (Salt *et al.* 2004).

The Control Pest Animals and Livestock Score has three components; the Feral Herbivores Score, the Exotic Predators Score and the Exclude Livestock Score. The values for the component scores are summed to give the final Control Pest Animals and Livestock Score (Table 14). A large weighting has been given to exclusion of livestock because of their tendency to concentrate in biologically sensitive areas like riparian zones (Jansen *et al.* 2007).

Landscape scale management guidelines

Landscape connectivity

The Landscape Connectivity Score is calculated using two separate scores, the Landscape Cover Score (Table 15) and the New Planting Area Weighting (Table 16). The component scores of the Landscape Cover Score are summed to give the final Landscape Cover Score (Table 15) and multiplied by the New Planting Area Weighting derived from Table 16, giving the final Landscape Connectivity Score.

Per cent cover depends on the scale at which cover is assessed. Therefore, like the neighbourhood component of the 'Habitat Hectares' method of Parkes *et al.* (2003), the Landscape Cover Score is calculated over three 'neighbourhoods', that is, three different sized areas around the plantation (Fig. 1).

The three neighbourhoods are as follows:

1. The plantation margin: the area from the plantation edge to a distance of 100 m from the plantation edge, i.e. it does not include the area which will be covered by the proposed plantation in the calculation of tree cover.
2. The 1-km neighbourhood: this includes the area which will be covered by the plantation plus the area from the plantation edge to a distance of 1 km from the plantation edge, that is, it includes the area of the proposed plantation in the calculation of tree cover.
3. The 5-km neighbourhood: this includes the area covered by the plantation plus the area covered from the plantation edge to a distance of 5 km from the plantation edge, that is, it includes the area of the proposed plantation in the calculation of tree cover.

The PBBS allocates the most points (maximum of 7) to the Plantation Margin Score. The biodiversity values of a plantation very near (within 100 m) or connected to remnant vegetation will be greater than a plantation disconnected or isolated from remnant vegetation.

© 2008 Ecological Society of Australia

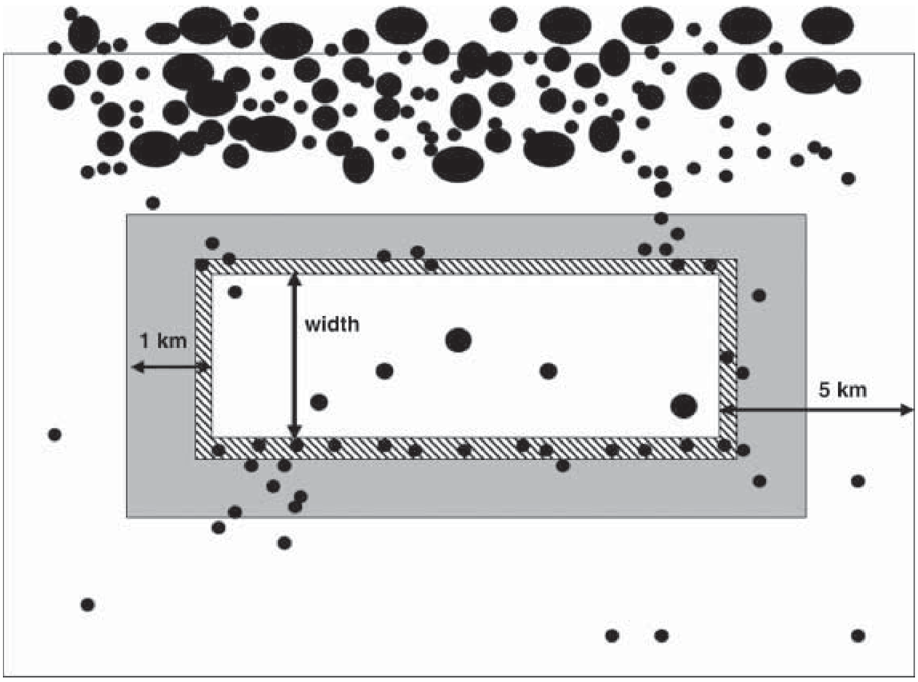

Figure 1. A schematic representation of the neighbourhoods used for calculating the Landscape Connectivity Score (not to scale). The black circles represent the existing vegetation cover used to calculate the percent vegetation cover values for all three neighbourhoods. The inner rectangle represents the area of the plantation. The hatched area represents the area of 100-m plantation margin. The entire area inside the boundary of the grey rectangle represents the 1-km neighbourhood of the proposed plantation. The entire area enclosed by the outer rectangle represents the 5-km neighbourhood. The width of the plantation, defined as the length of the narrowest dimension of the plantation, is indicated by the double-headed black arrow inside the inner rectangle.

