Condition and Biodiversity of Vegetation Remnants in the Murrumbidgee Irrigation Area

a baseline survey and recommendations for future monitoring

David J Eldridge

MURRUMBIDGEE IRRIGATION

MIA ENVIROWISE

LAND & WATER CONSERVATION

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New South Wales

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by

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The photographs on the covers show examples of
remnant vegetation in the Murrumbidgee Irrigation Area.

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Summary

In spring 2001 a survey of vegetation, soil and landscape condition was undertaken within areas of remnant native vegetation in the Murrumbidgee Irrigation Area and Districts (MIA). The aim of the survey was to provide information on the biodiversity and condition of sites within the remnants, and to test a set of methods for assessing changes in the condition of the sites through time and under changing management.

In the context of MIA EnviroWise, the long-term objectives of this benchmarking procedure are to improve the biodiversity and the condition of landscape and vegetation in the area of operation of Murrumbidgee Irrigation.

Forty four sites were selected within five vegetation communities: Blackbox (20 sites), Bimble Box–Pine (13), Boree (6), Belah–Rosewood (3) and Mallee (2). Detailed measurements of tree, shrub and groundstorey cover, plant biomass, shrub density, tree health, soil surface morphology and condition, landscape function and soil chemistry were made on large, permanently marked plots measuring 50 m x 20 m.

Using data on 25 biological and landscape attributes collected during the field exercise, three indices of condition (in the context of biodiversity) were developed for the Blackbox and Bimble Box–Pine communities. These indices were based on ecosystem structure, composition and function. Attributes for each site were rated according to their effect on the three indices, with a higher rating indicating a healthier ecosystem. For each vegetation community separately, data were subjected to multi-variate analysis to examine the relative distribution of sites in relation to the measured vegetation, soil and landscape attributes. Statistical tests on the vegetation and soil data examined possible relationships between sites and communities.

Across all sites a total of 297 plant species were recorded, including 18 tree species and 31 shrub species. There were no significant differences in the number of species found between the five vegetation communities. Across all sites, 72% of groundstorey species were native and 62% were perennial. The multi-variate analyses of the Blackbox and Bimble Box–Pine communities indicated a strong gradient in condition along the first dimension which corresponded closely with subjective assessment of sites made during the field survey.

Degraded sites were characterised by a denser cover of annual grasses and a greater proportion of exotic plants. Healthy sites had a richer cover of shrubs and perennial grasses, a greater proportion of perennial plants, more landscape structures, i.e. patchiness (obstructions on the soil surface), and more shrub species. There were no clear trends in soil surface condition in relation to condition gradients, but the carbon to nitrogen ratio was higher in remnants that were in better condition.

Management strategies are identified, which should enhance condition and biodiversity. They include strategic control of livestock stocking rates, planting of shrubs and trees to enhance the broad structure of the landscape and to bring adjacent remnants closer together, removal of biomass to reduce competition and the impact of wildfire, and release of water to supply environmental flows to Blackbox wetlands.

It is recommended that additional sampling sites be established in Boree and Saltbush–Grassland communities. Existing sites within the Mirrool Creek Floodway (n = 14) should also be incorporated into this program. Vegetation and landscape monitoring on all sites should be undertaken annually for three years, then five-yearly. Canopy health of Blackbox trees should be assessed annually. Monitoring should be supplemented with opportunistic studies of the diversity of ground-active invertebrates.

ACKNOWLEDGEMENTS

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1. Background

Murrumbidgee Irrigation Ltd (MI) is a locally owned irrigation authority supplying water and drainage services to farmers and communities in the Murrumbidgee Irrigation Area and Districts (MIA). The MIA and Districts Community Land and Water Management Plan (LWMP; now called MIA EnviroWise) was developed to deal with environmental issues in the area.

The objectives of MIA EnviroWise are:

- to reduce drainage and seepage to the groundwater,
- to maintain the quality of drainage water,
- to improve overall water quality,
- to manage water disposal,
- to reduce the costs of flooding, and
- to protect and enhance the natural environment.

In this context, the following biodiversity needs have been identified (MI 2001):

- collection of data and mapping of the distribution of flora, fauna, Aboriginal cultural sites, conservation reserves and environmentally sensitive land;
- development of a conservation strategy for areas of significant conservation value;
- development of farm conservation guidelines incorporating conservation and assessment of vegetation and landscapes;
- monitoring and reporting on biodiversity, natural resources and cultural heritage.

Specifically the aim of the biodiversity strategy is (MI 2001):

> to raise the awareness of biodiversity values within the MIA community and to undertake and support projects that will achieve biodiversity improvement by incorporating these values into the implementation of the LWMP.

Terms of Reference

This project was to undertake an assessment of vegetation and soil condition on 44 sites in the MIA in 2001 and specifically to:

1. develop methods, protocols, and appropriate systems for collection, manipulation, storage, assessment and reporting of data;
2. co-ordinate and lead the field data collection process on 44 native vegetation remnants in spring 2001;
3. collect information on vegetation attributes (including species, abundance and condition), soil surface condition and landscape attributes;
4. provide training to designated MI staff and nominated personnel;
5. develop baseline assessments of condition measures based on landscape structure, composition and function; and
6. produce a report outlining the results, including recommendations for future studies.

This report describes the background, methods and field results of the survey of biodiversity and condition of 44 sites in the MIA, and outlines a range of management options for enhancing biodiversity and condition on lands within the area of operation of Murrumbidgee Irrigation.

2. Assessing ecosystem health or condition

It is important for land managers to be able to determine the condition or health of a patch of land, for a number of reasons. Firstly, condition relates to the capacity of the vegetation to provide habitat and resources for native plants and animals (Oliver 2002). Secondly, vegetation condition has been identified as a performance measure for setting vegetation retention and revegetation targets in NSW (DLWC 1999, Oliver 2002), and has been identified as an environmental indicator for State of the Environment reporting (ANZECC 2000). Thirdly, the condition of a landscape is closely tied to its ability to recover from stress (resilience) and its ability to resist stress (stability). Thus, measures of condition provide insights into how a landscape will provide habitat for organisms and recover from disturbance; the measures are useful tools for managers.

Whilst methods for measuring changes in the distribution and abundance of plants and animals are relatively well known and accepted, methods for assessing ecosystem health or condition are relatively recent and less well known. Further, many different approaches have been used at a range of spatial scales. Approaches range from broad, landscape-level reconnaissance techniques which are generally poorly reproducible between observers, to detailed assessments of particular plant or animal taxa such as invertebrates, which often require specialist taxonomists. The results of many of these surveys can be difficult to interpret, varying greatly from place to place and through time. Methods which consider a range of ecosystem components (i.e. flora, fauna, soils and landscapes) rather than just one or two components (e.g. plants or invertebrates) are likely to produce more information about the condition of a landscape.

2.1 APPROACHES TO ASSESSING CONDITION

Traditionally many institutions have used the condition of the vegetation as a surrogate for the condition of the landscape and therefore as an indicator of overall biodiversity. Methods of assessing the condition of vegetation within the context of biodiversity are currently being investigated by the NSW Department of Land and Water Conservation (DLWC; Oliver 2001). At the time of writing this report the results were in their infancy.

Unfortunately, 'condition' is extremely value-laden and context-dependent, and has different meanings for land that is being managed for production, conservation or human settlement.

In the western part of New South Wales, DLWC uses a subjective method of assessing condition using a combination of vegetation richness, groundstorey (pasture) biomass and degree of erosion (Green *et al.* 1994). In the western United States, Pellant *et al.* (2000) have developed a system for assessing condition based on the degree to which a site departs from some imagined 'potential'. Both of these techniques rely heavily on a large body of operator experience, and therefore assessments often vary widely between recorders.

Other less formalised systems exist that monitor the health of limited components of the landscape, such as the health of trees which is used in the Save the Bush Toolkit (Wakefield and Goldney 1996), or vascular plants, used in the DLWC guidelines for assessing clearing applications under the Native Vegetation Conservation Act (DLWC 1999).

In summary, measurements of vegetation alone provide a useful indication of one component of condition, but do not provide a complete picture of total landscape condition.

One approach to vegetation condition assessment has focused on measuring the vertical attributes of vegetation such as tree, shrub and groundstorey cover, to arrive at a score for vegetation complexity (Catling and Burt 1995). This score has been shown to be highly correlated with bird diversity (see Freudenberger 1999), but, as Oliver (2001) points out, it ignores patchiness or spatial variation in vegetation and landscapes in a horizontal direction, and may not relate well to total ecosystem diversity which includes plants and invertebrates.

2.2 AN ECOSYSTEM FUNCTION APPROACH TO CONDITION ASSESSMENT

Noss (1990) proposed a system for assessing landscape condition (in the context of biodiversity) by developing three indices of condition or health — namely composition, structure and function.

The system, known as the Ecosystem Function approach, incorporates measurements of three components or elements of the landscape: the compositional elements (diversity); the structural elements (cover, remnant size, remnant connectivity, soil surface patchiness); and the functional elements (biomass, decomposition) (see Section 2.3).

The attributes comprising these elements can be determined using a suite of techniques from Landscape Function Analysis (LFA; Ludwig and Tongway 2000), Soil Surface Condition Assessment (Tongway 1995) and standard vegetation survey techniques. Thus the Ecosystem Function approach takes into account both the biological components and the physical status of the landscape and its surface.

The Ecosystem Function approach has the advantage that it incorporates data on the distribution and abundance of key components of biodiversity (plants and animals) and links these with indices of the condition of the landscape and its surface which can be tracked over time. This set of methods would seem to be appropriate for monitoring change in landscape condition from a biodiversity perspective in the MIA. A modification of this system has been used in the western United States where a slightly different set of three indices (biotic integrity, landscape function, landscape stability) is calculated (Pellant *et al.* 2000). Eldridge and Koen (2001) used similar indices to examine differences in the health of rangeland sites near Cobar, NSW.

The advantages of the Ecosystem Function approach are numerous. Ecosystem function:

- is not limited to one group of organisms, e.g. plants or invertebrates;
- considers the importance of other (particularly landscape) components;
- can incorporate various types of data at a site, e.g. plant, soil and management;
- can use data tailored to a particular region or issue;
- provides a holistic approach;
- is relatively transparent and relatively easily understood by land managers;
- can be used to derive indices which can be tracked over time.

2.3 COMPONENTS OF ECOSYSTEM HEALTH

The three components of ecosystem health used in this report are those proposed by Noss (1990). They are *landscape structure*, *landscape composition* and *landscape function*, and are described briefly below.

2.3.1 Landscape structure

'Landscape structure' attributes are related to the amount of cover offered by the biotic components of the landscape such as trees, shrubs, pasture and cryptogams, and also to the soil surface patchiness at small (<100 m) spatial scales (see Ludwig and Tongway 2000).

2.3.2 Landscape composition

'Landscape composition' attributes focus on the biota themselves (Andreasen *et al.* 2001). The choice of an appropriate attribute depends on the context of the study (whether productivity or biodiversity, etc.) and the amount of expert knowledge available in the study area.

In previous studies, the compositional attributes chosen have been 'focal species' such as declining woodland birds (Freudenberger 1999, Lambeck 1997), 'keystone species' (e.g. the prairie dog in western USA; Whicker and Detling 1988), 'indicator species', or weedy 'special interest' species such as annuals (Andreasen *et al.* 2001) among others. In some situations, a single indicator or group of indicator species may be useful — say, to test the impact of grazing or fire — but it can be problematic (Noss 1990). The population of exotic species in a landscape has been shown to be a reliable choice of indicator in some systems, such as aquatic systems, due to their capacity to radically alter the system.

In the present study, attributes such as the number of tree, shrub and grass species, as well as perenniality and the proportion of exotics in the groundstorey are used to derive indices of composition.

2.3.3 Landscape function

'Landscape function' is the effective operation of key landscape and ecological processes: e.g. biotic processes such as competition and herbivory, abiotic processes such as infiltration, and mixtures of both biotic and abiotic such as decomposition and disturbance. As many of these processes are difficult to measure, useful surrogates can be derived by assessing, for example, the morphology of the soil surface, which can indicate the capacity of the soil to cycle nutrients or absorb rainfall (Tongway 1995).

Attributes from which a measure of landscape function can be derived include canopy condition, the extent of hollows in the trees, biomass, the organic carbon content of the soil and soil texture.

3. Methods

In the study area, native vegetation remnants vary in condition, mostly as a result of differences in regional and local land management practices. Agricultural practices within the MIA are relatively intensive, and much of the native vegetation has been substantially altered, particularly on the heavier textured clay soils associated with the plains. Vegetation remnants are now generally restricted to hills and isolated depressions, or to areas deliberately set aside for forestry (see map, at centre of this report).

East of Barren Box Swamp where there is intensive irrigation, most of the remnants are extremely small. West of Barren Box Swamp, larger areas of native vegetation remain, mostly on soils that are not really suitable for agriculture or in areas used for pastoral production.

The field methods and analytical procedures used to describe biodiversity and assess condition in the MIA are described below.

3.1 INITIAL SITE SELECTION

There are several dominant vegetation communities in the MIA. For this study, five of them have been identified as being either vulnerable or endangered or depleted (WRRVMC 2001). They are (see Table 1):

- the Blackbox community,
- the Bimble Box–Pine community,
- the Boree community,
- the Rosewood–Belah community, and
- the Mallee community.

Within these comunities, areas were chosen for detailed assessment of condition and biodiversity, as follows.

1. On 1999 aerial photographs, areas of remnant vegetation that were clearly visible were outlined and digitised onto a map of the MIA using the ArcView software. Only woodland sites were selected; chenopod shrublands and grasslands on the Riverine Plain were not included in this survey.
2. The vegetation community characterising these remnants was identified using local knowledge and some ground-truthing.
3. Community groups and stakeholders, e.g. farmers and pastoralists, Greening Australia, irrigators, Murrumbidgee Irrigation, the Murrumbidgee Field Naturalists and government agencies (National Parks and Wildlife Service, Department of Land and Water Conservation) were consulted for advice on potential sites.

Table 1. Status of the main vegetation communities in the Murrumbidgee Irrigation Area and Districts (MIA)

Endangered = <10% of pre-European extent remaining, Vulnerable = 10–30% pre-European extent remaining, Depleted = 30–50% of pre-European extent remaining, Well retained = >50% of pre-European extent remaining

Vegetation community	Regional status	Current extent in the MIA (ha)
Bimble Box–Pine	Endangered	10 829[a]
Boree	Endangered	794
Rosewood–Belah	Vulnerable	4 220
Blackbox	Depleted	9 997
Mallee	Depleted	303
Dwyer’s Gum–Currawang	Well retained	b
Sandhill communities	Well retained	c
Red Gum	Well retained	c
Chenopod shrublands	Unknown	d
Grasslands	Unknown	d

[a] includes Bimble Box–Pine communities and Dwyer’s Mallee Gum communities, [b] included in Bimble Box–Pine statistics, [c] unknown at the scale of mapping, [d] vegetation not yet mapped. The figures for current extent of vegetation are based on calculations undertaken by the GIS unit, Murrumbidgee Irrigation, August 2001.

3.2 CALCULATING THE QUALITY OF REMNANTS — A 'FIRST CUT'

Using the general site selection procedures outlined above, and anecdotal information on remnants in the area, a list of 70 potential sites for detailed investigation was compiled. Each potential site was given a quality-score, derived using a combination of expert knowledge and local information gathered during reconnaissance surveys (e.g. Roberts and Wylks 1992, Harrison 2001).

Quality was assessed in terms of patch size, connectivity, water table depth, grazing status, tree health, extent of shrub and tree regeneration, and weediness (Table 2). Each attribute was rated from 0 to 3, with higher ratings for healthier or more intact sites. The values for each attribute were summed for each potential site and expressed as a percentage of 24, the maximum score for any site.

For example, a 23 ha site (rated 2 for size), 70 m distant from the next nearest patch (rated 2 for connectivity), with water table at 1.7 m (rated 1 for water table depth), ungrazed (rated 3 for grazing status), with healthy tree canopies (rating = 3), abundant tree regeneration (rating = 3), few shrubs (rating = 1) and <10% weeds (rating = 3) would receive an overall score of 2 + 2 + 1 + 3 + 3 + 3 + 1 + 3 (=18) out of a possible score of 24; therefore a value of 75%.

The selection of actual sites was based on the following criteria:

- variation in quality of remnant as determined by the scoring procedure described above;
- differences in management, e.g. grazed vs ungrazed;
- accessibility, i.e. proximity to road and rail lines;
- representativeness: unique or unusual sites were avoided;
- land tenure: freehold, crown land, rail reserves, State Forests, travelling stock reserves;
- degree of interest from landholders and agencies;
- opportunities to enhance knowledge of the natural environment;
- best knowledge at the time.

A final decision on which sites to monitor from within each of the five vegetation communities was made by examining the site scores obtained using the process described above. It was not always possible to find sites suitable for every combination. Because of the constraints of time and money, monitoring was restricted to 44 sites. Consequently, 20 Blackbox, 13 Bimble Box–Pine, six Boree, three Rosewood–Belah and two Mallee sites were established, reflecting the current distribution of these communities and potential opportunities to influence management. The initial quality-scores for each of these sites are shown in Table 3 along with the sizes of the remnants.

Procedures to test first-cut scores against derived data such as condition scores are currently being investigated and will be reported elsewhere.

3.3 PLOTS AND TRANSECT

At each site, a 0.1 ha (50 m x 20 m) plot, termed the 'vegetation plot' was established within a

Table 2. Attributes used to select sites for detailed measurements of condition. A larger rating equates with a healthier remnant.

Rating	Remnant size (ha)	Connectivity (distances apart)	Water table depth (m)	Grazing pressure	Tree health	Extent of tree regeneration	Shrub recruitment	Weed cover (%)
0	<10	>1 km	<1	heavy	tree dead	nil	none	>80
1	10–20	100 m–1 km	1–2	moderate	substantial leaf loss	<5 seedlings	<5 shrubs	50–80
2	20–50	10–100 m	2–4	light	some dieback	scattered seedlings	scattered shrubs	10–50
3	>50	<10 m	>4	nil	little leaf loss, crown healthy	abundant seedlings	abundant shrubs	<10

Table 3. Distribution of the 44 sites between vegetation communities: numbers (*n*), sizes and quality-scores of remnants in each community. Bimble Box–Pine communities were separated according to grazing status.

Size and score within community		Area (ha)		Quality-score (%)	
	n	Mean	Range	Mean	Range
Blackbox					
Large size, high score	3	103.8	128–809	69.7	>67
Large size, moderate score	2	235.0	78–392	56.0	54–58
Moderate size, low to moderate score	7	45.3	16–73	51.8	17–71
Small size, low to moderate score	8	5.0	1–15	20.5	8–58
Bimble Box–Pine					
Ungrazed	6	136.9	61–310	85.8	76–100
Grazed	7	195.5	24–612	54.0	43–72
Boree					
Large size, high score	3	79.6	18–148	74.0	71–75
Moderate size, moderate score	2	40.2	31–50	46.0	42–50
Small size, high score	1	9.9	–	92.0	–
Belah–Rosewood					
Variable	3	108.0	22–199	66.7	54–79
Mallee					
Variable	2	34.6	17–52	73.0	71–75
Average		91.2	1–809	62.3	8–100

larger 2 ha (100 m x 200 m) plot currently used for seasonal bird surveys. Within the 2 ha bird plot, the vegetation plot was aligned so it encompassed an area of homogeneous vegetation. As the distribution of vegetation differed between sites, the placement of this plot varied slightly between sites. A smaller 20 m x 20 m plot was sited centrally within the 50 m x 20 m vegetation plot, for detailed surveys. A 50 m transect was marked out on the long centreline of the vegetation plot for use in Landscape Function Analysis and Soil Surface Condition Assessment.

In each vegetation plot the general site characteristics were measured, as well as tree and shrub size, density and health. Soil samples for laboratory analyses were taken from within the vegetation plot. Within the smaller plot, the foliage cover of groundstorey plants, the landscape structure and the soil surface condition were assessed. These measurements are described in detail below.

Plate 1. Bimble box and perennial grasses, Scenic Hill, Griffith, May 2002

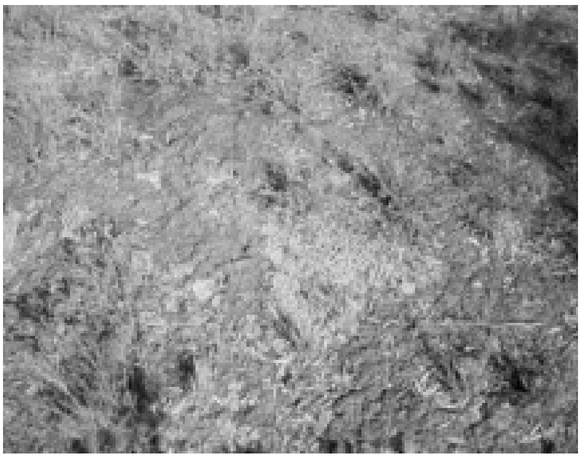


Plate 2. Soil surface with cryptogams, north-west of Griffith, May 2002

3.4 VEGETATION MEASUREMENTS

3.4.1 Foliage and canopy cover

The projected foliage cover of all vascular plants was measured, species by species, in the 20 m x 20 m plot. Extra species occurring only

Table 4. Categories of canopy dieback in individual trees in relation to percentage of live canopy

Category description	Tree canopy health score	Amount of live canopy (%)
Normal, healthy crowns	5	>90
Slight dieback in crowns	4	75–90
Moderate dieback in crowns	3	50–75
Severe dieback in crowns	2	25–50
Dead	1	<25

Plate 3. Examples of the five canopy health classes for the Blackbox community:
- top left = Class 1 (dead)
- lower left = Class 2 (severe dieback)
- top right = Class 3 (moderate dieback)
- middle right = Class 4 (slight dieback)
- lower right = Class 5 (healthy)

within the vegetation plot were recorded and their cover was assessed. The projected foliage cover of all woody plants (shrubs and trees) occurring within the vegetation plot was also measured. The biomass of groundstorey vegetation was estimated using a series of photo-standards developed for woodlands.

3.4.2 Tree health

Within the vegetation plot, the diameters (at breast height) of the trunks of all the trees or shrubs (shrubs were defined as woody plants >2.5 m tall) were recorded, species by species. Where trees were multi-stemmed at breast height, each stem was measured separately. Multi-stemmed trees however were recorded as only one tree.

An index of dieback or tree canopy health was calculated for all trees at all plots, adapting the method of Wylie *et al.* (1992). In the field, trees were each classed 1–5 for dead–healthy (Table 4, Plate 3). Then, the proportion of trees within each of the five categories was multiplied by a progressive weighting factor for increasing severity of dieback; i.e. canopy health for a plot was calculated as:

(% trees in Class 5 x 0.05) + (% trees in Class 4 x 0.04) + (% trees in Class 3 x 0.03) + (% trees in Class 2 x 0.02) + (% trees in Class 1 x 0.01).

In this way, the scores for trees in various health classes were averaged to give an overall canopy condition score for the plot. The number of clumps of mistletoe and the number of hollows in each tree were also recorded.

3.4.3 Shrub species measurements

Each vegetation plot was divided into five sub-plots, each 10 m x 20 m, within which the heights of the shrubs were measured so that the variability in height classes of the shrubs across the five sub-plots could be examined. Table 5 lists all species for which density and height measurements were made. Not all shrubs were

Table 5. Woody plants species for which measurements of height and density were recorded, and the communities in which they were recorded

Scientific name	Common name	Vegetation communities
Acacia decora	western golden wattle	Bimble Box–Pine
Acacia doratoxylon	currawang	Bimble Box–Pine
Acacia hakeoides	western black wattle	Mallee
Acacia homalophylla	yarran	Bimble Box–Pine
Acacia oswaldii	miljee	Mallee
Acacia pendula	myall	Boree
Alectryon oleifolius	rosewood	Blackbox, Rosewood–Belah
Allocasuarina luehmannii	bulloak	Bimble Box–Pine
Apophyllum anomalum	warrior bush	Bimble Box–Pine, Rosewood–Belah
Callitris glaucophylla	white cypress pine	Bimble Box–Pine, Boree
Casuarina cristata	belah	Blackbox, Rosewood–Belah
Chenopodium nitrariaceum	nitre goosefoot	Blackbox
Dodonaea viscosa	hopbush	Bimble Box–Pine, Boree
Eremophila longifolia	emubush	Bimble Box–Pine
Eucalyptus largiflorens	blackbox	Blackbox
Eucalyptus populnea subsp. *bimbil*	bimble box	Bimble Box–Pine
Geijera parviflora	wilga	Rosewood–Belah
Hakea tephrosperma	hooked needlewood	Bimble Box–Pine
Lycium ferocissimum	African boxthorn	Blackbox
Muehlenbeckia florulenta	lignum	Blackbox
Pittosporum phylliraeoides	butterbush	Bimble Box–Pine, Mallee
Rhagodia spinescens	thorny saltbush	Blackbox
Senna artemisioides nothosubsp. *artemisioides*	silver cassia	Bimble Box–Pine, Boree, Rosewood–Belah, Mallee
Senna artemisioides nothosubsp. *coriacea*	desert cassia	Rosewood–Belah

measured, and most sub-shrubs from the family Chenopodiaceae were included with the ground-storey plants. However, larger chenopod shrubs such as *Rhagodia spinescens* were measured. The height data are not analysed here.

3.4.4 Additional subjective scores

Additional attributes related to the management of each site were recorded subjectively (Table 6). The author also gave each site a subjective score for condition (in the context of biodiversity). The score was based on the author's impression of the status of a site, from personal experience with the soils and vegetation of the area, and it took into account attributes such as the health of the trees and shrubs, the diversity and floristics of the ground-storey vegetation, the stability of the soil, the presence of weeds and the presence of perennial plants. The scores assigned ranged from very poor condition (rating = 1) to excellent condition (rating = 10).

Table 6. Additional subjective scores at the sites

Attribute	1	2	3	4
Degree of grazing	high	moderate	slight	nil
Evidence of clearing	moderate	slight	nil	
Degree of regeneration	nil	slight	moderate	extensive
Evidence of fire	obvious	slight	nil	
Evidence of site erosion (% of site)	severe (>30%)	moderate (15–30%)	slight (5–15%)	nil (<5%)

Subjective condition assessment:
1 = extremely degraded to 10 = excellent

3.5 LANDSCAPE MEASUREMENTS

To assess the health of the soil surface and the structural arrangement of the soil surface, two field measurements were made, to determine:

i) how the landscape functions (Landscape Function Analysis), and

ii) how the soil surface is composed (Soil Surface Condition Assessment).

The measurements were made within the central 20 m section of the 50 m transect. They were used in the calculations of landscape structure and function.

3.5.1 Landscape Function Analysis

Landscape Function Analysis (Ludwig and Tongway 2000) looks at the arrangement of stable landscape elements or 'patches' at a site, and records the observations in the form of quantities. The pattern of landscape elements on the ground is important for determining the fate of runoff water, and therefore the movement of sediment and organic matter. It is an indication of landscape function.

Along the 20 m transect, the characteristics of *obstructions* were measured: i.e. perennial grasses, shrubs and permanent elements on the soil surface such as logs; and the *fetches* (or interspaces), i.e. the spaces between patches. For the purposes of these calculations, the interspaces are demarcated by grasses, shrubs or other obstructions that make contact with the soil over a distance of at least 1 cm. That is, if the transect crosses a grass, the butt or basal area diameter of the grass has to be at least 1 cm before it is regarded as an *obstruction*. Small perennial grasses or shrubs <1 cm in diameter are not treated as permanent obstructions; they are called a component of the interspace.

Three attributes of the field measurements were calculated to characterise the functional status of the site (Ludwig and Tongway 2000):

- the number of obstructions to overland flow (per 10 m length of transect), i.e. patchiness;
- the total width of these obstructions (in m per 10 m length of transect) ;
- the average fetch length, i.e. the distance between obstructions along the transect.

3.5.2 Soil Surface Condition Assessment

3.5.2.1 Methods

The condition or health of the soil surface can be assessed by measuring various attributes at a micro scale — a procedure termed Soil Surface Condition Assessment (Tongway 1995). The condition of the soil surface was measured in quadrats placed at five regular locations along the central 20 m transect. Eight attributes were observed within each of the five 0.5 m^2 quadrats.

- *Surface microtopography* is defined as the vertical distance between the lowest and highest points in the quadrat. It is recorded in five height classes, i.e. <5 mm, 5–8 mm, 8–15 mm, 15–25 mm, >25 mm. The microtopography relates to the potential for retention of rainfall on the soil surface.
- *Crust coherence* is a measure of the force required to disrupt the soil surface with an object equivalent in diameter to a pencil. Coherence, which was generally assessed dry under field conditions, shows whether the surface has the capacity to resist stress immediately upon wetting, or if it can reform after wetting (Tongway 1995). Crust coherence was classed as *sandy* (single grained; rated 1), *flexible* or self mulching (rated 2), *easily broken* (rated 3), *moderately hard* (rated 4), or *very hard* and brittle (rated 5).
- *Degree of surface cracking* measures the percentage of the surface covered with cracks: 0%, <10%, 10–25%, 25–50%, >50%. It relates to the capacity of the surface to disintegrate and erode. Degree of cracking is probably also a measure of the potential microsites where seeds can lodge.
- *Surface stability* of the soil, to the impact of raindrops, was determined using the Emerson slake test (Tongway 1995). It was ranked as stable, moderately stable, unstable or very unstable.
- *Cryptogam cover* (non-vascular plants, i.e. mosses, lichens, etc.) was estimated and later amalgamated into one of four percentage cover classes: 1–10%, 10–25%, 25–50%, >50%.
- *Degree of erosion* was assessed as <10%, 10–25%, 25–50%, >50%.
- *Plant cover* was assessed in two ways.
  (i) Total projected foliage cover, which is related to the capacity of the vegetation to intercept raindrops (*projected foliage cover*), was rated as 0%, <10%, 10–25%, 25–50% or >50%. (Projected cover is the percentage of the ground area covered when the plant or object is viewed from directly above.)
  (ii) The cover of the bases of perennial long-lived plants and other permanent cover components such as rocks and logs (called *basal cover of perennial grasses*) was recorded as <1%, 1–2%, 2–5%, >5%. It is related to the effect of cover on overland flow processes.
- *Litter cover* was rated as <10%, 10–25%, 25–50%, 50–75%, 75–100% (or 100% and very deep). The degree of *incorporation of litter*, as slight, moderate or extensive, and the *origin of litter* as local or transported were also assessed. The overall score for litter is the product of the scores for litter cover, incorporation and origin (see Table 7).

In each quadrat, the soil surface was given a score for each of the above attributes. The better the rating given in the classes above, the higher the score. For example, soil microtopography, classed as <5 mm, 5–8 mm, 8–15 mm, 15–25 mm or >25 mm, was assigned scores 1, 2, 3, 4 or 5, respectively. A rougher surface implies a better soil condition, so it gets a higher score. The range of scores is shown in Table 7.

Table 7. Individual quadrat observations used to calculate the three indices of surface health (stability, infiltration and nutrients). If all attributes are present, the range of total values for a particular quadrat is indicated in brackets. If some attributes are irrelevant, e.g. crusting on sandy soils, the indices are adjusted accordingly.

Index of surface health	Attributes used to calculate index	Range of scores
Stability	surface cracking	1–5
	surface stability	1–4
	crust coherence	1–5
	degree of erosion	1–4
	cryptogam cover	1–4
	projected foliage cover	1–5
	simple litter cover	1–6
		(7–33)
Infiltration	microtopography	1–5
	crust coherence	1–5
	simple litter cover	1–6
	soil texture	1–4
	basal cover of perennials	1–4
		(5–24)
Nutrients	simple litter cover (1–6) x litter origin (1, 1.5) x degree of incorporation (1, 1.5, 2)	1–18
	cryptogam cover	1–5
	microtopography	1–5
		(3–28)

3.5.2.2 Other soil measurements in the field

Soil texture, which affects infiltration capacity (see Table 7), was assessed in the vegetation plot using the bolus technique (Northcote 1992) and assigned to one of four classes: silty to heavy clay (class 4), sandy clay loam to sandy clay (class 3), sandy loam to silty loam (class 2) and sand to clayey sand (class 1). Bulk density was measured on intact cores, 50 mm diameter x 25 mm depth, at one location within the vegetation plot.

3.5.2.3 Calculation of soil surface health

Using the measurements and scores described above, three nominal soil surface condition characteristics can be calculated to indicate the health of the soil surface (Tongway 1995).

- *Stability* indicates how the soil withstands erosive forces or reforms after erosion.
- *Infiltration* indicates how soil water is partitioned between infiltration and runoff.
- *Nutrients* provides a measure of how efficiently organic material is recycled into the soil.

As an example, a quadrat's index of *stability* is derived as the sum of the seven relevant scores (Table 7) which it received, expressed as a percentage of 33, the maximum possible score. Sometimes an attribute could not be recorded within a given quadrat. For example, a slake test to assess surface stability cannot be performed on a loose sandy soil (Tongway and Hindley 1995). In a situation like this, the quadrat would receive a zero score for the non-existent attribute, and the maximum possible score would be reduced accordingly, i.e. by 4 if it were the slake test to be omitted. An index of the health or condition of the soil surface in each quadrat was calculated, for each of the three categories (*stability, infiltration, nutrients*), was calculated as the ratio between the sum of the observed attribute scores and the maximum possible score.

3.6 LABORATORY MEASUREMENTS

Composite samples of soil (top 0–20 mm) were collected from the vegetation plot for laboratory analysis of nitrogen and phosphorus. Organic carbon (OC) content was measured using the Walkley–Black wet combustion technique (Colwell 1969), and pH and electrical conductivity (EC) were determined using a 1:5 soil–water suspension shaken for 1 hour.

3.7 DATA ANALYSES

Three analytical approaches are described in this report. First, ecosystem measures of condition are calculated. Second, the data are subjected to multi-variate analyses. Finally, various uni-variate analyses (analysis of variance, correlation, etc.) are used to examine the strength of the relationships among selected attributes.

3.7.1 Deriving ecosystem measures of condition

The aim of this project is to develop and report on a method for assessing condition. Condition was assessed for two vegetation communities, Blackbox (n = 20) and Bimble Box–Pine (n = 13), as these are the dominant vegetation communities within the study area.

Condition was assessed in terms of three ecosystem measures or components: *landscape structure*, *landscape composition* and *landscape function* (Noss 1990; see Section 2.3). The measures were built up from scores given for 25 attributes (see Table 8) during the field survey (Appendix I).

At each site, the value of each of the 25 attributes was allocated to one of a number of classes (usually four or five depending on the vegetation community). The classes included the full range of values encountered for a particular attribute within a given vegetation community, and ranged from very low (poor condition) to very high (good condition). Each class was then assigned a particular score depending on its perceived effect upon either structure, composition or function. For example, the range of tree cover values in the Bimble Box–Pine community (values ranged from 0 to 31%) was divided into five classes based on percentage cover:
1 = <2%, 2 = 2.1–5%, 3 = 5.1–10%,
4 = 10.1–25% and 5 = >25% (Appendix II).
A site with 23% tree cover would fall within the 10.1–25% class, and therefore receive a score of 4 for 'tree cover'. (Classes for the Blackbox community are given in Appendix III.)

Table 8. The 25 attributes used to calculate the three measures of condition (indices of landscape stability, composition and function) for the Blackbox community. For the Bimble Box–Pine community, [a] range is 1–4, [b] range is 1–5, [c] range is 1–3, [d] range of scores is 11–48.

Attribute	Structure	Composition	Function
Cover of trees (%)	1–5		
Cover of tall shrubs (2–4 m) (%)	1–5		
Cover of sub-shrubs (0.5–2 m) (%)	1–5		
Cover of perennial grasses (%)	1–5		
Cover of annual grasses (%)	1–4		
Cover of forbs (%)	1–4		
Cover of bare ground (%)	1–4		
Cover of cryptogams (%)	1–3[a]		
Cover of litter (%)*	1–4[b]		
Cover of logs and debris (%)	1–4[c]		
Landscape patchiness	1–4		
Number of tree species		1–4	
Number of shrub species		1–4	
Number of vascular plant species		1–4	
Plant perenniality (%)		1–4	
Proportion of plants as native (%)		1–4	
Degree of shrub regrowth (%)		1–4	
Degree of mistletoe infestation (%)			1–4
Degree of canopy dieback (%)			1–5
Extent of tree hollows			1–4
Groundstorey biomass (t/ha)			1–4
Cover of erosion (%)			1–4
Cover of perennial grass butts (%)			1–5
Soil organic matter (%)			1–4
Soil texture			1–4
Range of scores	11–47[d]	6–24	8–34

*simple litter cover as shown in Appendixes II and III

The use of classes rather than absolute values reduces the possibility of differences in sites resulting from small (and insignificant) differences in a particular attribute, such as might occur with a change in groundstorey cover from, say, 30 to 33%.

3.7.2 Calculating values for structure, composition and function

Eleven of the attributes listed in Appendixes I and II or III were used to calculate an index of landscape structure (Table 8). Accordingly (see Table 9), a Bimble Box–Pine site with 31% tree

Table 9. An example of the calculations of landscape structure for Site 28 in the Bimble Box–Pine vegetation community. The value for a particular attribute is the real value for that site shown in Appendix II.

Attribute	Value	Score	Maximum score
Cover of trees (%)	31	5	5
Cover of tall shrubs (2–4 m) (%)	0	1	5
Cover of sub-shrubs (0.5–2 m) (%)	0.5	1	5
Cover of perennial grasses (%)	5	1	5
Cover of annual grasses (%)	0.5	1	4
Cover of forbs (%)	5	4	4
Cover of logs and debris (%)	1	2	3
Cover of bare ground (%)	8	4	4
Cover of cryptogams (%)	8	1	4
Cover of litter (%)	35	4	5
Soil surface patchiness	2.5	3	4
Overall score for structure		27	48

cover, no tall shrubs, 0.5% cover of sub-shrubs, 5% perennial grass cover, 0.5% annual grass cover, 5% forb cover, 8% bare ground 8% cryptogam cover, 35% litter cover, 1% log cover and 2.5 obstructions per 10 m of transect would receive a score of 56.3% for landscape structure (i.e. a score of 27 out of a maximum score of 48).

3.7.3 Using multi-variate analyses

To assist in the interpretation of the conditions of the study sites, two dummy reference sites were created for the Bimble Box–Pine and Blackbox communities. One reference site was notionally ‘in excellent condition’, whilst the other was notionally ‘in a severely degraded state’. The purpose of these dummy reference sites was to establish the extremes of a notional gradient in condition in the study sites.

The reference sites approach is well accepted in the study of ecosystem health or condition. Reference sites may be real or fictitious. An actual reference site in excellent condition might be in a National Park which has not been grazed by domestic animals and is judged to have ‘sustainable’ ecosystems (Andreasen *et al.* 2001). Similarly, a reference site for degraded conditions may be real or ‘constructed’. For this study the reference sites were constructed using expert knowledge and available data. They enabled the author to see a virtual picture of what these reference sites would look like in relation to the suite of 25 attributes used here to determine condition.

3.7.4 Analytical procedures for the multi-variate analyses

For the multi-variate analyses, the full set of 25 attributes was used to calculate ecosystem measures of condition.

For the Blackbox sites, a matrix comprising the 22 sites (which included the two dummy sites) by 25 attributes was converted to a similarity matrix using the Bray–Curtis similarity coefficients contained within the PRIMER (Version 4) statistical package (Clarke and Warwick 1994). A separate matrix was constructed for the Bimble Box–Pine sites (13 plus two dummy sites). The similarity matrices were subjected to non-metric Multi-Dimensional Scaling (MDS) using one of the PRIMER (Version 4) routines (Clark 1993, Clark and Warwick 1994) so that the author could determine the statistical distribution of sites in relation to each other, and in terms of the 25 recorded attributes.

For interpreting the resulting multi-variate biplots, each site is represented as a point in multi-dimensional space (in this case in two dimensions), and a measure of overall condition or health can be obtained as the (Euclidean) distance between the sites in relation to the reference ‘degraded’ and ‘excellent’ sites.

3.7.5 Univariate analyses

Throughout this report various relationships are presented between, for example, the three indices of landscape health (structure, composition and function) and the subjective measure of condition made at each site (Table 6).

The relationships were investigated using linear and non-linear regression with the statistical package Minitab (1997). Differences in attributes between sites or groups of sites were examined using one-way ANOVA (Minitab 1997) or, where appropriate, the non-parametric Kruskal–Wallis test, and significant differences between means were identified using least significant difference (LSD) procedures.