At the 1-km and 5-km neighbourhoods, a zero score is allocated to plantations within a landscape with ≥30% native vegetation. Research has shown that landscapes require a minimum 30% native vegetation cover to maintain ecological sustainability and connectivity (e.g. Andren 1994; Reid 1999, 2000; McIntyre *et al.* 2000; Watson *et al.* 2001; Radford *et al.* 2005). On this basis, in landscapes which already have ≥30% native vegetation, plantations provide little additional connectivity at the 1-km and 5-km scales, but potentially significant connectivity at the 100-m scale.

At the 1-km and 5-km neighbourhood scales, maximum points (4) are allocated to plantations being established where existing native vegetation cover is between 10% and 30%. Plantations are likely to have the greatest contribution to increasing connectivity at this level of cover (Radford *et al.* 2005). Only two points are allocated to plantations established in areas with <10% existing native vegetation because plantations will contribute less to connectivity in such highly fragmented landscapes.

The value of the Landscape Cover Score is then multiplied by the Plantation Size Weighting (Table 16), which effectively discounts the value of the Landscape Cover Score for plantation sizes < 50 ha. In highly cleared landscapes, a small plantation will contribute less to landscape connectivity than a large one. Also, the habitat values in a plantation of < 50 ha are likely to be limited. Thus, the Plantation Size Weighting discounts the connectivity effects of small plantations.

Plantation width

The 'wider', that is, less linear a plantation, the more protection it provides for wildlife by reducing the 'edge effect' (Salt *et al.* 2004). Note that in the calculations for the criteria, the width is always the smaller dimension of the plantation (Fig. 1). For an irregular shaped plantation, the width of a plantation can be estimated by fitting the area and perimeter to an equivalent rectangle and taking the minimum dimension. The Plantation Width Score is described in Table 17.

Table 17. Criteria and scores for the Plantation Width Score

Criteria	Plantation Width Score
Width >100 m	10
Width between 50–100 m	7
Width <50 m	0

Implementation of the Plantation Biodiversity Benefits Score

Although the landscape scale calculations are more accurately carried out within a GIS environment, the use of large-scale maps and current orthophoto maps and aerial photographs allow the scores to be readily approximated by eye.

A Microsoft Excel spreadsheet has been built to aid field calculations of the PBBS Version 2. This allows the operator to score all components of the PBBS, both site and landscape scale, and tallies the score for the components. Copies of this spreadsheet may be obtained on application to the first author. Field datasheets to allow the same function may also be obtained. Based on experience using the method in the field, it can take as little as 15 min to complete the score with all necessary maps, photos, or GIS at hand.

The PBBS has also been integrated into an SPIF, designed to assist investors to interactively place areas of planted vegetation, both plantation and environmental plantings of native vegetation, in the landscape, with the objective of improving the economic, environmental and biodiversity benefits accruing from such plantings. For the SPIF implementation of the PBBS, the scores for the site scale components are tallied through the SPIF user interface. Within the SPIF, the calculation of the scores for the landscape scale components is carried out spatially, within a GIS environment. SPIF has been developed by Ensis, a

© 2008 Ecological Society of Australia

joint venture of CSIRO, Australia and Scion, New Zealand. Further details can be obtained at: www.ensisjv.com/cef.