4. Results

4.1 REGIONAL ASSESSMENT OF FLORISTICS

In all, across the 44 sites, 297 vascular plant species were recorded: 18 tree species, 31 shrub species and 248 species of groundstorey plants (Appendix IV).

Of the groundstorey plants across all sites, 72% were native and 62% were perennial. Sites that were subjectively assessed as being in relatively good condition actually had a relatively small proportion of exotic species in the groundstorey ($F_{1,43}$ = 22.9, $P < 0.001$, $R^2 = 0.33$; Figure 1). This relationship was even stronger for the Blackbox sites when they were examined separately ($F_{1,19}$ = 28.5, $P < 0.001$, $R^2 = 0.59$).

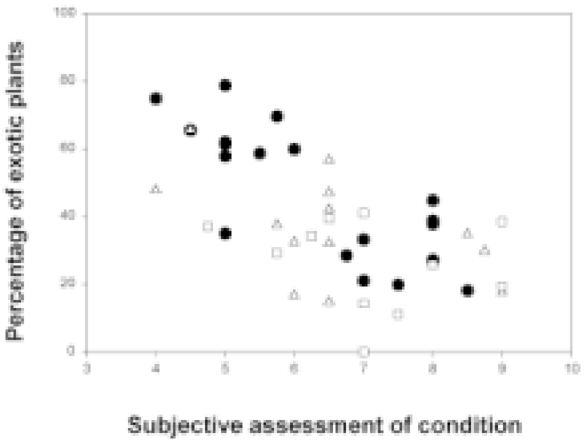


Figure 1. Numbers of exotic groundstorey plants as a proportion of all groundstorey vegetation, in relation to the subjective assessment of condition (● = Blackbox community, ∆ = Bimble Box–Pine community, ☐ = other communities)

On average, the Belah–Rosewood and Mallee communities supported significantly more trees per site than the Blackbox, Bimble Box–Pine and Boree communities ($F_{4.43}$ = 10.9, $P < 0.01$; Table 10).

There was about the same number of groundstorey plants per site in each of the five communities ($P > 0.05$; Table 10). On average, about half of the groundstorey plants at the Blackbox sites were native and/or perennial (Table 11). The Mallee vegetation community supported the greatest proportion of both native and perennial groundstorey plants, but differences between the communities were not significant ($P > 0.05$; see Table 11). No Rare or Threatened plant species, as listed under the Threatened Species Conservation Act, were recorded in the survey.

4.2 DESCRIPTION OF THE MAIN VEGETATION COMMUNITIES

Table 12 lists some of the biotic and abiotic features of the five vegetation communities.

4.2.1 The Blackbox community

The Blackbox community is restricted to floodplains, plains and relict drainage channels, often with characteristic gilgai pattern ranging from small crabholes about 30 cm across, to wide melon holes and sinkholes up to 20 m across and 1 m deep. Soil are predominantly medium to heavy grey clays (Ug5.24, Ug5.25, Ug5.28; Northcote 1992), sometimes overlain by clay loams and loams. Brown and grey soils occur on slightly elevated rises. Slopes are generally less than 1%.

Table 10. Diversity of plant forms by vegetation community. SEM = standard error of the mean. Values with the same letter do not differ significantly ($P < 0.05$).

Community	No. of sites	No. of trees		No. of shrubs		No. of groundstorey plants	
		Mean	SEM	Mean	SEM	Mean	SEM
Blackbox	20	1.4[a]	0.13	2.1[a]	0.38	26.6[a]	1.91
Bimble Box–Pine	13	1.9[a]	0.33	2.4[ac]	0.56	30.5[a]	2.31
Boree	6	1.0[a]	0	3.0[ac]	0.58	31.2[a]	2.23
Belah–Rosewood	3	3.3[b]	0.33	4.7[ac]	0.88	20.7[a]	6.96
Mallee	2	4.5[b]	0.50	6.0[bc]	4.0	21.0[a]	8.00

Table 11. Origin and life history of groundstorey plants by plant community. SEM = standard error of the mean. Values with the same letter do not differ significantly ($P < 0.05$).

Community	No. of sites	Native (%)		Perennial (%)	
		Mean	SEM	Mean	SEM
Blackbox	20	52.1[a]	4.21	56.9[a]	2.12
Bimble Box–Pine	13	61.9[a]	3.88	59.5[a]	2.80
Boree	6	63.8[a]	3.05	57.6[a]	3.20
Belah–Rosewood	3	73.6[a]	7.83	53.6[a]	1.87
Mallee	2	86.2[a]	13.8	81.1[a]	18.90

Table 12. Mean values for a range of biotic and abiotic attributes measured within the five vegetation communities, including the 25 attributes used to calculate measures of landscape health and some additional attributes

Vegetation community	Blackbox	Bimble Box–Pine	Boree	Rosewood–Belah	Mallee
No. of tree species	1.4	1.9	1.0	3.3	4.5
Cover of trees (%)	16.7	10.4	5.0	32.7	11.0
Density of trees (per ha)	116.5	362.3	46.7	203.3	185.0
Canopy health score	3.8	4.4	4.2	4.1	5.0
Mistletoes per live tree	0.0	0.04	0.7	0.1	0.0
Hollows per tree	3.0	1.3	0.06	0.6	0.0
No. of shrub species	2.1	2.4	3.0	4.7	6.0
No. of groundstorey species	26.6	30.5	31.2	20.7	21.0
Total number of species	30.1	34.7	35.2	28.7	31.5
% perennial plants	56.1	62.1	60.7	64.8	82.3
% native plants	53.3	64.4	66.4	79.2	87.1
Cover of tall shrubs (%)	0.0	1.2	0.0	0.3	0.5
Cover of sub-shrubs (%)	3.5	0.7	5.3	9.0	3.0
Cover of perennial grasses (%)	5.4	24.4	21.3	0.8	13.8
Cover of annual grasses (%)	21.3	7.9	4.9	3.0	0.8
Cover of forbs (%)	17.7	10.5	13.0	5.3	14.5
Cover of logs and debris (%)	1.1	0.7	0.8	2.5	0.5
Cover of grass butts (%)	0.6	4.3	4.1	0.07	3.0
Cover of bare soil (%)	16.1	13.1	16.3	15.0	9.5
Cover of cryptogams (%)	2.3	29.5	16.3	21.3	61.0
Cover of litter (%)	34.6	30.7	23.7	43.3	31.0
Biomass (t/ha)	1.3	1.3	1.2	0.3	0.6
No. of obstructions (per 10 m)	2.1	6.2	5.0	1.3	6.0
Remnant size (ha)	84.4	159.9	54.9	108.0	34.6
Length of perimeter (m)	4230.3	5810.4	3347.6	5674.0	3094.5
Area to perimeter ratio	0.012	0.02	0.01	0.02	0.01
Subjective condition score	6.4	6.7	7.3	6.4	7.5
Organic carbon (%)	5.9	2.7	2.6	2.1	1.8

Plate 4. Blackbox community, west of Griffith, May 2002

Site erosion was typically low on the clay soils (<5%), and restricted to the interface with sandy soils. The relatively sparse cover of perennial grasses at most sites (<5%) and the typically sparse cover of logs and debris on the surface (Table 12) are reflected in the low value of landscape patchiness (mean = 2.1 patches per 10 m of transect). Despite this, the soils are very stable and fertile, with high concentrations of organic carbon (mean = 5.9%) which exceeded values for other vegetation communities.

Blackbox (*Eucalyptus largiflorens*) is the characteristic tree in this community, with tree densities ranging from 10 to 400 trees/ha (mean = 117 trees/ha, Table 12). Tree health, as assessed by the degree of canopy dieback, ranged from excellent to poor, with a mean canopy health score of 3.8 (~75% of canopy healthy; see Table 4). Blackbox had the largest mean number of hollows (mean = 3.0 hollows per tree) for trees in the study (Table 12). Shrub cover was generally very low in the Blackbox community, though sites in good health tended to carry a moderate to dense cover of spiny saltbush (*Rhagodia spinescens*). On regularly inundated sites, lignum (*Muehlenbeckia florulenta*) grew at a range of densities. In terms of plant cover, the groundstorey vegetation was dominated by:

barley grass (*Hordeum leporinum*),
great brome (*Bromus diandrus*),
climbing saltbush (*Einadia nutans* subsp. *nutans*),
ryegrass (*Lolium* sp.),
white-top (*Austrodanthonia caespitosa*),
rough speargrass (*Austrostipa scabra*),
London rocket (*Sisymbrium irio*),
smooth mustard (*Sisymbrium erysimoides*),
prairie grass (*Bromus cartharticus*),
Paterson's curse (*Echium plantagineum*),
horehound (*Marrubium vulgare*), and
common nardoo (*Marsilea drummondii*).

A full list of species by site and vegetation community is given in Appendix IV.

4.2.2 The Bimble Box–Pine community

The Bimble Box–Pine community occurs over extensive areas of slightly to gently undulating plains, sandplains, footslopes and midslopes. The soils are predominantly deep, loamy calcareous earths (Gn2.12, Gn2.13) sometimes with calcareous material at depth. Adjacent to the ranges, soil profiles are dominated by colluvial material eroded from the higher country. In many places rock outcropping occurs over 5–10% of the site. On steeply sloping country with little vegetation cover, calcareous red earths are moderately susceptible to water erosion in the form of gullying, rilling and water sheeting. Organic carbon concentrations were found to be moderate (2.7%) for this soil type.

Calcareous red earths support an extensive cover of cryptogams (here, up to 60% cover; mean = 29.5%) and a dense cover of litter (30.7%). The moderately high degree of landscape patchiness (on average 6.2 obstructions per 10 m transect) was contributed by grass butts (4.3% cover) rather than logs and other surface obstructions (mean 0.7%).

The dominant trees in this community are bimble box (*Eucalyptus populnea*) and cypress pine (*Callitris glaucophylla*). Tree densities

Plate 5. Pine regeneration, Scenic Hill, Griffith, May 2002

Plate 6. Blackbox with spiny saltbush understorey, Amsbury Common, Leeton, May 2002

range from nil to 2700 trees/ha (mean = 362 trees/ha, Table 12), reflecting the dense pine regeneration on some sites. The mean tree cover was 10.4%. Generally trees were healthy with few being infested with mistletoe, and had an average density of 1.3 hollows per tree. As with the Blackbox community, there were few shrub species and shrub cover was very low.

Across all sites, common groundstorey species, in order of declining cover, included:

rough speargrass,
oats (*Avena* sp.),
mulga grass (*Thyridolepis mitchelliana*),
great brome,
Paterson's curse,
brush wiregrass (*Aristida behriana*),
common white sunray (*Rhodanthe floribunda*),
curly windmill grass (*Enteropogon acicularis*),
white-top,
tucker's speargrass (*Austrostipa tuckeri*),
corrugated sida (*Sida corrugata*), and
barley grass.

4.2.3 Boree community

Boree is generally found on either floodplains with gilgai, or elevated plains with source-bordering dunes, or the levees of prior streams. Sink holes and gilgai, where they occur, are restricted to small (<1 m across) depressions, to 30 cm deep. The soils of this community grade from compacted, grey clays (Ug5.24, Ug5.28) to sandy and loamy duplex soils on the prior stream levees (Dr2, Db2, Db4). Because of the coarser texture of the surface soil, these landscapes are susceptible to wind erosion when they lose their protective vegetation cover.

The dominant tree in this community is boree (*Acacia pendula*) which occurs at a relatively low density of <100 trees/ha (Table 12). Tree cover averaged 5% in these sites. Trees were generally healthy (>75% healthy) but some contained mistletoe and/or bag moth. The cover of shrubs such as *Senna artemisioides* and *Dodonaea viscosa* was moderately high at some sites (Appendix IV). The cover of perennial grasses such as white-top, rough speargrass and windmill grass was moderately high (mean = 21%) in this community. Other common groundstorey species (by cover) included (see Appendix IV): burr medic (*Medicago polymorpha* var. *vulgaris*), climbing saltbush, great brome, ruby saltbush (*Enchylaena tomentosa*), and corrugated sida.

4.2.4 Belah–Rosewood community

The Belah–Rosewood community occurs on level (slope <1%) plains and sandplains of calcareous earths (Gc1.12, Gc1.22). Calcareous earths have a predominantly loam to clay loam surface texture and are susceptible to wind and water erosion when the surface is unvegetated.

A feature of this vegetation community is its often high degree of soil surface patchiness, reflecting major differences in the soils between vegetated and unvegetated patches within plots (Tongway and Ludwig 1990). Vegetated patches supporting trees and shrubs and (often termed runon areas), were separated by long, low essentially bare slopes (termed runoff areas) dominated by cryptogamic crusts (Eldridge 2001).

Plate 7. Boree community north of Griffith, May 2002

The Belah–Rosewood community supported a dense cover of trees, at densities of 70 (cleared woodland) to 250 trees/ha (uncleared woodland; mean = 203 trees/ha; Table 12). The dominant trees were belah (*Casuarina cristata*), rosewood (*Alectryon oleifolius*), wilga (*Geigera parviflora*) and warrior bush (*Apophyllum anomalum*). Tree health, as assessed by canopy health and mistletoe infestation, was very good. Trees contained a mean of 0.6 hollows per tree (Table 12). Cover of shrubs in undisturbed communities was high (mean = 9.0%) with the most common shrub being ruby saltbush. Other shrubs included punty bush (*Senna artemisioides* subsp. *filifolia*) and desert cassia (*Senna artemisioides* nothosubsp. *coriacea*). Across all Belah–Rosewood sites, the species with the greatest groundstorey cover were: rough speargrass, barley grass, smooth mustard, burr medic, and buckbush (*Salsola kali* var. *kali*).

4.2.5 The Mallee community

Mallee communities are restricted to areas of deep, siliceous, earthy and brownish sands (Uc1, Uc5) on generally level to slightly undulating plains. The soils are relatively susceptible to wind erosion when cover is sparse (Eldridge 1989). The soils often have limestone exposed on the surface, and their high pH makes them a suitable substrate for cryptogams (mean cryptogam cover = 61%; Table 12).

The community is characterised by mallees — multi-stemmed, stunted *Eucalyptus* species — which have an underground rootstock (lignotuber). The dominant species is congoo mallee (*Eucalyptus dumosa*), followed by grey box (*E. microcarpa*) and pointed mallee (*E. socialis*). Tree cover averaged 11%, with an average density of 185 trees/ha (Table 12). Trees were healthy and showed no obvious evidence of mistletoe infestation. Floristically the mallee communities supported a large number of shrubs (mean = 6.0) including broombush (*Melaleuca uncinata*), and cactus pea (*Bossiaea walkeri*), as well as the low spreading flax-lily (*Dianella revoluta*). Shrub cover averaged 3.5%. The cover of perennial grasses such as brush wiregrass (*Aristida behriana*), white-top, rough speargrass and porcupine grass (*Triodia scariosa* subsp. *scariosa)* was moderately high (13.8%; Table 12).

4.3 MULTI-VARIATE ANALYSES OF BLACKBOX AND BIMBLE BOX–PINE SITES

4.3.1 Introduction

For the Blackbox and Bimble Box–Pine sites, 25 of the attributes collected at each site (Table 8) were used for input into the PRIMER statistical packages. The aim of the analysis was to examine whether sites differed in relation to the measured biotic, soil and landscape variables. Raw data were first transformed into class values from 1 to 4 or 1 to 5 (see Section 3.7) before being input into the statistical package.

4.3.2 MDS biplots

The MDS biplots for the Blackbox and Bimble Box–Pine communities are shown in Figure 2. The location of the reference sites labelled 'excellent' and 'degraded', indicates a strong gradient in Blackbox sites along Dimension 1, but a tighter gradient for the Bimble Box–Pine community (Figure 2). This gradient represents

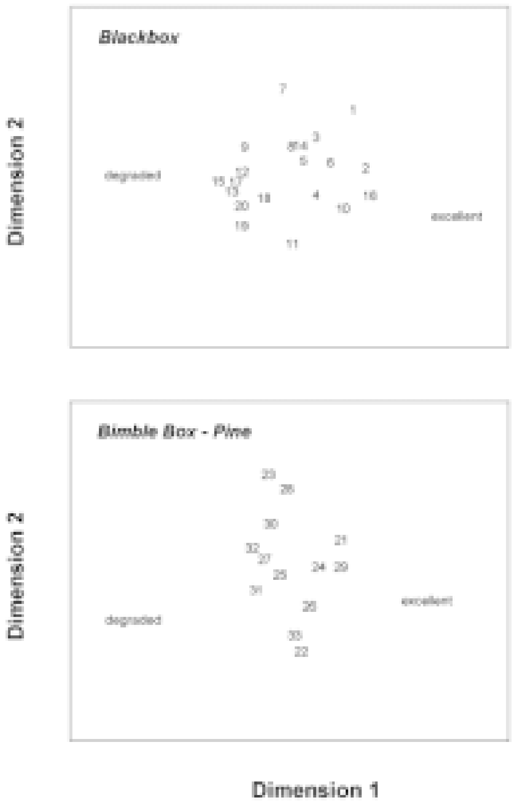


Figure 2. Non-metric multi-dimensional scaling (MDS) biplots for the Blackbox and Bimble Box–Pine communities

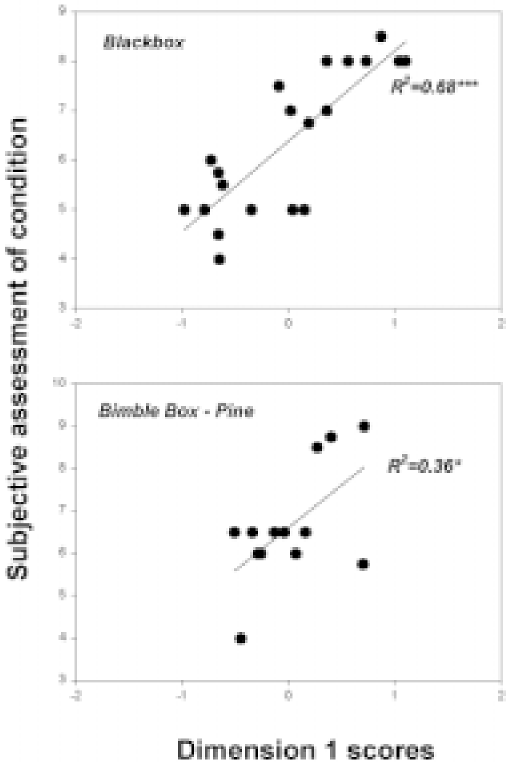


Figure 3. Relationships between Dimension 1 scores from the non-metric MDS and the subjective assessment of condition for the Blackbox and Bimble Box–Pin communities (Dimension 1 by subjective condition)

an increase in the magnitudes of desirable attributes (e.g. number of species, cover of trees, canopy health of trees) from sites on the left-hand side of the biplots to those on the right-hand side. Therefore, Dimension 1 can be regarded as representing a gradient in condition.

To examine whether Dimension 1 corresponds to an increase in condition from left-hand side to right-hand side, the subjective assessment of condition made at each site was plotted against the scores obtained from Dimension 1 (Figure 3). The significant relationships between subjective assessments of condition and the Dimension 1 scores for both the Blackbox ($F_{1,18}$ = 38.5 R^2 = 0.68, P < 0.001) and Bimble Box–Pine ($F_{1,11}$ = 6.3, R^2 = 0.36, P = 0.029) communities confirms that Dimension 1 corresponds with a gradient in condition.

Using the non-metric MDS biplots, the attributes of five sites identified as relatively degraded (13, 15, 17, 19, 20) were compared with those from five sites regarded as healthy (1, 2, 6, 10, 16). Healthy sites were characterised by a significantly sparser cover of annual grasses and groundstorey plants, as well as fewer exotic plant species. Healthy sites had a significantly denser cover of perennial grasses and sub-shrubs, a greater diversity of shrub species, and greater landscape patchiness as indicated by the number of obstructions and their total width (Table 13).

4.3.3 Relating MDS Dimension 1 scores to measures of soil surface condition

As indicated earlier (Section 3.5.2), measurements and observation of the soil surface can be used to provide three nominal measures of the health of the soil surface (Tongway 1995): i.e. how the soil withstands erosive forces or reforms after erosion (*stability*); how soil water is distributed between infiltration and runoff (*infiltration*); and how efficiently organic material is recycled into the soil (*nutrients*).

Table 13. Characteristics of five healthy sites (sites 1, 2, 6, 10, 16) and five unhealthy sites (13, 15, 17, 19, 20) identified by the non-metric MDS. Only significantly different attributes are shown.

Attribute	Healthy sites	Unhealthy sites	*P*
Cover of annual grasses (%)	2.1	49.2	<0.001
Cover of perennial grasses (%)	14.6	0	0.032
Cover of sub-shrubs (%)	10.0	0.4	0.028
Native plants (%)	66.5	32.7	<0.001
Exotic plants (%)	33.5	67.3	<0.001
No. of shrub species	3.4	0.4	0.005
Total groundstorey cover	36.0	63.4	0.010
Subjective condition score	8.1	5.3	<0.001
No. of obstructions per 10 m	3.6	0.1	0.006
Total obstruction width (m/10 m)	0.62	0.01	0.048

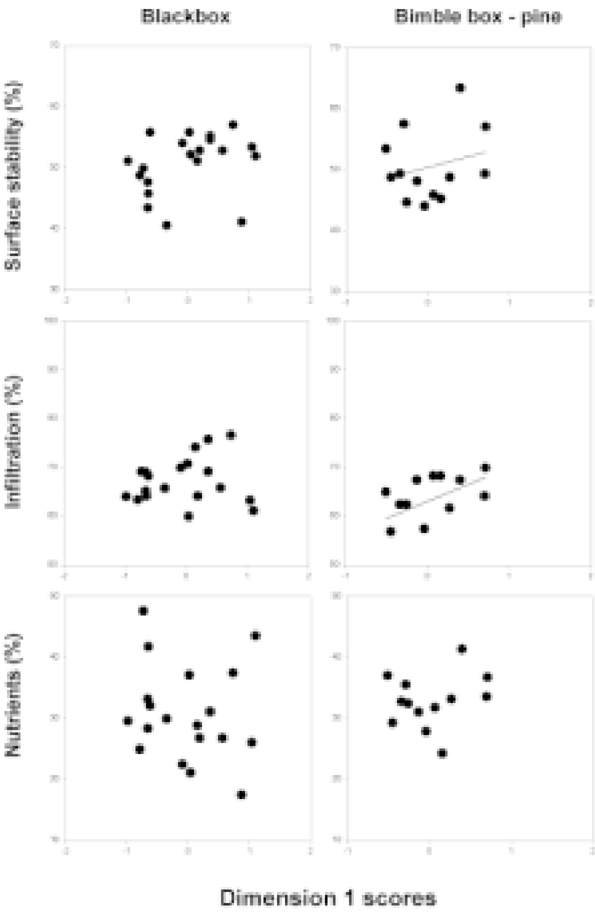


Figure 4. Relationships between the non-metric MDS Dimension 1 scores and three indices of soil surface condition (stability, infiltration and nutrients) for Blackbox and Bimble Box–Pine communities

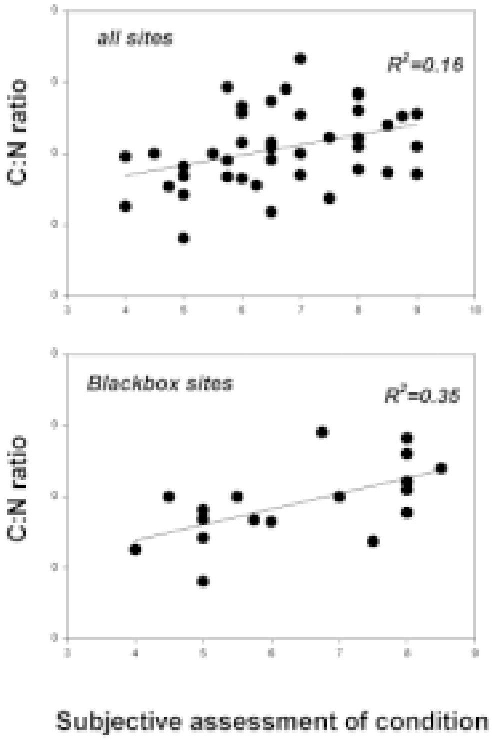


Figure 5. Distribution of ratios of carbon to nitrogen (C:N) in relation to changing subjective assessment of condition for all 44 sites (top graph), and the Blackbox sites only (bottom graph)

There were poor relationships between the non-metric MDS Dimension 1 scores and *stability, infiltration* and *nutrients* for both vegetation communities (Figure 4). There were some ill-defined trends of increasing surface stability and infiltration with increases in condition (increased Dimension 1 score) in the Bimble Box–Pine community. The trends were not statistically significant ($P > 0.05$).

4.3.4 Ecosystem measures of structure, composition and function

The distribution of scores for structure, composition and function demonstrate that in general, the Blackbox and Bimble Box–Pine communities have similar ranges of values (Table 14).

Table 14. Distribution of scores for structure (%), composition (%) and function (%) for the Blackbox and Bimble Box–Pine communities. SEM = standard error of the mean. *P* value and R^2 refer to the strength of the relationships between the scores and a subjective assessment of condition. n.s. = not significant; n.a. = not applicable.

Community	Mean	SEM	Minimum	Maximum	*P* value	R^2
Blackbox						
Structure	53.1	1.5	41.7	70.8	<0.001	0.48
Composition	59.2	2.6	37.5	83.3	<0.001	0.73
Function	71.6	1.2	61.8	82.4	n.s.	n.a
Bimble Box–Pine						
Structure	55.1	1.4	45.8	62.5	<0.001	0.59
Composition	67.0	2.7	50.0	83.3	<0.001	0.71
Function	68.8	2.5	55.9	85.3	<0.001	0.53

Increases in the subjective assessment of condition were associated with increasing structure, composition and function ($R^2 = 0.53$–0.73, $P < 0.001$; Table 14). However, for the Blackbox community there was no significant relationship between function and subjective assessment of condition (Figure 4). Surprisingly, there were no meaningful relationships between the three ecosystem measures of condition and the Axis 1 scores.

4.3.5 Soils

Overall, the concentrations of organic carbon at Blackbox sites were about double those found at the other vegetation communities (Table 12). For all sites, the ratio of total carbon to total nitrogen (C:N) was lower in sites assessed to be in poorer health ($R^2 = 0.16$, $P < 0.01$), and this trend was more strongly pronounced in the Blackbox sites ($R^2 = 0.35$, $P < 0.001$; Figure 5). There were no clear trends evident in most of the other soil data collected for the sites.

5. Discussion

This study should not be viewed as a definitive view of the state of the vegetation and soils in the MIA. The sites within each vegetation community were chosen so that they spanned a range of landscape conditions, from severely degraded to excellent. They were not selected randomly. Consequently the results do not necessarily reflect the contemporary state of vegetation and soils in the MIA.

Notwithstanding this fact however, some broad trends were apparent.

- Degraded sites were characterised by a greater cover of annual grasses and a greater proportion of exotic plants.
- Healthy sites had a denser cover of shrubs and perennial grasses, a greater proportion of perennial plants, more landscape structure, i.e. more soil surface patchiness, and more shrub species.
- Some soil indices, such as the ratio of carbon to nitrogen, were well correlated with subjective scores of condition and, therefore, indices of ecosystem health.

5.1 LANDSCAPE AND VEGETATION CONDITION

The study has been based on the idea that natural ecosystems work well or poorly (i.e. their ecosystem function is in good or poor condition) depending on the quality of their composition, structure and functional features. It has demonstrated that measuring these three components of condition provides a useful and ecologically meaningful method of detecting differences between sites within the Blackbox and Bimble Box–Pine vegetation communities. The multi-variate analyses of data collected from both communities showed that there is a strong gradient in condition, similar to the gradient in scores assigned subjectively to the sites during the field survey.

This Ecosystem Function approach has the advantage that it uses data showing the distribution and abundance of key components of the biodiversity (forbs, grasses, shrubs, trees) and cover and biomass of plants, as well as data about soil surface condition and the spatial arrangement of the landscape (landscape function analysis, observations of soil surface patchiness and configuration, etc.).

Scores for composition, structure and function can be tracked over time, enabling managers to monitor the impacts of actions such as altering flows to blackbox wetlands, reducing livestock stocking rates, and planting midstorey plants. Unlike statistical multi-variate techniques, the use of the three indices is relatively straightforward and therefore easily understood by land managers, and the indices can be adjusted at any time to accommodate the input of new information as monitoring proceeds.

Long-term monitoring of structure, composition and functional features will provide a wealth of data to show how well the sites are functioning over time. It is unfortunate that monitoring data are often used solely to assign a mathematical score to sites (Pellant *et al.* 2000), as agencies and governments strive to calculate a numerical value on which to base the degree of change of resources under their care. For example, in a long-term study of rangelands in the Chihuahuan Desert, Holechek *et al.* (2001) found that the annual condition of sites showed considerable annual variation, and values had to be averaged over several years before a characteristic trend could be identified.

Vegetation condition or health is a highly value-laden and context-dependent concept which can only ever be described qualitatively (Wilson and Tupper 1982, Wilson *et al.* 1984, Watson 1997, Pellant *et al.* 2000). The relative weighting scores applied to the attributes measured at the sites (see Appendixes II and III) are likely to vary from observer to observer, depending on the observer's experience, background and personal biases. For example, pastoralists are likely to see biomass production as important, but ecologists are likely to be more concerned with vegetation structure and diversity and its impact upon native fauna. That is why the multi-variate approach has also been

Table 15. Management options for improving the condition of sites. For grazing, A = minimal grazing, B = strategic grazing practised. RLPB = Rural Lands Protection Board.

Site no.	Vegetation community	Latitude (S)	Longitude (E)	Tenure	Area (ha)	Grazing status	Subjective condition score
1	Blackbox	34 09 36	145 38 56	Private	808.9	Grazed	8.5
2	Blackbox	34 21 48	145 56 09	Private	72.5	Grazed[A]	8.0
3	Blackbox	34 30 51	145 47 15	Private	127.8	Grazed	7.0
4	Blackbox	34 31 48	146 11 13	Crown	72.5	Grazed	8.0
5	Blackbox	34 07 18	145 30 42	RLPB	174.7	Grazed	6.8
6	Blackbox	34 13 33	146 08 10	Private	40.3	Grazed[A]	8.0
7	Blackbox	34 24 08	145 54 37	Private	15.5	Ungrazed	7.5
8	Blackbox	34 12 39	145 34 07	Private	392.0	Grazed	7.0
9	Blackbox	34 19 39	145 55 52	Private	2.9	Grazed	5.5
10	Blackbox	34 23 35	146 13 54	Private	18.6	Ungrazed	8.0
11	Blackbox	34 24 26	145 56 34	Private	40.1	Grazed	5.0
12	Blackbox	34 17 03	145 50 35	Private	1.1	Grazed	4.0
13	Blackbox	34 21 46	146 08 05	Private	57.1	Grazed	5.0
14	Blackbox	34 05 03	145 35 45	Private	77.8	Grazed	5.0
15	Blackbox	34 25 02	146 18 53	Private	14.7	Grazed[B]	5.0
16	Blackbox	34 33 28	146 23 05	Crown	7.9	Ungrazed	8.0
17	Blackbox	34 35 22	146 08 57	Private	4.4	Ungrazed	6.0
18	Blackbox	34 23 26	146 07 42	Private	3.1	Grazed[A]	5.0
19	Blackbox	34 33 15	146 25 57	Private	2.5	Grazed	5.8
20	Blackbox	34 22 54	146 04 07	Private	3.2	Ungrazed	4.5
21	Bimble Box–Pine	34 23 15	146 11 48	Crown	310.7	Ungrazed	9.0
22	Bimble Box–Pine	34 25 02	146 18 53	Private	100.4	Ungrazed	6.5
23	Bimble Box–Pine	34 09 53	145 54 28	Private	184.3	Ungrazed	6.0
24	Bimble Box–Pine	34 22 51	146 14 14	Private	61.4	Grazed	8.8
25	Bimble Box–Pine	34 21 23	146 12 32	RLPB	89.3	Ungrazed	6.5
26	Bimble Box–Pine	34 12 59	146 11 48	Private	75.4	Ungrazed	8.5
27	Bimble Box–Pine	34 21 41	146 15 58	Private	84.6	Grazed	6.5
28	Bimble Box–Pine	34 14 44	146 14 09	State Forest	611.9	Grazed	6.5
29	Bimble Box–Pine	34 34 40	146 26 43	Crown	239.7	Grazed	5.75
30	Bimble Box–Pine	34 09 29	145 54 29	Private	24.4	Grazed	6.0
31	Bimble Box–Pine	34 14 35	146 00 03	Private	185.2	Grazed	4.0
32	Bimble Box–Pine	34 22 53	146 14 14	Private	46.6	Grazed	6.5
33	Bimble Box–Pine	34 26 33	146 18 57	Private	65.1	Grazed	6.0
34	Boree	34 21 48	145 52 55	Private	72.6	Ungrazed	9.0
35	Boree	34 17 45	145 49 30	Private	17.8	Grazed	6.5
36	Boree	34 12 18	145 57 22	Crown	9.9	Ungrazed	9.0
37	Boree	34 27 33	145 57 37	Private	49.8	Grazed	7.0
38	Boree	34 12 10	145 33 27	Private	30.6	Grazed	5.8
39	Boree	34 10 03	145 46 02	Private	148.3	Grazed	6.3
40	Belah–Rosewood	34 00 01	145 33 28	RLPB	198.7	Ungrazed	7.0
41	Belah–Rosewood	34 06 12	145 35 53	Private	103.8	Grazed	7.5
42	Belah–Rosewood	34 03 26	145 37 33	Private	21.6	Grazed	4.8
43	Mallee	34 08 07	146 01 32	RLPB	17.1	Ungrazed	8.0
44	Mallee	34 11 33	146 03 54	Private	52.0	Ungrazed	7.0

used above, with the inclusion of two reference sites. It ensures that all elements of the landscape are included in the assessment of condition, whether they are related more strongly to rangeland productivity (biomass, perenniality) or to habitat value (cover, floristics). The multivariate approach also makes it possible to graph the way the sites change relative to each other over time.

5.2 STRATEGIES TO ENHANCE CONDITION AND BIODIVERSITY

Freudenberger (2001) identified a number of actions that would increase the probability of retaining birds within fragmented landscapes. If a landscape can be enhanced to make it a better habitat for woodland birds, the improvement is likely to have positive follow-on effects for

Table 15. continued.
x = activity required, xx = activity already adopted.

Possible management actions			
Manage grazing	Control boxthorn	Enhance mid- and understorey	Fence
x	x		
		x	
x		x	
x	x	x	
		x	
			x
	x		
x			
x		x	x
			xx
x		x	x
x	x	x	x
x		x	x
x	x	x	
x		x	xx
	x		xx
		xx	
x			xx
x	x	x	x
x		x	xx
		x	xx
		x	x
		x	
x		x	
x		x	
x		x	
x		x	
x		x	
x		x	
		x	
		x	
			x
x	x		
x			
x			
x		x	x

other biota (Freudenberger 1999, 2001) such as plants, reptiles and macro-invertebrates. Thus actions taken for the benefit of birds are likely to increase the biodiversity value and overall condition of vegetation remnants.

The actions identified by Freudenberger are, in order of priority:

1) protection of existing vegetation remnants,
2) establishment of local provenances of trees, shrubs and grasses within fenced remnants,
3) enlargement of existing remnants, and
4) creation of linkages between individual remnant patches.

The actions, described more fully below, are recommended for enhancing the biodiversity value and condition of remnants in the MIA. To improve the condition of the study sites, Table 15 shows management options for each site.

5.2.1 Action 1: Protection of existing remnants

5.2.1.1 Managing species composition by grazing

Existing vegetation remnants can be protected and enhanced by strategic grazing. Land managers generally use a continuous grazing or 'set stocking' strategy whereby sheep or cattle are kept in large paddocks at set stocking rates, and numbers are not adjusted in relation to seasonal conditions except during prolonged dry periods. This is a very rigid system, providing land managers with little control over selective grazing, little flexibility, and little opportunity to respond to changing seasonal conditions (Earl and Jones 1996).

A more useful strategy is to adjust stocking rates so that the needs of the stock are matched by the feed supply on offer (Dankerwerts *et al.* 1993). This system is flexible and results in high production per unit area, but it requires a high degree of management.

A number of strategies are available to land managers to help them cope with the varying ratios of need and feed, and at the same time both reduce the chance of land degradation and maximise biodiversity. The strategies include *conservative* or low risk stocking (McKeon *et al.* 1994), *tactical* grazing and *time-controlled* grazing (Hacker 1993).

The conservative or low risk stocking strategy assumes that any over-utilisation of the pasture, and therefore feed shortage, will occur sufficiently rarely to keep economic loss to a minimum (McKeon and Howden 1992). Conservative stocking has the advantages that there is low economic and ecological risk, and that low levels of management are required.

Tactical grazing strategies, on the other hand, allow land managers to plan management actions whilst retaining the flexibility to respond to changes in seasonal conditions (George 1996). All the forms of tactical grazing are useful for manipulating the composition or biomass of the vegetation, to eliminate woody species for example. Among tactical grazing strategies, the crash-grazing of perennial grass pastures in late-winter early-spring can reduce the biomass and cover of winter-growing annuals. Fencing can be used to better manage the grazing of remnants.

There is growing evidence that simply excluding grazing from vegetation remnants (with or without fencing) may not be enough to ensure the persistence of a diverse groundstorey plant community and hence high-condition remnants, at least in the short-term (Lunt and Morgan 1999, Berry 2000). In fact, many native plant species may fail to reappear after the removal of grazing (e.g. Semple 1986, Conway 2000). The accumulation of plant biomass (see below) and the reduced numbers of gaps in the vegetation appear to be two main reasons for falling diversity of native species once grazing has been excluded. Other factors, such as irreversible change in soil condition and declines in ecosystem function, are probably equally influential (Westoby *et al.* 1989). In some grassland conservation reserves in Victoria, management's inability to control plant biomass has caused some important vegetation remnants to become degraded (Lunt and Morgan 1999), with irreversible declines in populations of threatened species (Scarlett and Parsons 1990, 1993) and the death of perennial grasses and forbs beneath grass litter (Morgan and Lunt 1999, Conway 2000).

5.2.1.2 Removal of excessive plant biomass by grazing or slashing

It is essential to prevent a large accumulation of dead grass, both to encourage the regeneration of groundstorey plants and to prevent the risk of wildfire that would probably have devastating effects on trees and shrubs. Grass biomass can be removed by strategic grazing of fenced remnants (GA 2000), a strategy similar to the grazing regime practised in intermittently-grazed woodlands along many of the travelling stock reserves in eastern Australia (Nowland 1997, Berry 2000). Fenced remnants should be regarded as just another paddock, albeit with a different grazing regime, and may even be used as laneways or holding paddocks at times of the year which are not critical to perennial plants.

The health or condition of the vegetation should be watched to identify how much high-intensity short-duration (crash) grazing the fenced remnant vegetation can take, the type of animals to be used (e.g. sheep vs cattle), specific requirements of the desirable species within the pasture, seasonal conditions, and the presence of, or risk of, invasion by weeds (Nowland 1997). Perennial species can withstand prolonged grazing if they are rested between grazing periods, depending on the growth stage of the vegetation (Wilson 1990).

There may be conflict between the need to reduce biomass to promote the establishment of groundstorey plants, and the grazing of shrubs by livestock. Thus, the land manager must choose a grazing regime that allows regenerating shrubs and trees to be protected from browsing and/or trampling.

An alternative strategy could be to remove excess vegetation by mechanical means or by burning in spring or autumn (colloquially known as a 'cool burn'). Mowing with a small slasher attached to a wheeled tractor can control weeds effectively in areas where trees have been planted in rows. However, given the patchy nature of natural regeneration, this strategy is not likely to be practical and will probably lead to large amounts of surface litter with resulting disturbance to native groundstorey plants.

5.2.1.3 Weed control

The field survey demonstrated that, in general, exotic plants (weeds) were not a major component of the vegetation at the sites (Appendix IV). However, there was a strong tendency for large numbers of exotic plants in the groundstorey to be associated with poor site condition (Figure 1).

Given the broadacre nature of rangeland ecosystems, it is not practical nor feasible to spray weeds with herbicides in many grazing situations. Instead, management should aim to reduce stocking intensities during periods when palatable native plants are establishing. Strategic

Plate 8. Dense *Austrodanthonia caespitosa*, Amsbury Common, Leeton, May 2002

Plate 9. Boree with hopbush and perennial grasses, north of Griffith, May 2002

grazing may offer control where weeds have a high biomass (Leslie 2002). Herbicide application may be a useful way of enhancing the regeneration of eucalypts and shrubs by reducing competition from exotic grasses.