Discussion

The PBBS adopts a simple mathematical system, an approach recommended by McElhinny *et al*. (2005), for reasons of clarity and to make it easy to visualize the effects at a site level. It is an additive index, or scorecard approach. It is acknowledged that scorecards have significant limitations, in that they assume that the different components are substitutable (Burgman *et al*. 2001) and there are many ways to get exactly the same score (Fig. 2). Unlike measures of habitat and woodland structural complexity, this may not be so much of an issue for the PBBS, as management practices may well be substitutable, within the limitations of the weightings given to each component of the score, for example, the score is very sensitive to the existence of paddock trees, so it will always be difficult to get a high value for the PBBS if they are left out of the equation. The value of such a simple and transparent system is gained from working through the scorecard in a structured way, considering the configuration, management and locations of alternative plantation designs.

The absolute value of the final score is secondary, as it is the relative values that are important. A possible method of comparing the relative contribution of different scoring criteria to the total scores for more than one plantation is illustrated by the use of a 'benefits profile' (Fig. 2). This profile provides a graphical aid for comparing the contribution of each criterion to the total score for each plantation. Such a profile allows the land manager to assess and select a preferred option on the basis of which criteria are judged to be the most relevant or important.

Several of the stakeholders who reviewed the PBBS suggested that a particular habitat feature, the paddock tree, is over-represented in the score. It has been suggested that the PBBS should score all aspects of the incorporation, retention and protection of the paddock tree in a single component of the scoring system and reduce the weighting.

Unlike the existing scores for assessing native vegetation condition, for example, Parkes *et al*. (2003), the Salt *et al*. (2004) approach, and hence the PBBS, was not designed to score points for particular components of habitat structure. It was intended to pinpoint and reward actual management behaviours that have been assessed by researchers as being most likely to result in habitat conditions which will benefit native biodiversity. Therefore, the aim of this project was to develop and quantify explicit criteria for management activities that are likely to enhance the biodiversity benefits of plantations, as opposed to assessing the current and/or future condition of different habitat components. For this reason the PBBS adheres as closely as possible to the structure of the Salt *et al*. (2004) approach, including the placement of heavy emphasis on the incorporation, retention and protection of paddock trees.

Other stakeholders have raised the question of whether misleading scores can be gained where a plantation is placed in an open woodland/grassland landscape where the notional 'native forest' is quite different from the pre-existing vegetation. However, we stress that the PBBS does not assess the desirability or otherwise of placing a plantation into a landscape and is only concerned with its ecological resemblance to a notional generic 'unmodified native forest' (Salt *et al*. 2004).

The PBBS is not a substitute for monitoring actual biodiversity gains and losses derived from plantation forestry. Rather it is a tool that synthesizes existing predictive understanding of how biodiversity can be enhanced in plantations, based on decades of research and management (Salt *et al*. 2004).

The PBBS provides a starting point, to be modified as better knowledge from current and future research becomes available. Research is needed to assess the actual biodiversity outcomes that are achieved by application of these management guidelines. The method also requires broader field-testing for practicality of use. The data from such tests should be analysed to examine the sensitivity of the score to the weightings for the various management guidelines and their components or the need for other attributes to be included. The results of such research and analysis should provide the basis for adaptation of the management guidelines, criteria and weightings.