Weeds with burrs or spiked fruit such as bathurst burr (*Xanthium spinosum*) and silverleaf nightshade (*Solanum elaegnifolium*) are likely to be more prevalent in disturbed areas, particularly on flooded ground. Weeds such as great brome (*Bromus diandrus*) and barley grass (*Hordeum leporinum*) occupy large areas of degraded land, increasing the risk of wildfire. Weeds common in remnants monitored during the study included horehound (*Marrubium vulgare*), capeweed (*Arctotheca calendula*) and members of the family Brassicaceae. Like other weeds of disturbed areas, these plants tend to restrict the growth of more desirable species, and the burrs may contaminate wool and hides (Cunningham *et al.* 1981).

Of particular concern in some remnants in this study is the presence of the noxious weed African boxthorn (*Lycium ferocissimum*) which was recorded at eight sites, predominantly in Blackbox communities. Despite the presence of African boxthorn, which may have been present as only a few plants, some of these sites were rated as being in good health. African boxthorn provides suitable habitat for birds, but also harbours vermin (rabbits) and becomes a nuisance along fences and creeks, and the fruit have been known to harbour fruit fly (APAPCB 2001).

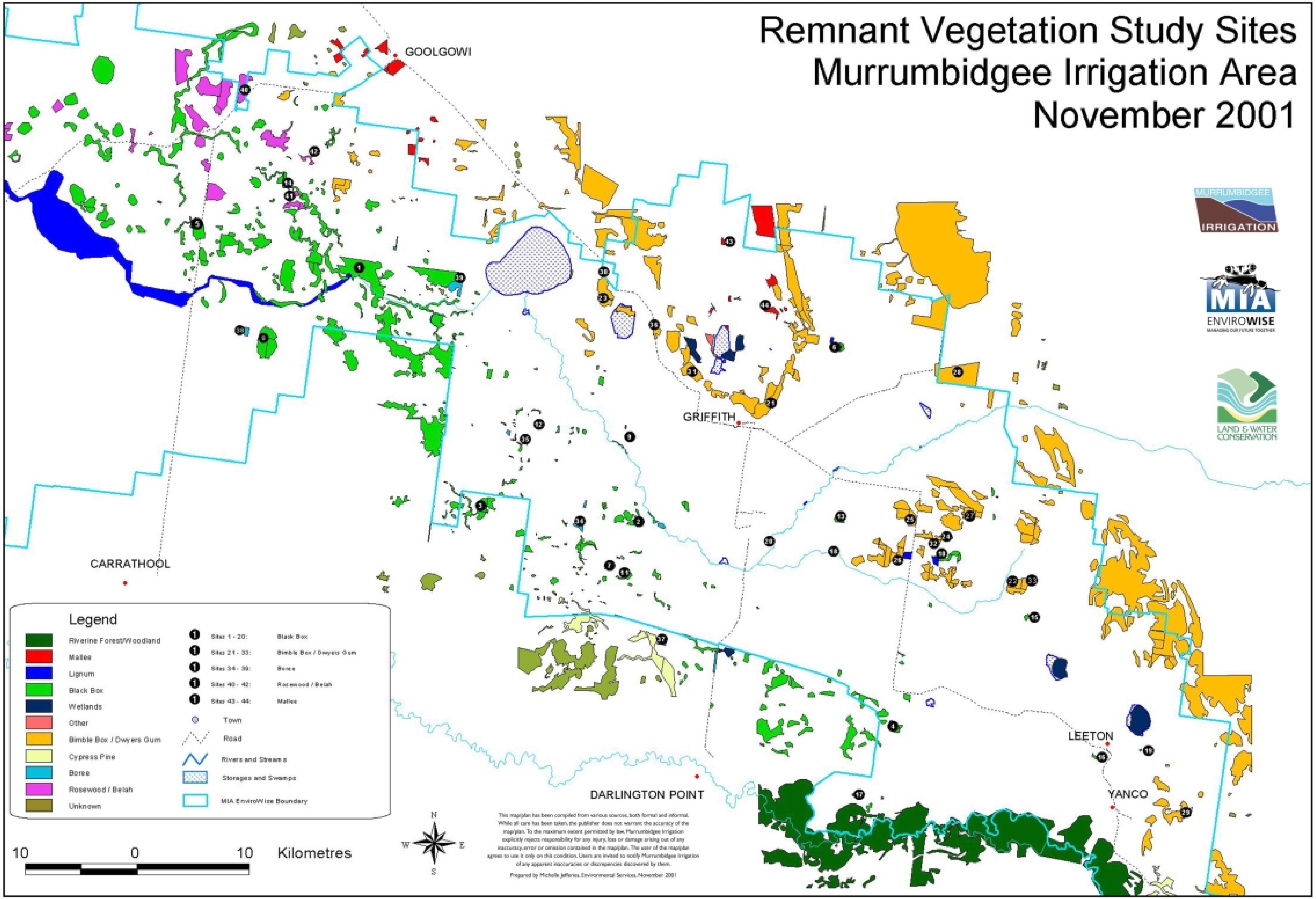
Large plants can be removed with heavy machinery and small plants can be dug up. All the plants must be destroyed, preferably by burning (DPIWE 1998). The foliage can be treated with glyphosate or triclopyr. Picloram-based herbicides should not be used, because the active ingredient remains active in the soil for a long time and may leach into the groundwater. For basal, stump or regrowth treatment, triclopyr and diesel or glyphosate formulation 1:1 with water can be used effectively (DPIWE 1998).

5.2.1.4 Water issues and blackbox trees

Some blackbox remnants may not be getting enough water, causing reductions in the health of the trees. Blackbox relies on periodic flooding with freshwater to leach salt from the rootzone (Thorburn *et al.* 1993, Taylor *et al.* 1996), particularly in semi-arid areas. Thus the health of blackbox trees is intimately linked with the degree of inundation, depth to groundwater and salinity levels (Jolly *et al.* 1993, Taylor *et al.* 1996). It may be necessary to divert water for periodic artificial flooding of blackbox remnants that are isolated from natural flooding, if these stands are to survive. Conversely, other remnants may be receiving too much water with the water table very close to the surface and therefore close to the rooting zone. Pumping of the water may be an option to ensure their survival.

5.2.2. Action 2: Establishment of local provenances within remnants

Midstorey vegetation (shrub layer) and understorey vegetation (typically native grasses and herbs) are essential for the survival of fauna and flora in vegetation remnants (GA 1999). Both



Remnant Vegetation Study Sites
Murrumbidgee Irrigation Area
November 2001
GOOLGOWI
GRIFFITH
CARRATHOOL
DARLINGTON POINT
LEETON
YANCO
MURRUMBIDGEE IRRIGATION
MIA ENVIROWISE
MANAGING OUR FUTURE TOGETHER
LAND & WATER CONSERVATION
Legend
Riverine Forest/Woodland
Mallee
Lignum
Black Box
Wetlands
Other
Bimble Box / Dwyers Gum
Cypress Pine
Boree
Rosewood / Belah
Unknown
Sites 1 - 20: Black Box
Sites 21 - 33: Bimble Box / Dwyers Gum
Sites 34 - 39: Boree
Sites 40 - 42: Rosewood / Belah
Sites 43 - 44: Mallee
Town
Road
Rivers and Streams
Storages and Swamps
MIA EnviroWise Boundary
10 0 10 Kilometres
N
W
E
S
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Prepared by Michelle Jefferies, Environmental Services, November 2001

Plate 10. Bimble box and shrub regeneration, Whitton Stock Reserve, May 2002

understorey and midstorey vegetation provide habitat, protect the soils, ensure stability of the landscape, and have their own intrinsic value. They provide a range of essential ecosystem goods and services and assist in the maintenance of biodiversity.

The natural regeneration of midstorey and understorey vegetation should be encouraged by appropriate weed control, grazing management and supply of water to simulate flood events (see 5.2.1 above). In some situations, planting is the only option. When plants are to be replaced, local provenances and local species should be used. On severely salt-affected areas or in degraded gullies, non-local species may be more desirable because of their greater tolerance of degraded conditions. For extensive areas, plants can be direct seeded. For smaller areas, tube-stock or seedlings may be preferred. In either case, weeding or the use of herbicides (pre- and post-sowing/planting) may be necessary. Appropriate techniques for revegetation are often site-specific, and information should be sought from relevant organisations (e.g. GAV 1999).

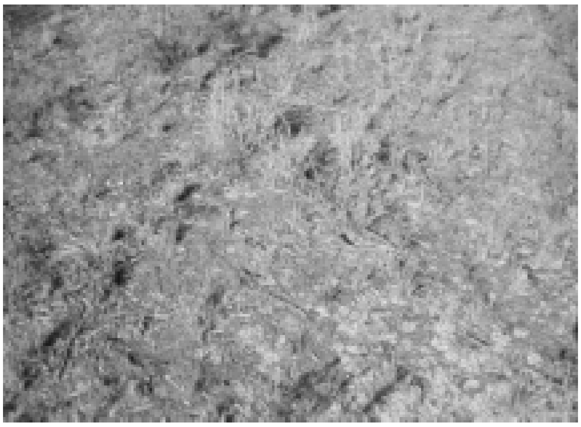

Plate 11. Perennial grasses and soil lichens, Travelling Stock Reserve north of Griffith, May 2002

Plate 12. Bimble box regeneration at Whitton Stock Reserve, May 2002

5.2.3 Actions 3 and 4: Enlargement of remnants and provision of linkages between remnants

In the MIA, strategic planting activities already underway should be targeted, to increase both the size of remnants and their connections to other remnants. For example, the width of linear remnants along ridgetops could be increased by strategic fencing of hillside remnants and planting of trees and shrubs within the fenced areas. These remnants should then be linked with other remnants lower down the slope, possibly by fencing along existing fence lines, so allowing tree and shrub species to regenerate in the absence of grazing.

Strips of vegetation linking remnants or patches should ideally be at least 25–50 m wide (Barrett 2000, Kinross 2000, Freudenberger 2001). Within the MIA there are relatively large areas of contiguous habitat remaining in national parks (Cocoparra National Park) and state forests (Binya State Forest). In this study, the distance from any remnant to the nearest five remnants >1 ha in area ranged from 0.02 km to 6.09 km, with a median distance of 0.69 km for the Blackbox community.

5.3 FUTURE DATA COLLECTION AND MONITORING

The success or otherwise of changes in land management can only be judged if there is detailed monitoring both before and after any changes are made. This study has provided benchmark information on the condition of vegetation, soils and landscapes, and its data can be compared with data collected in other studies in the future.

5.3.1 Further data collection and analyses

Table 16 identifies two types of sites: new sites (sites requiring initial data collection) and existing sites (the 44 sites described in this report) which will form the basis of ongoing data collection. It is recommended that three additional sites be established in the Boree community, and six new sites in the Saltbush–Grassland community (see Table 16) to more adequately reflect the distributions of these vegetation types within the MIA. Fourteen additional Blackbox sites located along the Mirrool Creek Floodway should also be added as new sites which require initial data collection. New sites will be measured using the protocol described in this report.

For existing sites, the following measurements need to be repeated during field measurements on the same plot:

- foliage (or canopy) cover of groundstorey plants, shrubs and trees by species, including evidence of tree regeneration;
- landscape function assessment;
- soil surface condition assessment.

Shrub distribution and soil physical and chemical properties do not need to be re-measured after the initial measurements. It is intended that a Field Procedures Guide to data collection, including information on the location of sites and quadrats will be prepared in the near future.

For detailed landscape condition and flora surveys, all sites are to be measured annually for three years and thence five-yearly, irrespective of the date at which initial measurements were made (Table 16). After three years of annual data collection, landscape condition (composition, structure and function) data should be assessed and reported on. After three years of annual monitoring, a decision will be made on whether to discontinue some sites or measure them less frequently. This decision needs to be made in relation to degree of site change and importance of that vegetation community within the MIA.

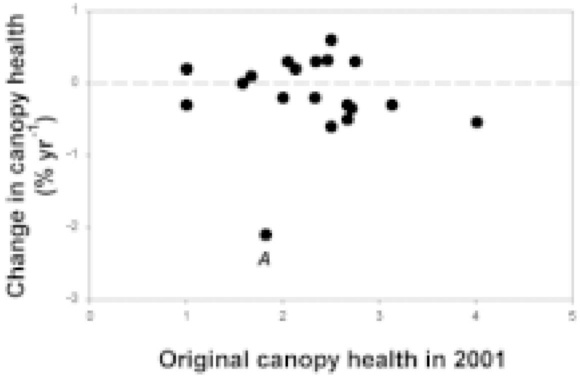

Figure 6. Changes in canopy health of trees (% per year) in relation to original canopy health. Note: these data are fictitious and do not reflect real changes at the sites.

5.3.2 Monitoring tree canopy condition

Soil salinity is the major factor affecting the health of blackbox (Jolly *et al.* 1993, Taylor *et al.* 1996), and on clay soils within irrigation areas the accumulation of salts in the soil (Taylor *et al.* 1996) is likely to eventually kill the blackbox stands. Periodic flooding with freshwater is necessary to prolong the life of the blackbox stands.

Annual monitoring of the health of blackbox trees is recommended at all 20 Blackbox community sites, using the adapted canopy dieback method (see section 3.4.2). Additionally, a further 14 sites in the Mirrool Creek Floodway, which have been monitored in 1992, 1997 and 2002 using a similar system (Roberts and Wylks 1992), should be incorporated into an overall MIA 'Tree Health Monitoring Program'. Canopy health data for the additional 14 sites are directly comparable with the data here, and together these data will form a valuable picture of regional changes in the health of blackbox trees in the MIA. Additional information should be collected on frequency of flooding and the depths to groundwater and also, where possible, the electrical conductivity of the groundwater.

A method of tracking the mean (or median) health of sites is shown graphically in Figure 6. For any particular site, the original canopy health score in 2001 is plotted against the change in score, expressed as a percentage annual increase or decrease. Sites like Site A in Figure 6, where an increase or decrease in

Table 16. Summary of requirements for monitoring biodiversity and condition in the Murrumbidgee Irrigation Area

Component	**Description of activity**	**Personnel required**	**Frequency of implementation**
Landscape condition assessment	Detailed assessment of parameters required to measure landscape structure, composition and function (including vegetation and soil assessment) using procedures outlined in the ‘Condition and Biodiversity of Vegetation Remnants in the MIA’ report. Existing 44 sites: • repeat sampling using the procedures for existing sites outlined in this report. New sites: • incorporate additional sites: i) Boree community (*n* = 3), ii) Saltbush-Grassland community (*n* = 6), and iii) Mirrool Creek Floodway sites (*n* = 14) into existing study.	Ecologist	Existing 44 sites: • repeat measurements annually for a total of 3 years; thence every 5 years. New sites: • collect baseline information and then measure annually for a total of 3 yrs; thence every 5 yrs.
Tree canopy condition assessment	Establish photopoints at the 20 Blackbox sites. Measure the condition of tree canopies at the 20 sites using the procedure documented in this report (section 3.4.2). Continue annual canopy health monitoring at the 14 Mirrool Creek Floodway sites using procedure of Roberts and Wylks (1992).	MI Field Officers	Measure annually for 3 yrs, then review.
Photopoint setup	Establish photopoints at all sites.	MI Field Officers	Take photos when sites are visited to record measurements as above.
Additional opportunistic studies	Study of surface dwelling invertebrates at all sites using small wet pitfall traps. Changes in selected measures of soil biology (e.g. microbial diversity, microbial activity) at selected sites.	Honours or post-graduate students under MI supervision	As the opportunity arises

canopy health is markedly greater than at other sites, can be examined and appropriate action can be taken to examine the cause of the change and reverse it.

5.3.3 Bird surveys

Birds have been identified as useful indicators of landscape health (Freudenberger 1999, 2001, Lambeck 1999). Separate from this study, seasonal bird surveys were begun at all 44 sites in spring 2001, using standard methods. The surveys are expected to continue seasonally for at least three years and every 3–5 years thereafter. They will provide valuable data which will be presented in a separate report, and the results will be linked with this study's vegetation and condition data.

5.3.4 Implementation of management recommendations

Given the value of these sites within the MIA, it would be extremely valuable to implement a range of management strategies at a selection of sites. In order of priority, these are deemed to be strategic grazing, planting of understorey species (shrubs), weed control and additional flows to blackbox depressions. A decision about which strategies to implement and which sites to use will depend on landholder interest. Implementation of some of the recommendations to enhance biodiversity and condition should be seen as a key outcome of this benchmarking process.

5.4 ADDITIONAL INVESTIGATIONS

Future research and monitoring (Table 16) should aim to complement the information already collected at the monitoring sites, and add to the information on diversity of additional taxa for each of the vegetation communities.

Ground-dwelling invertebrates such as beetles, spiders and ants have been shown to be good indicators of the quality of the landscape (Andersen 1993, Bisevac and Majer 1999, Major *et al.* 1999, Read and Andersen 2000). These organisms are easily sampled and their abundance allows valid statistical assessments to be made. They often respond to changes at small spatial scales which occur earlier than in other taxa (e.g. Bryannah 1995). Although changes in ground-dwelling invertebrates may not always be indicative of changes in management, studies of this nature may be useful in reinforcing some of the values of healthy remnants. Other studies of soil changes in relation to increased remnant condition e.g. microbial activity, microbial biomass, would be useful additions to this benchmarking process.

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Appendix I.

Biotic and abiotic characteristics of the 44 study sites (pages 37–44)

Site no.	Vegetation community	Latitude (S)	Longitude (E)	Soil surface stability (%)	Soil surface infiltration (%)	Soil surface nutrients (%)	Evidence of site erosion	Evidence of fire
1	Blackbox	34 09 36	145 38 56	41.2	49.2	17.5	4	3
2	Blackbox	34 21 48	145 56 09	53.5	63.3	26.1	4	3
3	Blackbox	34 30 51	145 47 15	54.7	69.2	31.1	3	3
4	Blackbox	34 31 48	146 11 13	55.3	75.8	31.2	4	3
5	Blackbox	34 07 18	145 30 42	52.9	64.2	26.8	4	3
6	Blackbox	34 13 33	146 08 10	52.9	65.9	26.8	4	3
7	Blackbox	34 24 08	145 54 37	54.1	70	22.5	4	3
8	Blackbox	34 12 39	145 34 07	55.9	70.8	37.2	4	3
9	Blackbox	34 19 39	145 55 52	55.9	68.3	32.1	4	3
10	Blackbox	34 23 35	146 13 54	57.1	76.7	37.5	4	3
11	Blackbox	34 24 26	145 56 34	52.3	60	21.1	4	3
12	Blackbox	34 17 03	145 50 35	45.8	64.2	41.8	4	3
13	Blackbox	34 21 46	146 08 05	48.8	63.4	25	4	3
14	Blackbox	34 05 03	145 35 45	51.2	74.2	28.9	4	3
15	Blackbox	34 25 02	146 18 53	51.2	64.1	29.6	4	3
16	Blackbox	34 33 28	146 23 05	52	61.2	43.6	4	3
17	Blackbox	34 35 22	146 08 57	50	69.2	47.7	4	3
18	Blackbox	34 23 26	146 07 42	40.6	65.8	30	4	3
19	Blackbox	34 33 15	146 25 57	47.7	69.1	28.4	4	3
20	Blackbox	34 22 54	146 04 07	43.5	65.2	33.2	4	3
21	Bimble Box–Pine	34 23 15	146 11 48	57.1	70	36.8	4	2
22	Bimble Box–Pine	34 25 02	146 18 53	45.3	68.3	24.3	4	3
23	Bimble Box–Pine	34 09 53	145 54 28	57.6	49.7	35.6	3	3
24	Bimble Box–Pine	34 22 51	146 14 14	63.5	67.5	41.4	4	3
25	Bimble Box–Pine	34 21 23	146 12 32	48.2	67.5	31.1	4	3
26	Bimble Box–Pine	34 12 59	146 11 48	48.8	61.7	33.2	4	3
27	Bimble Box–Pine	34 21 41	146 15 58	49.4	62.5	32.8	4	3
28	Bimble Box–Pine	34 14 44	146 14 09	44.1	57.5	27.9	4	3
29	Bimble Box–Pine	34 34 40	146 26 43	49.4	64.2	33.6	4	3
30	Bimble Box–Pine	34 09 29	145 54 29	44.7	62.5	32.5	4	3
31	Bimble Box–Pine	34 14 35	146 00 03	48.8	56.9	29.3	3	3
32	Bimble Box–Pine	34 22 53	146 14 14	53.5	65	37.1	4	3
33	Bimble Box–Pine	34 26 33	146 18 57	45.9	68.3	31.8	4	3
34	Boree	34 21 48	145 52 55	48.8	67.5	30.7	4	3
35	Boree	34 17 45	145 49 30	47.1	60.8	27.8	4	3
36	Boree	34 12 18	145 57 22	52.3	58.3	31.8	4	3
37	Boree	34 27 33	145 57 37	44.1	66.7	26.4	4	3
38	Boree	34 12 10	145 33 27	44.7	63.8	25	4	3
39	Boree	34 10 03	145 46 02	43	51.7	23.6	4	3
40	Belah–Rosewood	34 00 01	145 33 28	52.9	52.5	32.9	4	3
41	Belah–Rosewood	34 06 12	145 35 53	52.9	60.8	37.1	4	3
42	Belah–Rosewood	34 03 26	145 37 33	43.5	55.8	25	4	3
43	Mallee	34 08 07	146 01 32	58.2	55.8	39.6	4	3
44	Mallee	34 11 33	146 03 54	57	58.3	44.7	4	3