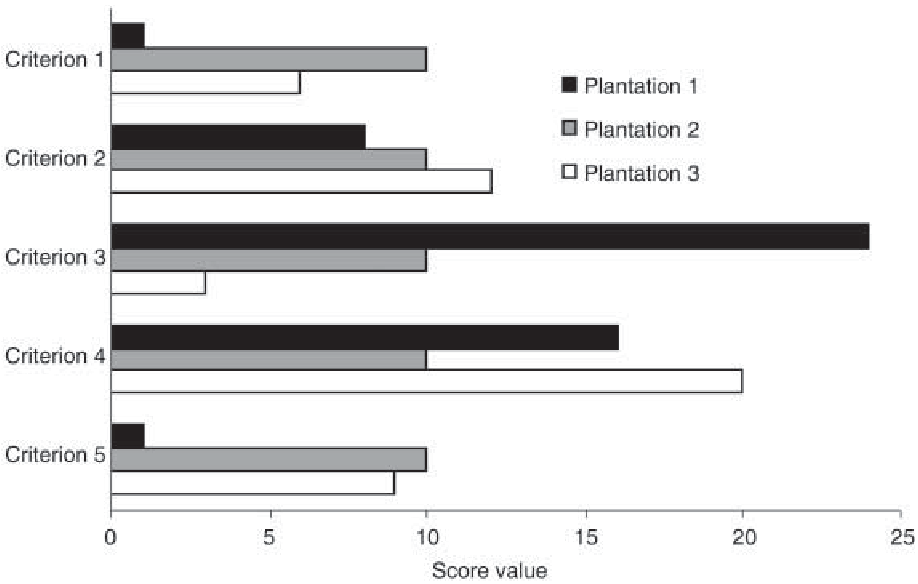

Figure 2. A 'benefits profile' showing the scores for each of five criteria for three hypothetical plantations. The total score, over all criteria, is the same (50) for each plantation, yet the scores for each criterion are different.

Acknowledgements

We are grateful for valuable advice and feedback from a wide range of forestry and NRM agency staff and research ecologists

© 2008 Ecological Society of Australia

including: Tim Barlow, Manager, Biodiversity Programs, Goulburn Broken Catchment Management Authority; Phil Gibbons, Project Officer, NSW Department of Environment and Conservation; Phil Green, Operations Manager, Willmott Forests; Charlie Hawkins, Environmental Products Manager, Ensis; Richard Loyn, Senior Ecologist, Arthur Rylah Institute; Louise Maud, Executive Officer, South-east Private Forestry; Ian McArthur, Executive Officer, Southern Tablelands Farm Forestry Network Inc.; Members of the Southern Tablelands Farm Forestry Network Inc.; Terry Noody, Coordinator, Upper Clarence Landcare Network; David Parkes, Senior Policy Analyst, Victorian Department of Sustainability and Environment; Phil Polglase, Program Leader, Commercial Environmental Forestry Program, Ensis; Miles Prosser, Senior Policy Analyst, Australian Plantation Products and Paper Industry Council; Jo Roberts, National Plantation Strategy Coordinator, Plantations 2020; David Salt, Science Writer; Trevor Smith, Private Forester, Bega Valley; Richard Stanton, Manager – Policy, Australian Plantation Products and Paper Industry Council; James Todd, Senior Policy Officer, Victorian Department of Sustainability and Environment; Bernard Young, Executive Officer, Plantations North; Charlie Zammit, Assistant Secretary, Natural Resource Management Policy Branch, Commonwealth Department of Environment and Heritage. This list of individuals does not imply their endorsement of the PBBS, but rather indicates the breadth and diversity of feedback sought during the development of the PBBS to date. We also acknowledge financial support from the Commonwealth Department of Agriculture, Forestry and Fisheries and from CSIRO Sustainable Ecosystems. We thank Deb O'Connell for the idea of the benefits profile. We thank Mike Austin, Dani Ayers, Julian Seddon, Dave Spratt, Andre Zerger and two anonymous reviewers for valuable comments on the manuscript.

References

Andren H. (1994) Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. *Oikos* **71**, 355–366.

Burgman M. A., Breininger D. R., Duncan B. W. and Ferson S. (2001) Setting reliability bounds on habitat suitability indices. *Ecological Applications* **11**, 70–78.

Carruthers S. and Paton D. C. P. (2005) *The Conservation Value of Paddock Trees. A review prepared for Land & Water Australia and the South Australian Native Vegetation Council*. Native Vegetation R&D Program, Land and Water Australia, Canberra, ACT. [Cited 18 Feb 2008] Available from URL: www.lwa.gov.au/downloads/final_reports/DEP11_Review.pdf.

Cawsey E. M. and Freudenberger D. (2005) *Biodiversity Benefits of Commercial Environmental Forestry: The Plantation Biodiversity Score. August 2005*. CSIRO Sustainable Ecosystems, Canberra, ACT. [Cited 18 Feb 2008] Available from URL: www.ensisjv.com/cef – go to Downloads.

Cawsey E. M. and Freudenberger D. (2006) *A Method of Assessing Biodiversity Benefits of Plantation Forestry Designs: The Plantation Biodiversity Score Version 2.0. September 2006*. CSIRO Sustainable Ecosystems, Canberra, ACT. [Cited 18 Feb 2008] Available from URL: www.ensisjv.com/cef – go to Downloads.