Site no.	Vegetation community	Biomass (t/ha)	Obstructions (per 10 m)	Total obstruction width (m/10 m)	Mean fetch length (m)	Grass butt cover (%)	No. of live trees	No. of dead trees	Total no. trees
1	Blackbox	0.15	1.5	0.495	4.88	0	49	4	53
2	Blackbox	1.2	6.5	0.34	1.39	4.15	4	0	4
3	Blackbox	1.1	3	0.135	2.83	1.7	2	0	2
4	Blackbox	1.4	2	0.07	3.95	0.7	3	0	3
5	Blackbox	0.2	2	0.12	3.96	0	12	0	12
6	Blackbox	0.7	3	1.63	2.78	0.8	44	2	46
7	Blackbox	1.2	8	1.52	1.12	0	17	2	19
8	Blackbox	0.55	2.5	0.235	3.27	0	5	0	5
9	Blackbox	0.15	0	0	0	0	3	0	3
10	Blackbox	0.75	2	0.14	3.97	1.5	13	0	13
11	Blackbox	0.65	3.5	0.36	0.229	1.9	1	2	3
12	Blackbox	1.6	0	0	0	0	6	0	6
13	Blackbox	1.3	0	0	0	0	6	0	6
14	Blackbox	0.45	1	0.54	6.63	0	4	0	4
15	Blackbox	2.1	0	0	0	0	2	0	2
16	Blackbox	1.2	5	0.47	1.75	1.2	7	1	8
17	Blackbox	1.6	0	0	0	0	8	0	8
18	Blackbox	2.4	0.5	2.5	9.93	0	5	1	6
19	Blackbox	4.6	0	0	0	0	23	0	23
20	Blackbox	2.1	0.5	0.025	8.58	0	6	0	6
21	Bimble Box–Pine	2	9.5	0.7	0.93	3	6	0	6
22	Bimble Box–Pine	1.7	6.5	0.915	1.41	9.8	0	0	0
23	Bimble Box–Pine	0.07	0	0	0	0	246	23	269
24	Bimble Box–Pine	1.95	13	1.12	0.68	9.9	9	0	9
25	Bimble Box–Pine	1.9	3.5	0.48	9.54	4.5	12	0	12
26	Bimble Box–Pine	4	9.5	2.06	1.68	6.1	6	1	7
27	Bimble Box–Pine	0.7	3	0.22	2.77	1.7	2	0	2
28	Bimble Box–Pine	0.3	2.5	0.485	3.97	0.7	121	0	121
29	Bimble Box–Pine	0.55	9.5	0.735	0.95	6.6	6	0	6
30	Bimble Box–Pine	0.6	4	0.39	2.06	1.6	13	9	22
31	Bimble Box–Pine	0.6	4.5	0.705	1.88	2	9	2	11
32	Bimble Box–Pine	0.55	8.5	0.715	1.07	4	4	0	4
33	Bimble Box–Pine	1.3	6	0.81	9.41	6.1	2	0	2
34	Boree	2.2	8	0.775	1.13	6.2	0	0	0
35	Boree	1.7	7.5	1.26	1.11	11.3	0	0	0
36	Boree	1.1	6.5	0.395	1.4	3.5	6	0	6
37	Boree	0.75	4	0.195	2.19	0.9	5	3	8
38	Boree	0.7	2.5	0.37	3.25	2.8	4	0	4
39	Boree	0.45	1.5	1.32	5.07	0	10	0	10
40	Belah–Rosewood	0.5	1.5	0.76	4.96	0	25	0	25
41	Belah–Rosewood	0.2	1.5	0.045	4.92	0	29	0	29
42	Belah–Rosewood	0.25	1	0.64	6.64	0.2	7	0	7
43	Mallee	0.75	9.5	0.815	0.95	6	11	0	11
44	Mallee	0.45	2.5	0.79	3.14	0	26	0	26

Site no.	Vegetation community	Cover of trees (%)	Cover of tall shrubs (%)	Cover of small–medium shrubs (%)	Cover of perennial grasses (%)	Cover of annual grasses (%)	Cover of forbs (%)
1	Blackbox	28	0	14	1	0.5	0.5
2	Blackbox	9	0	3	27	8	2
3	Blackbox	10	0	4	5	7	11
4	Blackbox	15	0	3	15	25	2
5	Blackbox	21	0	3	0.5	0.5	10
6	Blackbox	36	0	0	8	0.5	17
7	Blackbox	1	0	0	0.5	0.5	79
8	Blackbox	11	0	0	0.5	4	21
9	Blackbox	10	0	0	0	5	10
10	Blackbox	18	0	15	8	0.5	27
11	Blackbox	6	0	0	11	30	1
12	Blackbox	25	0	0.5	0	21	49
13	Blackbox	10	0	0	0	60	10
14	Blackbox	33	0	7	2	27	24
15	Blackbox	10	0	0	0	31	19
16	Blackbox	15	0	18	29	1	2
17	Blackbox	25	0	0	0	60	2
18	Blackbox	21	0	0.5	0	50	30
19	Blackbox	15	0	2	0	64	9
20	Blackbox	15	0	0	0	31	29
21	Bimble Box–Pine	3	1	6	45	2	38
22	Bimble Box–Pine	0	0	0	40	12	18
23	Bimble Box–Pine	20	0	0	0.5	0.5	4
24	Bimble Box–Pine	9	0	0.5	43	2	10
25	Bimble Box–Pine	24	0	0	28	12	5
26	Bimble Box–Pine	8	1	0.5	30	23	12
27	Bimble Box–Pine	2	1	0	21	13	6
28	Bimble Box–Pine	31	0	0.5	5	0.5	5
29	Bimble Box–Pine	2	12	1	32	10	3
30	Bimble Box–Pine	14	0	1	12	2	2
31	Bimble Box–Pine	10	0	0	31	12	12
32	Bimble Box–Pine	2	0	0	13	3	4
33	Bimble Box–Pine	10	0	0	17	10	18
34	Boree	n.a.	0	0	33	9	8
35	Boree	n.a.	0	0	41	6	8
36	Boree	4	0	16	21	0.5	9
37	Boree	5	0	10	13	10	27
38	Boree	7	0	0.5	18	1	6
39	Boree	12	0	5	2	3	20
40	Belah–Rosewood	25	1	16	1	0	2
41	Belah–Rosewood	67	0	5	1	1	3
42	Belah–Rosewood	6	0	6	0.5	8	11
43	Mallee	12	0	1	27	1	4
44	Mallee	10	1	5	0.5	0.5	25

n.a. = not applicable

Site no.	Vegetation community	Cover of logs & debris (%)	Cover of bare soil (%)	Cover of cryptogams (%)	Cover of litter (%)	Overall ground-storey cover (%)	Canopy condition score
1	Blackbox	2	45	0	35	15	4.42
2	Blackbox	1	45	0	15	40	5.00
3	Blackbox	1	15	0	25	27	5.00
4	Blackbox	0.5	0	0	25	45	3.33
5	Blackbox	0.5	30	0	57	13	3.25
6	Blackbox	5	20	0	15	25	3.33
7	Blackbox	1	0	0	17	80	3.95
8	Blackbox	0.5	50	16	35	25	4.00
9	Blackbox	1	5	0	80	15	3.67
10	Blackbox	0.5	2	0	85	50	3.54
11	Blackbox	3	40	0	15	42	1.99
12	Blackbox	0.5	5	0	55	70	3.66
13	Blackbox	0.5	10	0	20	70	3.29
14	Blackbox	1	15	0	35	60	5.00
15	Blackbox	0.5	5	0	35	50	3.50
16	Blackbox	0.5	15	30	35	50	3.87
17	Blackbox	0.5	2	0	30	62	3.50
18	Blackbox	2	0	0	37	80	4.33
19	Blackbox	0.5	2	0	23	75	2.87
20	Blackbox	0	15	0	17	60	4.18
21	Bimble Box–Pine	0.5	0	58	17	85	4.00
22	Bimble Box–Pine	0.5	2	11	25	70	n.a.
23	Bimble Box–Pine	0.5	3	60	30	5	4.67
24	Bimble Box–Pine	0.5	2	58	30	55	4.22
25	Bimble Box–Pine	0.5	5	23	50	45	5.00
26	Bimble Box–Pine	0.5	3	35	30	65	4.50
27	Bimble Box–Pine	0.5	8	17	50	40	5.00
28	Bimble Box–Pine	1	8	8	35	10	4.67
29	Bimble Box–Pine	0.5	7	37	35	45	5.00
30	Bimble Box–Pine	0.5	42	38	20	17	3.10
31	Bimble Box–Pine	0.5	25	7	37	55	3.46
32	Bimble Box–Pine	0.5	50	28	10	20	5.00
33	Bimble Box–Pine	2	15	3	30	45	4.50
34	Boree	0.5	20	4	27	50	n.a.
35	Boree	0	20	3	30	55	n.a.
36	Boree	0.5	3	78	15	30	4.34
37	Boree	2	15	0	35	60	3.25
38	Boree	0	25	9	15	25	5.00
39	Boree	2	15	4	20	30	4.10
40	Belah–Rosewood	1	10	55	35	19	4.84
41	Belah–Rosewood	6	15	9	70	10	4.31
42	Belah–Rosewood	0.5	20	0	25	25	3.14
43	Mallee	0.5	2	84	25	32	5.00
44	Mallee	0.5	17	38	37	30	4.96

n.a. = not applicable

Site no.	Vegetation community	No. of mistletoes per live tree	Mean hollows per live tree	Mean hollows per dead tree	Mean hollows per tree	Cover of tree trunks (live+ dead) (%)	No. of tree species
1	Blackbox	0.0	0	0	0	0.06	3
2	Blackbox	0.0	2	0	2	0.03	2
3	Blackbox	0.0	3	0	3	0.00	1
4	Blackbox	0.0	4.7	0	4.7	0.08	1
5	Blackbox	0.0	1.3	0	1.3	0.09	2
6	Blackbox	0.0	0.7	0	0.7	0.14	1
7	Blackbox	0.0	2.8	2	4.8	0.13	1
8	Blackbox	0.0	2.2	0	2.2	0.06	1
9	Blackbox	0.0	7	0	7	0.07	1
10	Blackbox	0.0	0.5	0	0.5	0.12	1
11	Blackbox	0.0	7	0	7	0.06	2
12	Blackbox	0.0	6.3	0	6.3	0.11	1
13	Blackbox	0.0	1.5	0	1.5	0.08	1
14	Blackbox	0.0	3.75	0	3.75	0.09	1
15	Blackbox	0.0	2	0	2	0.06	1
16	Blackbox	0.0	1.4	0	1.4	0.16	2
17	Blackbox	0.0	3.5	0	3.5	0.19	1
18	Blackbox	0.0	2.2	6	8.2	0.21	2
19	Blackbox	0.0	0.3	0	0.3	0.16	2
20	Blackbox	0.0	0.2	0	0.2	0.15	1
21	Bimble Box–Pine	0.0	0	0	0	0.03	2
22	Bimble Box–Pine	n.a.	n.a.	n.a.	n.a.	n.a.	0
23	Bimble Box–Pine	0.0	0	0	0	0.05	1
24	Bimble Box–Pine	0.0	0	0	0	0.01	2
25	Bimble Box–Pine	0.0	0.75	0	0.75	0.05	2
26	Bimble Box–Pine	0.0	0	4	4	0.03	1
27	Bimble Box–Pine	0.0	0	0	0	0.0019	2
28	Bimble Box–Pine	0.4	0	0	0	0.06	5
29	Bimble Box–Pine	0.0	0	0	0	0.11	1
30	Bimble Box–Pine	0.0	0.3	0.4	0.7	0.58	2
31	Bimble Box–Pine	0.0	0.3	0	0.3	0.07	3
32	Bimble Box–Pine	0.0	0	0	0	0.0036	2
33	Bimble Box–Pine	0.0	9.5	0	9.5	0.11	1
34	Boree	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
35	Boree	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
36	Boree	0.0	0	0	0	0.01	1
37	Boree	0.8	0.25	0	0.25	0.04	1
38	Boree	0.0	0	0	0	0.04	1
39	Boree	2.0	0	0	0	0.05	1
40	Belah–Rosewood	0.0	1.2	0	1.2	0.17	4
41	Belah–Rosewood	0.0	0.7	0	0.7	0.15	3
42	Belah–Rosewood	0.4	0	0	0	0.05	3
43	Mallee	0.0	0	0	0	0.04	4
44	Mallee	0.0	0	0	0	0.03	5

n.a. = not applicable

Site no.	Vegetation community	No. of shrub species	No. of ground-storey species	Total no. of species	% perennial plants	% annual plants	% native plants	% exotic plants
1	Blackbox	5	17	25	77.3	22.7	81.8	18.2
2	Blackbox	2	34	38	50.0	50.0	61.1	38.9
3	Blackbox	4	34	39	68.4	31.6	78.9	21.1
4	Blackbox	4	25	30	69.0	31.0	62.1	37.9
5	Blackbox	3	31	36	62.9	37.1	71.4	28.6
6	Blackbox	3	19	23	63.6	36.4	72.7	27.3
7	Blackbox	3	17	21	80.0	20.0	80.0	20.0
8	Blackbox	2	31	34	57.6	42.4	66.7	33.3
9	Blackbox	0	17	18	58.8	41.2	41.2	58.8
10	Blackbox	2	47	50	46.9	53.1	55.1	44.9
11	Blackbox	1	37	40	47.4	52.6	42.1	57.9
12	Blackbox	1	19	21	35.0	65.0	25.0	75.0
13	Blackbox	0	29	30	41.4	58.6	37.9	62.1
14	Blackbox	4	33	38	59.5	40.5	64.9	35.1
15	Blackbox	0	19	20	42.1	57.9	21.1	78.9
16	Blackbox	5	21	28	65.4	34.6	61.5	38.5
17	Blackbox	0	15	16	60.0	40.0	40.0	60.0
18	Blackbox	1	25	28	42.3	57.7	38.5	61.5
19	Blackbox	2	31	35	51.5	48.5	30.3	69.7
20	Blackbox	0	32	33	43.8	56.3	34.4	65.6
21	Bimble Box–Pine	5	29	36	79.4	20.6	82.4	17.6
22	Bimble Box–Pine	1	29	30	56.7	43.3	43.3	56.7
23	Bimble Box–Pine	2	16	19	72.2	27.8	83.3	16.7
24	Bimble Box–Pine	3	44	49	68.1	31.9	70.2	29.8
25	Bimble Box–Pine	0	28	30	71.4	28.6	67.9	32.1
26	Bimble Box–Pine	1	45	47	56.5	43.5	65.2	34.8
27	Bimble Box–Pine	2	36	40	55.3	44.7	57.9	42.1
28	Bimble Box–Pine	3	24	32	70.4	29.6	85.2	14.8
29	Bimble Box–Pine	7	33	41	67.5	32.5	62.5	37.5
30	Bimble Box–Pine	4	33	39	62.2	37.8	67.6	32.4
31	Bimble Box–Pine	2	21	26	52.2	47.8	52.2	47.8
32	Bimble Box–Pine	0	34	36	52.9	47.1	52.9	47.1
33	Bimble Box–Pine	1	25	27	42.3	57.7	46.2	53.8
34	Boree	2	24	27	61.5	38.5	61.5	38.5
35	Boree	1	32	34	54.5	45.5	60.6	39.4
36	Boree	5	26	32	74.2	25.8	80.6	19.4
37	Boree	3	36	40	64.1	35.9	59.0	41.0
38	Boree	3	38	42	58.5	41.5	70.7	29.3
39	Boree	4	31	36	51.4	48.6	65.7	34.3
40	Belah–Rosewood	6	8	18	71.4	28.6	85.7	14.3
41	Belah–Rosewood	5	22	30	63.0	37.0	88.9	11.1
42	Belah–Rosewood	3	32	38	60.0	40.0	62.9	37.1
43	Mallee	2	29	35	64.5	35.5	74.2	25.8
44	Mallee	10	13	28	100.0	0.0	100.0	0.0

Site no.	Vegetation community	Soil texture	OC (%)	Kjeldahl N (ppm)	Total phosphorus (ppm)	EC (dS/m)	pH (1:5 water)	Remnant area (ha)
1	Blackbox	clay	3.0	2500	400	1.86	6.91	808.899
2	Blackbox	clay	7.2	5100	540	2.74	6.88	72.530
3	Blackbox	clay	3.6	3600	370	3.30	6.52	127.767
4	Blackbox	clay	7.2	6500	730	2.49	6.31	72.540
5	Blackbox	clay	3.2	2200	290	3.26	6.94	174.696
6	Blackbox	clay	3.2	3600	400	3.29	6.76	58.663
7	Blackbox	clay	11.0	16000	1200	7.86	6.91	15.503
8	Blackbox	clay	2.4	2400	280	3.07	6.62	124.099
9	Blackbox	clay	2.8	2800	310	2.39	6.56	2.876
10	Blackbox	clay	6.6	6300	600	5.65	6.59	18.586
11	Blackbox	clay	6.4	7600	710	3.85	6.42	40.104
12	Blackbox	clay	4.8	7600	880	8.15	6.44	1.091
13	Blackbox	clay	9.4	*	820	3.16	6.34	57.105
14	Blackbox	clay	3.6	5060	640	3.62	6.79	77.803
15	Blackbox	clay	2.6	6400	440	2.93	6.83	14.662
16	Blackbox	clay	5.6	4300	560	2.06	6.66	7.939
17	Blackbox	clay	5.2	6300	610	2.98	6.29	4.449
18	Blackbox	clay	10.0	11000	1100	4.99	6.23	3.125
19	Blackbox	clay	9.2	11000	1300	2.85	6.27	2.500
20	Blackbox	clay	11.0	11000	970	4.31	6.42	3.200
21	Bimble Box–Pine	clay loam	3.2	2500	360	2.83	6.67	310.708
22	Bimble Box–Pine	clay loam	2.4	2500	330	2.12	6.97	100.373
23	Bimble Box–Pine	clay loam	1.6	1200	230	1.70	6.78	184.316
24	Bimble Box–Pine	clay loam	2.4	1900	250	2.82	6.68	61.416
25	Bimble Box–Pine	clay loam	2.6	4400	420	2.28	6.94	89.328
26	Bimble Box–Pine	clay loam	2.6	3000	330	1.74	6.72	75.374
27	Bimble Box–Pine	clay loam	2.8	2600	340	3.26	7.11	84.577
28	Bimble Box–Pine	clay loam	2.4	2300	310	1.39	6.87	611.921
29	Bimble Box–Pine	clay loam	2.2	1500	160	2.39	6.66	239.656
30	Bimble Box–Pine	clay loam	3.6	2800	260	3.22	6.69	24.406
31	Bimble Box–Pine	clay loam	4.6	4700	440	3.17	7.02	185.201
32	Bimble Box–Pine	clay loam	2.2	2300	260	2.69	6.73	46.602
33	Bimble Box–Pine	clay loam	2.8	2600	380	2.55	7.00	65.122
34	Boree	clay loam	2.2	2100	260	1.28	7.01	72.638
35	Boree	loam	2.6	1900	240	2.94	7.21	17.793
36	Boree	clay loam	1.8	2100	280	1.25	6.88	9.942
37	Boree	clay	4.0	4700	390	6.91	6.97	49.835
38	Boree	clay	2.0	2100	310	1.29	6.74	30.594
39	Boree	loam	2.8	3600	310	5.29	6.91	148.273
40	Belah–Rosewood	clay loam	1.4	1100	250	2.52	6.93	198.652
41	Belah–Rosewood	clay loam	3.0	2700	440	1.95	6.84	103.830
42	Belah–Rosewood	clay loam	2.0	2600	370	2.23	6.86	21.613
43	Mallee	loam	2.0	1400	180	2.57	7.28	17.066
44	Mallee	loam	1.6	960	140	0.64	6.88	52.026

* = missing data

Site no.	Vegetation community	Remnant perimeter (m)	Area to perimeter ratio	Remnant isolation (m)	Understorey type	Extent of grazing	Extent of clearing	Degree of tree regrowth	Subjective condition score
1	Blackbox	24028.733	0.034	258	native	high	nil	extensive	8.50
2	Blackbox	5989.175	0.012	597	native	slight	nil	nil	8.00
3	Blackbox	5955.316	0.021	20	native	slight	slight	nil	7.00
4	Blackbox	4995.397	0.015	1083	native	moderate	slight	moderate	8.00
5	Blackbox	5977.948	0.029	717	native	slight	nil	nil	6.75
6	Blackbox	4011.763	0.015	1594	native	nil	moderate	moderate	8.00
7	Blackbox	2189.310	0.007	967	native	moderate	moderate	nil	7.50
8	Blackbox	4804.213	0.026	1708	native	slight	nil	nil	7.00
9	Blackbox	850.725	0.003	1283	exotic	high	slight	nil	5.50
10	Blackbox	1906.133	0.010	395	native	nil	moderate	moderate	8.00
11	Blackbox	3974.231	0.010	949	exotic	nil	slight	nil	5.00
12	Blackbox	500.249	0.002	1398	exotic	high	slight	nil	4.00
13	Blackbox	3065.298	0.019	3246	exotic	high	slight	nil	5.00
14	Blackbox	9622.620	0.008	244	exotic	moderate	slight	nil	5.00
15	Blackbox	1592.925	0.009	3286	exotic	high	slight	nil	5.00
16	Blackbox	1510.006	0.005	4945	native	nil	slight	moderate	8.00
17	Blackbox	798.946	0.006	1855	exotic	nil	nil	nil	6.00
18	Blackbox	792.654	0.004	3004	exotic	slight	nil	moderate	5.00
19	Blackbox	972.626	0.003	3009	exotic	moderate	slight	nil	5.75
20	Blackbox	1068.603	0.003	6093	exotic	nil	nil	nil	4.50
21	Bimble Box–Pine	11458.283	0.027	399	native	nil	nil	extensive	9.00
22	Bimble Box–Pine	4213.545	0.024	1736	native	nil	moderate	moderate	6.50
23	Bimble Box–Pine	6268.218	0.029	587	native	nil	slight	extensive	6.00
24	Bimble Box–Pine	4891.190	0.013	383	native	nil	moderate	extensive	8.75
25	Bimble Box–Pine	4091.934	0.022	687	native	nil	moderate	moderate	6.50
26	Bimble Box–Pine	4061.720	0.019	328	native	nil	slight	moderate	8.50
27	Bimble Box–Pine	3731.215	0.023	174	native	moderate	moderate	moderate	6.50
28	Bimble Box–Pine	10889.118	0.056	1213	native	slight	moderate	extensive	6.50
29	Bimble Box–Pine	11568.921	0.021	991	native	slight	slight	extensive	5.75
30	Bimble Box–Pine	2291.243	0.011	988	native	moderate	moderate	moderate	6.00
31	Bimble Box–Pine	5839.404	0.032	823	exotic	moderate	moderate	nil	4.00
32	Bimble Box–Pine	2789.791	0.017	321	mixed	high	moderate	moderate	6.50
33	Bimble Box–Pine	3440.396	0.019	1668	mixed	moderate	moderate	moderate	6.00
34	Boree	3840.644	0.019	584	native	slight	nil	moderate	9.00
35	Boree	1826.324	0.010	295	mixed	slight	nil	moderate	6.50
36	Boree	1777.082	0.006	1213	native	nil	nil	extensive	9.00
37	Boree	2843.205	0.018	655	native	slight	nil	moderate	7.00
38	Boree	2337.965	0.013	2300	native	moderate	nil	nil	5.75
39	Boree	7460.225	0.020	317	mixed	high	nil	moderate	6.25
40	Belah–Rosewood	6980.486	0.028	1600	native	moderate	nil	moderate	7.00
41	Belah–Rosewood	8103.997	0.013	234	native	high	moderate	moderate	7.50
42	Belah–Rosewood	1937.446	0.011	1189	native	high	moderate	nil	4.75
43	Mallee	1905.009	0.009	4323	native	nil	slight	moderate	8.00
44	Mallee	4283.885	0.012	720	native	nil	nil	extensive	7.00

Appendix II. Bimble Box–Pine community ratings

Ratings used to calculate the three indices of landscape health for the Bimble Box–Pine community. Higher ratings correspond to better health.

Attribute and description	Min	Max	Mean	Median	Ratings 1	2	3	4	5	Max
Trees (%) (% cover of trees)	0	31.0	10.4	9.0	0–2	2.1–5	5.1–10	10.1–25	>25	5
Tall shrub (%) (% cover of tall shrubs (2–4 m))	0	12.0	1.2	0	0–2	2.1–5	5.1–10	10.1–25	>25	5
Sub-shrub (%) (% cover of sub-shrubs (0.5–2 m))	0	6.0	0.7	0	0–2	2.1–5	5.1–10	10.1–25	>25	5
Perennial grass (%) (% cover of perennial grasses)	0.5	45.0	24.4	28.0	0–5	5.1–10	10.1–25	25.1–50	>50	5
Annual grass (%) (% cover of annual grasses)	0.5	23.0	7.9	10.0	0–10	10.1–25	25.1–50	>50		4
Forb (%) (% cover of forbs)	2.0	38.0	10.5	6.0	>50	25.1–50	10–25	<10		4
Bare (%) (% area of bare ground)	0	50.0	13.1	7.0	>50	25–50	10–25	<10		4
Cryptogam (%) (% cover of cryptogams)	3.0	60.0	29.5	28.0	<25	25–50	50.1–75	>75		4
Litter (%) (% cover of litter)	10.0	50.0	30.7	30.0	<5	5–10	10.1–25	25.1–50	>50	5
Logs (%) (% cover of logs and debris)	0.5	2.0	0.7	0.5	<1	1–2	>2			3
Patchiness (no. of obstructions / 10 m)	0	2.1	0.7	0.7	0	<2	>2.1–4	>4		4
Tree species (no. of tree species)	0	5.0	1.8	1.2	0	1	2-5	>5		4
Shrub species (no. of shrub species)	0	7.0	2.4	2.0	0	<3	3-5	>5		4
Plant species (no. of groundstorey species)	16.0	45.0	30.5	29.0	<10	10–25	25.1–40	>40		4
Perennials (%) (% plant perenniality)	42.3	79.4	62.1	62.2	<25	25–50	50.1–75	>75		4
Natives (%) (% of natives)	43.3	85.2	64.4	65.2	<25	25–50	50.1–75	>75		4
Regrowth (% of shrub regrowth)	nil	extens	mod	nil	nil	slight	mod	extensive		4
Mistletoe (%) (% infestation with mistletoe)	0	0.5	0.04	0	>50	25.1–50	10–25	<10		4
Canopy (%) (% health of tree canopy)	3.1	5.0	4.4	4.6	<1.0	1.1–2	2.1–3	3.1–4	>4	5
Hollows (extent of tree hollows)	0	9.5	1.3	0	<1	1–2	2.1–5	>5		4
Biomass (t) (groundstorey biomass (t))	0.1	4.0	1.2	0.7	<1	1–2	2.1–4	>4		4
Erosion (%) (% cover of erosion)	2.5	10.0	3.7	2.5	>30	15.1–30	5–15	<5		4
Butt cover (%) (% cover of perennial grass butts)	0	9.9	4.3	4.0	<2	2–5	5.1–7	7.1–10	>10	5
Organic matter (%) (% soil organic matter)	1.6	4.6	2.7	2.6	<1	1–2	2.1–5	>5		4
Texture (soil texture)	clay loam	clay loam	clay loam	clay loam	sand	loam	clay loam	clay		4

Appendix III. Blackbox community ratings

Ratings used to calculate the three indices of landscape health for the Blackbox community. Higher ratings correspond to better health.

Attribute and description	Min	Max	Mean	Median	Ratings					
					1	2	3	4	5	Max
Trees (%) (% cover of trees)	1.0	36.0	16.7	15.0	0–2	2.1–5	5.1–10	10.1–25	>25	5
Tall shrub (%) (% cover of tall shrubs (2–4 m))	0	0	0	0	0–2	2.1–5	5.1–10	10.1–25	>25	5
Sub-shrub (%) (% cover of sub-shrubs (0.5–2 m))	0	18.0	3.5	0.5	0–2	2.1–5	5.1–10	10.1–25	>25	5
Perennial grass (%) (% cover of perennial grasses)	0	29.0	5.4	0.5	0–5	5.1–10	10.1–25	25.1–50	>50	5
Annual grass (%) (% cover of annual grasses)	0.5	64.0	21.3	15.5	0–10	10.1–25	25.1–50	>50		4
Forb (%) (% cover of forbs)	0.5	79.0	17.7	10.5	>50	25.1–50	10–25	<10		4
Bare (%) (% area of bare ground)	0	50.0	16.1	12.5	>50	25–50	10–25	<10		4
Cryptogam (%) (% cover of cryptogams)	0	30.0	2.3	0	<25	25–50	50.1–75	>75		4
Litter (%) (% cover of litter)	15.0	85.0	34.6	32.5	<10	10.1–25	25.1–50	>50		4
Logs (%) (% cover of logs and debris)	0	5.0	1.1	0.5	<1	1–2	>2			3
Patchiness (no. of obstructions / 10 m)	0	2.5	0.4	0.1	0	<2	>2.1–4	>4		4
Tree species (no. of tree species)	1.0	3.0	1.4	1.0	0	1	2-5	>5		4
Shrub species (no. of shrub species)	0	5.0	2.1	2.0	0	<3	3-5	>5		4
Plant species (no. of groundstorey species)	15.0	47.0	26.7	27.0	<10	10–25	25.1–40	>40		4
Perennials (%) (% plant perenniality)	35.0	80.0	56.2	58.2	<25	25–50	50.1–75	>75		4
Natives (%) (% of natives)	21.1	81.1	53.3	58.1	<25	25–50	50.1–75	>75		4
Regrowth (% of shrub regrowth)	nil	extens	mod	nil	nil	slight	mod	extensive		4
Mistletoe (%) (% infestation with mistletoe)	0	0	0	0	>50	25.1–50	10–25	<10		4
Canopy (%) (% health of tree canopy)	2.0	5.0	3.8	3.7	<1.0	1.1–2	2.1–3	3.1–4	>4	5
Hollows (extent of tree hollows)	0	8.2	3.0	2.1	<1	1–2	2.1–5	>5		4
Biomass (t) (groundstorey biomass (t))	0.2	4.6	1.3	1.2	<1	1–2	2.1–4	>4		4
Soil surface erosion (%) (% cover of erosion)	2.5	10.0	2.9	2.5	>30	15.1–30	5–15	<5		4
Butt cover (%) (% cover of perennial grass butts)	0	4.2	0.6	0	<2	2–5	5.1–7	7.1–10	>10	5
Organic matter (%) (% soil organic matter)	2.4	11.0	5.9	5.4	<1	1–2	2.1–5	>5		4
Texture (soil texture)	clay	clay	clay	clay	sand	loam	clay loam	clay		4

Appendix IV. Listing of vascular plants, and occurrence by site

Genus and species	Common name	Form	Life history	Origin
Abutilon otocarpum	desert Chinese-lantern	Forb	Perennial	Native
Acacia brachybotrya	grey mulga	Shrub large	Perennial	Native
Acacia decora	western golden wattle	Shrub large	Perennial	Native
Acacia doratoxylon	currawang	Shrub large	Perennial	Native
Acacia hakeoides	western black wattle	Shrub large	Perennial	Native
Acacia havilandiorum	haviland's wattle	Shrub large	Perennial	Native
Acacia homalophylla	yarran	Tree tall	Perennial	Native
Acacia oswaldii	miljee	Shrub large	Perennial	Native
Acacia pendula	myall	Tree tall	Perennial	Native
Actinobole uliginosum	flannel cudweed	Forb	Annual	Native
Agropyron scabrum	common wheatgrass	Grass	Perennial	Native
Agrostis avenacea var. *avenacea*	blown grass	Grass	Perennial	Native
Aira cupaniana	silvery hairgrass	Forb	Annual	Exotic
Ajuga australis	Australian bugle	Forb	Perennial	Native
Alectryon oleifolius	western rosewood, bonaree	Tree tall	Perennial	Native
Allocasuarina luehmannii	bulloak	Tree tall	Perennial	Native
Alternanthera denticulata	lesser joyweed	Forb	Annual	Native
Alternanthera sp. A		Forb	Perennial	Native
Amaranthus sp.	amaranth	Forb	Annual	Exotic
Amphibromus macrorhinus		Grass	Perennial	Native
Amphipogon caricinus	greybeard grass	Grass	Perennial	Native
Amyema quandang ssp. *bancroftii*	grey mistletoe	Forb	Perennial	Native
Apophyllum anomalum	warrior bush	Tree tall	Perennial	Native
Arctotheca calendula	capeweed	Forb	Annual	Exotic
Aristida behriana	brush wiregrass	Grass	Perennial	Native
Aristida contorta	kerosene grass	Grass	Perennial	Native
Aristida jerichoensis var. *jerichoensis*	no. 9 wiregrass	Grass	Perennial	Native
Arthropodium minus	small vanilla-lily	Forb	Perennial	Native
Aster subulatus	bushy starwort	Forb	Annual	Exotic
Atriplex crassipes		Forb	Annual	Native
Atriplex leptocarpa	slender-fruited saltbush	Forb	Perennial	Native
Atriplex pseudocampanulata	mealy saltbush	Forb	Annual	Native
Atriplex semibaccata	creeping saltbush	Forb	Perennial	Native
Atriplex spinibractea	spiny-fruit saltbush	Forb	Perennial	Native
Atriplex stipitata	bitter saltbush	Forb	Perennial	Native
Atriplex suberecta	lagoon saltbush	Forb	Annual	Native
Austrodanthonia auriculata	lobed wallaby grass	Grass	Perennial	Native
Austrodanthonia caespitosa	white-top	Grass	Perennial	Native
Austrodanthonia duttoniana	brown-back wallaby grass	Grass	Perennial	Native
Austrodanthonia eriantha	hill wallaby grass	Grass	Perennial	Native
Austrodanthonia setacea	small-flowered wallaby grass	Grass	Perennial	Native
Austrodanthonia sp.	wallaby grass	Grass	Perennial	Native
Austrostipa aristiglumis	plains grass	Grass	Perennial	Native
Austrostipa bigeniculata	yanganbil	Grass	Perennial	Native
Austrostipa densiflora	foxtail speargrass	Grass	Perennial	Native
Austrostipa elegantissima	feather speargrass	Grass	Perennial	Native
Austrostipa scabra	rough speargrass	Grass	Perennial	Native
Austrostipa setacea	corkscrew grass	Grass	Perennial	Native
Austrostipa tuckeri	tucker's speargrass	Grass	Perennial	Native
Avena barbata	bearded oat	Grass	Annual	Exotic
Avena fatua	wild oat	Grass	Annual	Exotic
Avena sp.	oat	Grass	Annual	Exotic
Boerhavia dominii	tarvine	Forb	Perennial	Native
Bossiaea walkeri	cactus pea	Shrub medium	Perennial	Native
Brachychiton populneus subsp. *populneus*	kurrajong	Tree tall	Perennial	Native
Brachycome lineariloba	hard-headed daisy	Forb	Annual	Native

Genus and species	Common name	Form	Life history	Origin
Bracteantha bracteata	golden everlasting	Forb	Perennial	Native
Bracteantha viscosa	sticky everlasting	Forb	Perennial	Native
Brassica tournefortii	wild turnip	Forb	Annual	Exotic
Bromus arenarius	sand brome	Grass	Annual	Native
Bromus cartharticus	prairie grass	Grass	Perennial	Exotic
Bromus diandrus	great brome	Grass	Annual	Exotic
Bromus hordeaceus	soft brome	Grass	Perennial	Exotic
Bromus molliformis	silky brome	Grass	Annual	Exotic
Bromus rubens	red brome	Grass	Annual	Exotic
Bulbine bulbosa	bulbine lily, golden lily	Forb	Perennial	Native
Calandrinia edremaea	small purslane	Forb	Annual	Native
Callitris glaucophylla	white cypress pine	Tree tall	Perennial	Native
Calocephalus sonderi	pale beauty-heads	Forb	Annual	Native
Calotis cuneifolia	purple burr-daisy	Forb	Perennial	Native
Calotis hispidula	bogan flea	Forb	Annual	Native
Calotis scabiosifolia		Forb	Perennial	Native
Capsella bursa-pastoris	shepherd's purse	Forb	Annual	Exotic
Carex inversa	knob sedge	Forb	Perennial	Native
Carthamus lanatus	saffron thistle	Forb	Annual	Exotic
Cassytha melantha	mallee strangle-vine	Shrub medium	Perennial	Native
Casuarina cristata	belah	Tree tall	Perennial	Native
Centaurea melitensis	Maltese cockspur	Forb	Annual	Exotic
Centaurium tenuiflorum	branched centaury	Forb	Annual	Exotic
Chamaesyce drummondii	caustic weed	Forb	Perennial	Native
Cheilanthes sieberi subsp. *sieberi*	mulga fern	Forb	Perennial	Native
Chenopodium album	fat-hen	Forb	Annual	Exotic
Chenopodium curvispicatum	cottony saltbush	Forb	Perennial	Native
Chenopodium desertorum subsp. *anidiophyllum*	mallee goosefoot	Forb	Perennial	Native
Chenopodium desertorum subsp. *desertorum*	mallee goosefoot	Forb	Perennial	Native
Chenopodium desertorum subsp. *microphyllum*	small-leaf goosefoot	Forb	Annual	Native
Chenopodium melanocarpum	black crumbweed	Forb	Annual	Native
Chenopodium murale	nettle-leaf goosefoot	Forb	Annual	Exotic
Chenopodium nitrariaceum	nitre goosefoot	Shrub medium	Perennial	Native
Chloris gayana	rhodes grass	Grass	Perennial	Exotic
Chloris truncata	windmill grass	Grass	Perennial	Native
Chondrilla juncea	skeleton-weed	Forb	Perennial	Exotic
Chrysocephalum apiculatum	yellow buttons	Forb	Perennial	Native
Cirsium vulgare	spear thistle	Forb	Annual	Exotic
Clematis microphylla var. *microphylla*	small-leaved clematis	Shrub small	Perennial	Native
Convolvulus erubescens	Australian bindweed	Forb	Perennial	Native
Conyza bonariensis	flax-leaf fleabane	Forb	Annual	Exotic
Crassula colorata var. *acuminata*	dense stonecrop	Forb	Annual	Native
Crassula sieberiana	Australian stonecrop	Forb	Annual	Native
Crassula sp.	stonecrop	Forb	Annual	Native
Cucumis myriocarpus	paddy melon	Forb	Annual	Exotic
Cynodon dactylon	couch grass, bermuda grass	Grass	Perennial	Native
Daucus glochidiatus	Australian carrot	Forb	Annual	Native
Dianella longifolia var. *longifolia*	smooth flax-lily	Forb	Perennial	Native
Dianella revoluta	spreading flax-lily	Forb	Perennial	Native
Dichopogon strictus	chocolate-lily	Grass	Perennial	Native
Digitaria brownii	cotton panic grass	Grass	Perennial	Native
Dodonaea boroniifolia	fern-leaf hopbush	Shrub medium	Perennial	Native
Dodonaea viscosa subsp. *angustifolia*	broad-leaf hopbush	Shrub medium	Perennial	Native
Dodonaea viscosa subsp. *angustissima*	narrow-leaf hopbush	Shrub medium	Perennial	Native
Echium plantagineum	paterson's curse, salvation jane	Forb	Annual	Exotic
Eclipta platyglossa	yellow twin-heads	Forb	Annual	Native
Einadia nutans	climbing saltbush	Shrub small	Perennial	Native