Forrester D. I., Bauhaus J., Cowie A. L. and Vanclay J. K. (2006) Mixed-species plantations of *Eucalyptus* with nitrogen-fixing trees: A review. *Forest Ecology and Management* **223**, 211–230.

Gibbons P. and Lindenmayer D. (2002) *Tree Hollows and Wildlife Conservation in Australia*. CSIRO Publishing, Melbourne, Vic.

Gibbons P., Briggs S. V., Ayers D. Y. *et al*. (in press) An operational method to assess impacts of land clearing on terrestrial biodiversity. *Ecological Indicators*.

Harwood C. (1990) Aspects of species and provenance selection. In: *Sowing the Seeds: Direct Seeding and Natural Regeneration Proceedings*, pp. 127–134. 22–25 May 1990, Adelaide Convention Centre. Greening Australia, Canberra, ACT.

Jansen A., Askey-Doran M., Petit N. and Price P. (2007) Impacts of land management practices on riparian land. In: *Principles for Riparian Lands Management* (eds S. Lovett and P. Price), pp. 159–174. Land and Water Australia, Canberra, ACT. [Cited 18 Feb 2008] Available from URL: http://www.lwa.gov.au/products_details.asp?pc=PX061170.

Kavanagh R., Law B., Lemckert F. *et al*. (2005) *Biodiversity in Eucalypt Plantings Established to Reduce Salinity*. A report for the RIRDC/Land & Water Australia FWPRDC/MDBC Joint Venture Agroforestry Program. RIRDC Publication no 05/165. RIRDC Project No SFN-3A. [Cited 18 Feb 2008] Available from URL: http://www.rirdc.gov.au/reports/AFT/05-165sum.html.

Lindenmayer D. B. and Franklin J. F. (2002) *Conserving Forest Biodiversity: A Comprehensive Multiscaled Approach*. Island Press, Washington, D.C.

Loyn R. H. (1980) Bird populations in a mixed eucalypt forest used for production of wood in Gippsland, Victoria. *Emu* **80**, 145–156.

Loyn R. H. (1985) Bird populations in successional forests of Mountain Ash *Eucalyptus regnans*. *Emu* **85**, 213–230.

Loyn R. H. (2004) Research for ecologically sustainable forest management in Victorian eucalypt forests. In: *The Conservation of Australia's Forest Fauna*, 2nd edn. (ed. D. Lunney), pp. 783–806. Royal Zoological Society of New South Wales, Mosman, NSW.

McElhinny C., Gibbons P., Brack C. and Bauhus J. (2005) Forest and woodland stand structural complexity: its definition and measurement. *Forest Ecology and Management* **218**, 1–24.

McIntyre S., McIvor J. G. and MacLeod N. D. (2000) Principles for sustainable grazing in eucalypt woodlands: Landscape-scale indicators and the search for thresholds. In: *Management for Sustainable Ecosystems* (eds P. Hale, A. Petrie, D. Maloney and P. Sattler). Centre for Conservation Biology, University of Queensland, Brisbane, Qld.

New B. and England M. (2002) *Farm Forestry; Designing for Increased Biodiversity; Adelaide Hills & Fleurieu Peninsula*. Primary Industries and Resources, Adelaide, SA.

Oliver I. and Parkes D. (2003) *A Prototype Toolkit for Scoring the Biodiversity Benefits (and Disbenefits) of Land Use Change*. Centre for Natural Resources, Department of Land and Water Conservation, Parramatta, NSW. [Cited 18 Feb 2008] Available from URL: www.forest-trends.org/biodiversityoffsetprogram/BBop%20library%202/Australia/Not%20Printed/Prototype%20BioDiv%20-Toolkit.pdf.

Parkes D., Newell G. and Cheal D. (2003) Assessing the quality of native vegetation: The 'Habitat Hectares' approach. *Ecological Management & Restoration* **4**, S29–S38.

Radford J. Q., Bennett A. F. and Cheers G. J. (2005) Landscape-level thresholds of habitat cover for woodland-dependent birds. *Biological Conservation* **124**, 317–337.

Recher H. F., Majer J. D. and Ganesh S. (1996) Eucalypts, arthropods and birds: on the relation between foliar nutrients and species richness. *Forest Ecology and Management* **85**, 177–195.

Reid J. R. W. (1999) *Threatened and declining birds in the New South Wales sheep-wheat belt: I. Diagnosis, characteristics and management*. Report to the NSW National Parks and Wildlife Service. CSIRO Wildlife and Ecology, Canberra, ACT. [Cited 18 Feb 2008] Available from URL: http://www.nationalparks.nsw.gov.au/pdfs/we_declining_bird_report_99_reid.pdf.

Reid J. R. W. (2000) *Threatened and declining birds in the New south Wales sheep-wheat belt: II. Landscape relationships – modelling bird atlas data against vegetation cover*. Report to the NSW National Parks and Wildlife Service. CSIRO Wildlife and Ecology, Canberra, ACT. [Cited 18 Feb 2008] Available from URL: http://www.nationalparks.nsw.gov.au/pdfs/report_birds_wheat_sheep_belt_complete.pdf.

Salt D., Lindenmayer D. and Hobbs R. (2004) *Trees and Biodiversity; A Guide for Australian Farm Forestry*. Agroforestry Guideline Series. Joint Venture Agroforestry Program and RIRDC, Canberra, ACT.

Stirzaker R., Vertessy R. and Sarre A. (2002) *Trees, Water and Salt*. Agroforestry Guideline Series. Joint Venture Agroforestry Program and RIRDC, Canberra, ACT.

Turnbull J. W. and Griffin A. R. (1986) The concept of provenance and its relationship to intraspecific classification in forest trees. In: *Intraspecific Classification of Wild and Cultivated Plants* (ed. B. T. Styles), pp. 157–189. Clarendon, Oxford, UK.

Watson J., Freudenberger D. and Paull D. (2001) An assessment of the focal species approach for conserving birds in variegated landscapes in southeastern Australia. *Conservation Biology* **15**, 1364–1373.

© 2008 Ecological Society of Australia

Appendix Glossary

Buffer	Area not disturbed during site preparation and plantation establishment.
Coupe	An area of forest felled in a single operation.
Dead wood	Fallen trees, logs and branches from the original native vegetation in the areas to be covered by the plantation, for example, paddock trees.
Environmental weed	A 'declared' weed; see http://www.weeds.org.au/ and refer to local and state agencies.
Exotic	From another country or region; includes species which are native to Australia but are not native to the area in which a plantation is to be placed.
Fallen logs	Fallen logs and branches from plantation trees of whatever species.
Felled trees	Felled plantation trees.
Herbivore	An animal that feeds chiefly on plants; includes livestock and feral pigs.
Local species	Species recognised by botanists or seed collectors as indigenous to the relevant region.
Paddock tree	Trees around which other components of a native vegetation community have been removed (Carruthers & Paton 2005) and which do not form part of a 'remnant' (see definition below).
Plantation	A discrete area of cultivated trees.
Plantation width	The width of a rectangle calculated by fitting the area and perimeter of a plantation to an equivalent rectangle and taking the minimum dimension.
Predator	An animal that lives by killing and eating other animals.
Provenance	The geographical place of origin of a population of seed or plants, or the population of plants growing at a particular geographical location (Turnbull & Griffin 1986; Harwood 1990).
Prunings	Branches which have been cut or have fallen naturally from plantation trees.
Region	Geographical region, for example, an IBRA region http://www.deh.gov.au/parks/nrs/ibra/index.html
Remnant	The definition of a native remnant is contained within the legislation of the relevant state (see http://live.greeningaustralia.org.au/nativevegetation/pages/pdf/Authors%20D/10_DEH_2004.pdf).
Thinning, standard density	Removal of stems in a plantation in a manner which maintains even stem density and stem size across the plantation.
Thinning, variable density	Removal of stems in a plantation in a manner which provides variation in stem density and size across the plantation, including small gaps and areas left unthinned.
Watercourse	Any watercourse mapped at a large scale (i.e. 1:50 000).
Wildling	Individuals of a plantation species which is not local to the region which spread beyond the area of the plantation (Salt *et al*. 2004).

 © 2008 Ecological Society of Australia