Genus and species	Common name	Form	Life history	Origin
Einadia nutans subsp. *linifolia*	climbing saltbush	Shrub small	Perennial	Native
Einadia nutans subsp. *nutans*	climbing saltbush	Shrub small	Perennial	Native
Eleocharis acuta	common spike-rush	Forb	Perennial	Native
Elymus scaber	wheatgrass	Grass	Perennial	Native
Elymus scaber var. *scaber*	common wheatgrass	Grass	Perennial	Native
Enchylaena tomentosa	ruby saltbush	Shrub small	Perennial	Native
Enneapogon intermedius	tall bottlewashers	Grass	Perennial	Native
Enteropogon acicularis	curly windmill grass	Grass	Perennial	Native
Epilobium hirtigerum	hoary willow-herb	Forb	Perennial	Native
Eragrostis setifolia	neverfail	Grass	Perennial	Native
Eremophila longifolia	emubush	Shrub medium	Perennial	Native
Erodium cicutarium	common crowfoot	Forb	Perennial	Exotic
Erodium crinitum	blue crowfoot	Forb	Perennial	Exotic
Eucalyptus dumosa	congoo mallee	Tree tall	Perennial	Native
Eucalyptus largiflorens	black box	Tree tall	Perennial	Native
Eucalyptus leptophylla	slender-leaf mallee	Tree tall	Perennial	Native
Eucalyptus microcarpa	grey box	Tree tall	Perennial	Native
Eucalyptus populnea subsp. *bimbil*	bimble box	Tree tall	Perennial	Native
Eucalyptus socialis	pointed mallee	Tree tall	Perennial	Native
Geijera parviflora	wilga	Tree tall	Perennial	Native
Glycine clandestina species complex	twining glycine	Forb	Perennial	Native
Gnaphalium gymnocephalum		Forb	Annual	Exotic
Gonocarpus elatus	hill raspwort	Forb	Perennial	Native
Goodenia fascicularis	silky goodenia	Forb	Perennial	Native
Goodenia glabra	smooth goodenia	Forb	Perennial	Native
Goodenia glauca	pale goodenia	Forb	Perennial	Native
Goodenia pinnatifida	scambled eggs	Forb	Annual	Native
Goodenia sp.	goodenia	Forb	Perennial	Native
Gynandriris setifolia	thread iris	Forb	Perennial	Exotic
Hakea tephrosperma	hooked needlewood	Shrub medium	Perennial	Native
Halgania cyanea	mallee blue-flower	Forb	Perennial	Native
Haloragis aspera	rough raspwort	Forb	Perennial	Native
Harmsiodoxa brevipes var. *brevipes*	short cress	Forb	Annual	Native
Hedypnois rhagadioloides subsp. *cretic*	Cretan weed	Forb	Annual	Exotic
Helichrysum semipapposum	clustered everlasting	Forb	Perennial	Native
Helminthotheca echioides	ox-tongue	Forb	Annual	Exotic
Hordeum leporinum	barley grass	Grass	Annual	Exotic
Hyalosperma glutinosum subsp. *glutinosa*	golden sunray	Forb	Annual	Native
Hydrocotyle laxiflora	stinking pennywort	Forb	Perennial	Native
Hypericum perforatum	St. John’s wort	Forb	Perennial	Exotic
Hypochaeris glabra	smooth catsear	Forb	Annual	Exotic
Hypochaeris radicata	flatweed	Forb	Perennial	Exotic
Ixiolaena tomentosa	woolly plover-daisy	Shrub small	Perennial	Native
Juncus aridicola	tussock rush	Forb	Perennial	Native
Juncus radula	hoary rush	Forb	Perennial	Native
Juncus usitatus	common rush	Forb	Perennial	Native
Lactuca saligna	wild lettuce	Forb	Annual	Exotic
Lactuca serriola	prickly lettuce	Forb	Annual	Exotic
Lamarckia aurea	golden-top	Grass	Annual	Exotic
Lavatera plebeia	Australian hollyhock	Forb	Perennial	Native
Lepidium africanum	peppercress	Forb	Perennial	Exotic
Lepidium pseudohyssopifolium		Forb	Annual	Native
Lolium loliaceum	rigid ryegrass	Grass	Annual	Exotic
Lolium rigidum	wimmera ryegrass	Grass	Annual	Exotic
Lolium sp.	ryegrass	Grass	Annual	Exotic
Lomandra filiformis	wattle mat-rush	Forb	Perennial	Native
Lomandra multiflora subsp. *multiflora*	many-flowered mat-rush	Forb	Perennial	Native
Lomandra sp.	mat-rush	Forb	Perennial	Native
Lycium ferocissimum	African boxthorn	Shrub medium	Perennial	Exotic
Lythrum hyssopifolium	hyssop loosestrife	Forb	Annual	Native

Genus and species	Common name	Form	Life history	Origin
Maireana aphylla	cottonbush	Shrub small	Perennial	Native
Maireana brevifolia	yanga bush	Shrub small	Perennial	Native
Maireana coronata	crown fissure-weed	Forb	Perennial	Native
Maireana decalvans	black cottonbush	Shrub small	Perennial	Native
Maireana enchylaenoides	wingless fissure-weed	Forb	Perennial	Native
Maireana eriantha	woolly bluebush	Forb	Perennial	Native
Maireana excavata	bottle fissure-weed	Shrub small	Perennial	Native
Maireana pentagona	slender fissure-weed	Forb	Perennial	Native
Maireana sp.	bluebush	Forb	Perennial	Native
Malacocera tricornis	soft-horns	Forb	Perennial	Native
Malva parviflora	small-flowered mallow	Forb	Annual	Exotic
Marrubium vulgare	horehound	Forb	Perennial	Exotic
Marsilea drummondii	common nardoo	Forb	Perennial	Native
Medicago laciniata	cut-leaf medic	Forb	Annual	Exotic
Medicago minima	small woolly burr medic	Forb	Annual	Exotic
Medicago polymorph	burr medic	Forb	Annual	Exotic
Medicago truncatula	barrel medic	Forb	Annual	Exotic
Melaleuca uncinata	broombush	Tree short	Perennial	Native
Modiola caroliniana	red-flowered mallow	Forb	Perennial	Exotic
Monachather paradoxa	bandicoot grass	Grass	Perennial	Native
Muehlenbeckia florulenta	lignum	Shrub medium	Perennial	Native
Myriocephalus pluriflorus	woolly heads	Forb	Annual	Native
Onopordum acaulon	stemless thistle	Forb	Annual	Exotic
Oxalis perenans		Forb	Perennial	Native
Panicum decompositum	native millet	Grass	Perennial	Native
Panicum effusum	hairy panic	Grass	Perennial	Native
Parsonsia eucalyptophylla	gargaloo	Shrub small	Perennial	Native
Paspalidium gracile	slender panic	Grass	Perennial	Native
Paspalum dilatatum	paspalum	Grass	Perennial	Exotic
Persicaria lapathifolia	pale knotweed	Forb	Annual	Native
Petrorhagia nanteuilii	profliferous pink	Forb	Annual	Exotic
Petrorhagia velutina	velvet pink	Forb	Annual	Exotic
Phalaris aquatica	phalaris	Grass	Perennial	Exotic
Phalaris minor	lesser canary grass	Grass	Annual	Exotic
Phleum pratense	timothy grass	Grass	Perennial	Exotic
Pimelea micrantha		Forb	Perennial	Native
Pittosporum phylliraeoides	butterbush	Tree tall	Perennial	Native
Plantago drummondii	dark sago-weed	Forb	Annual	Native
Plantago turrifera	small sago-weed	Forb	Annual	Native
Podolepis muelleri	small copper-wire daisy	Forb	Perennial	Native
Podospermum resedifolium	scorzonera	Forb	Annual	Exotic
Polygonum aviculare	wireweed	Forb	Annual	Native
Pseudognaphalium pseudo-luteum	jersey cudweed	Forb	Annual	Native
Pterocaulon sphacelatum	fruit-salad plant, applebush	Forb	Perennial	Native
Ptilotus exaltatus var. *exaltatus*	showy foxtail	Forb	Perennial	Native
Ptilotus extenuatus		Forb	Perennial	Native
Ptilotus obovatus	silver-tails	Forb	Perennial	Native
Ptilotus semilanatus	lambs tails	Forb	Perennial	Native
Ptilotus spathulatus	pussy-tails	Forb	Perennial	Native
Rapistrum rugosum	turnip weed	Forb	Annual	Exotic
Rhagodia spinescens	thorny saltbush	Shrub small	Perennial	Native
Rhodanthe corymbiflora	grey sunray	Forb	Annual	Native
Rhodanthe diffusa	ascending sunray	Forb	Annual	Native
Rhodanthe floribunda	common white sunray	Forb	Annual	Native
Romulea rosea var. *australis*	onion grass	Forb	Perennial	Exotic
Rumex brownii	slender dock	Forb	Perennial	Native
Rumex crispus	curled dock	Forb	Perennial	Exotic
Rumex crystallinus	shiny dock	Forb	Annual	Native
Rumex sp.	dock	Forb	Annual	Exotic
Rumex tenax	a dock	Forb	Perennial	Native
Salsola kali var. *kali*	buckbush	Forb	Annual	Native
Salvia verbenacea	wild sage	Forb	Perennial	Exotic
Santalum lanceolatum	sandalwood	Tree short	Perennial	Native

Genus and species	Common name	Form	Life history	Origin
Scaevola aemula	common fan-flower	Shrub small	Perennial	Native
Schismus barbatus	Arabian grass	Grass	Annual	Exotic
Sclerolaena birchii	galvanized burr	Forb	Perennial	Native
Sclerolaena diacantha	grey copperburr	Forb	Perennial	Native
Sclerolaena lanicuspis	woolly copperburr	Forb	Perennial	Native
Sclerolaena muricata	roly-poly	Forb	Perennial	Native
Sclerolaena muricata var. *muricata*	roly-poly	Forb	Perennial	Native
Sclerolaena muricata var. *villosa*	grey roly-poly	Forb	Perennial	Native
Sclerolaena stelligera	star copperburr	Forb	Perennial	Native
Sclerolaena tricuspis	streaked poverty-bush	Forb	Perennial	Native
Senecio quadridentatus	cotton fireweed	Forb	Perennial	Native
Senecio runcinifolius	tall groundsel	Forb	Annual	Native
Senna artemisioides nothosubsp. *coriacea*	desert cassia	Shrub medium	Perennial	Native
Senna artemisioides subsp. *filifolia*	punty bush	Shrub medium	Perennial	Native
Sida ammophila	sand sida	Forb	Perennial	Native
Sida corrugata	corrugated sida	Forb	Perennial	Native
Sida cunninghamii	ridge sida	Forb	Perennial	Native
Sida fibulifera	pin sida	Forb	Perennial	Native
Sida trichopoda	high sida	Forb	Perennial	Native
Silybum marianum	variegated thistle	Forb	Annual	Exotic
Sisymbrium erysimoides	smooth mustard	Forb	Annual	Exotic
Sisymbrium irio	London rocket	Forb	Annual	Exotic
Solanum elaegnifolium	silver-leaf nightshade	Forb	Perennial	Exotic
Solanum ellipticum	velvet potato-bush	Forb	Perennial	Native
Solanum esuriale	quena	Forb	Perennial	Native
Solanum nigrum	black-berry nightshade	Forb	Perennial	Exotic
Sonchus oleraceus	common sowthistle	Forb	Annual	Exotic
Spergularia rubra	sandspurry	Forb	Annual	Exotic
Sporobolus caroli	fairy grass	Grass	Perennial	Native
Stackhousia monogyna	creamy candles	Forb	Perennial	Native
Tetragonia tetragonoides	New Zealand spinach	Forb	Annual	Native
Teucrium racemosum	grey germander	Forb	Perennial	Native
Thyridolepis mitchelliana	mulga grass	Grass	Perennial	Native
Thysanotus patersonii	twining fringe-lily	Forb	Perennial	Native
Tragopogon porrifolius	salsify	Forb	Annual	Exotic
Tricoryne elatior	yellow rush-lily	Forb	Perennial	Native
Trifolium angustifolium	narrow-leaf clover	Forb	Annual	Exotic
Trifolium arvense	haresfoot clover	Forb	Annual	Exotic
Trifolium campestre	hop clover	Forb	Annual	Exotic
Trifolium glomeratum	clustered clover	Forb	Annual	Exotic
Trifolium striatum	knotted clover	Forb	Annual	Exotic
Trifolium subterraneum	sub clover	Forb	Annual	Exotic
Trifolium tomentosum	woolly clover	Forb	Annual	Exotic
Triodia scariosa subsp. *scariosa*		Grass	Perennial	Native
Tripogon loliiformis	five-minute grass	Grass	Annual	Native
Triptilodiscus pygmaeus	common sunray	Forb	Annual	Native
Urtica urens	small nettle	Forb	Annual	Exotic
Vicia sativa		Forb	Annual	Exotic
Vittadinia condyloides		Forb	Perennial	Native
Vittadinia cuneata	fuzzweed	Forb	Perennial	Native
Vittadinia cuneata var. *cuneata* *forma cuneata*		Forb	Perennial	Native
Vittadinia gracilis		Forb	Perennial	Native
Vulpia bromoides	squirrel-tail fescue	Grass	Annual	Exotic
Vulpia myuros	rat's-tail fescue	Grass	Annual	Exotic
Wahlenbergia communis	tufted bluebell	Forb	Perennial	Native
Wahlenbergia fluminalis	river bluebell	Forb	Perennial	Native
Wahlenbergia gracilis	Australian bluebell	Forb	Perennial	Native
Wahlenbergia luteola		Forb	Perennial	Native
Wahlenbergia sp.	bluebell	Forb	Perennial	Native
Xanthium spinosum	bathurst burr	Forb	Annual	Exotic
Zygophyllum sp.	twinleaf	Forb	Annual	Native

SITES:									Blackbox											
Genus and species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Abutilon otocarpum				1			1													
Acacia brachybotrya																				
Acacia decora																				
Acacia doratoxylon																				
Acacia hakeoides																				
Acacia havilandiorum																				
Acacia homalophylla																				
Acacia oswaldii																				
Acacia pendula																				
Actinobole uliginosum		1																		
Agropyron scabrum																				
Agrostis avenacea var. *avenacea*										4										
Aira cupaniana																				
Ajuga australis																				
Alectryon oleifolius	3	1																		
Allocasuarina luehmannii																				
Alternanthera denticulata		1																		1
Alternanthera sp. A										1	1			1						
Amaranthus sp.											1									
Amphibromus macrorhinus										1										
Amphipogon caricinus																				
Amyema quandang ssp. *bancroftii*																				
Apophyllum anomalum																				
Arctotheca calendula				1							1			1						1
Aristida behriana																				
Aristida contorta																				
Aristida jerichoensis var. *jerichoensis*																				
Arthropodium minus																				
Aster subulatus										1					1			1	1	
Atriplex crassipes																			1	
Atriplex leptocarpa	1		1		1			3												
Atriplex pseudocampanulata																				
Atriplex semibaccata	1		1	1	1			1			1		1			1	1			10
Atriplex spinibractea						1	20													
Atriplex stipitata																				
Atriplex suberecta												16						1		
Austrodanthonia auriculata																				
Austrodanthonia caespitosa		10	1	15	1	8		1		3	1			1		22	1	1		
Austrodanthonia duttoniana																		1		
Austrodanthonia eriantha																				
Austrodanthonia setacea						1	1													
Austrodanthonia sp.																				
Austrostipa aristiglumis																				1
Austrostipa bigeniculata																				
Austrostipa densiflora																	1			
Austrostipa elegantissima																				
Austrostipa scabra	1	15	4	1	1	1	1	1		2	1			2		5				
Austrostipa setacea																				
Austrostipa tuckeri																				
Avena barbata																				
Avena fatua																1				
Avena sp.		1			1				1		1				8		1	1	1	
Boerhavia dominii		1	1								1			1					1	
Bossiaea walkeri																				
Brachychiton populneus subsp. *populneus*																				
Brachycome lineariloba																				

Bimble Box–Pine													Boree						Rosewood–Belah			Mallee	
21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
1		1							2														
																							1
					1	1		4															
2																							
																			1				
																							1
							4																
								2															
													1	1	4	5	7	12					
					1				1														
1																							
			1			1		1	1		1												
																						1	1
																			4	1	1		
			1				1																
																				1			
			1																				
																1		3					
							1												1	1			
	1				1	1		3	1	1		8		1		1	1						
20	1	1	8	2		1			1		1			2								12	
														1								2	
			15								1												1
1																							
																				1			
																				1			
													2	1		3	1	1			1		
						1	1																
																5			1				
						8																	
15			1	2			2				1	2	18	13	20	5	6	1		1	1	5	
					1																		
		1								15													
	3																						
														3									
3	16																						
1																							
							1													1		1	
	21	1	8	10	3	12	3	2	2	6	12	15	13	13	1	5	12	2	1	1	6	8	1
1																							
				8				15															
											2												
																						1	
2	12		2	10	5	1		10	1			8	1	2	1			1					
						1				1	1	1	1			1	1	1					
																							3
										1													2
							1																

Genus and species	SITES:								Blackbox											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Bracteantha bracteata																				
Bracteantha viscosa																				
Brassica tournefortii				1								20								
Bromus arenarius																				
*Bromus carthartic*us												1					1		25	1
Bromus diandrus		1							3			1			20	1	45	15	5	8
Bromus hordeaceus																				
Bromus molliformis								1							2			1		1
Bromus rubens																				
Bulbine bulbosa		1	1			1		1						1						
Calandrinia eremaea					1	1		1												
Callitris glaucophylla																				
Calocephalus sonderi			1				1													
Calotis cuneifolia																				
Calotis hispidula					1															
Calotis scabiosifolia			1																	
Capsella bursa-pastoris										1										
Carex inversa										1	1		2					5	1	1
Carthamus lanatus		2						1		1										
Cassytha melantha																				
Casuarina cristata					1						3							20	3	
Centaurea melitensis					1															
Centaurium tenuiflorum										1										
Chamaesyce drummondii		1	1				1				1		1	1						
Cheilanthes sieberi subsp. *sieberi*																				
Chenopodium album												1							1	
Chenopodium curvispicatum			1																	
Chenopodium desertorum subsp. *anidiophyllum*																				
Chenopodium desertorum subsp. *desertorum*																				
Chenopodium desertorum subsp. *microphyllum*						1														
Chenopodium melanocarpum												1								
Chenopodium murale												15								1
Chenopodium nitrariaceum	3				1															
Chloris gayana																				
Chloris truncata		2	1			1		1	1		10	1		1						
Chondrilla juncea																				
Chrysocephalum apiculatum																				
Cirsium vulgare										1	1		2		1					1
Clematis microphylla var. *microphylla*																				
Convolvulus erubescens		1	1				1			1				1						
Conyza bonariensis										1		1								
Crassula colorata var. *acuminata*																1				
Crassula sieberiana											1									
Crassula sp.	1	1			1	1		1						1						
Cucumis myriocarpus																				1
Cynodon dactylon									2	1		2	2		1				1	5
Daucus glochidiatus																				
Dianella longifolia var. *longifolia*																				
Dianella revoluta																				
Dichopogon strictus																				
Digitaria brownii																				
Dodonaea boroniifolia																				
Dodonaea viscosa subsp. *angustifolia*																				
Dodonaea viscosa subsp. *angustissima*																				
Echium plantagineum		1	1	1					1		1	1	1	1	12	1	1		5	1
Eclipta platyglossa										1										
Einadia nutans	3			1	8		60			5				1					1	

Bimble Box–Pine													Boree						Rosewood–Belah			Mallee	
21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
			1				1																
1				1																			
																	1						
1	8	4		2	17	1			1		1	2	8	3	1	1				1		1	
	1																						
						1		1			1		1	1									
												1											
1				1	1		1										1			1			
									1									1		1			
		20	8	1	8	1	22		12	7	1										1		
					1	1			1		1		1	2		1	1	1			1		
																	1						
	1		1		1						4												
																							1
																			15	65			
																						1	
			1																				
1			1	1	1	1		1		1	1	1	1	1	1	1	1						
	1	1	1	2		1	1	1	2						1								1
																1		1					
																							1
								1															
							2								1			1	1	1	1	1	
						1				2													
																		2					
										1													
			1			1	1				1		2	10		3		1			1		
	1										1												
		1			1				1						1							1	1
																							1
1	1		1	1	1	1	1	1	1					1		1	1			1	1		
			1							2	1												
													1			1							
					1	1	1	1				1		1			1	1		1	1		
					1																		
				1											1								
1																						1	
																						1	8
				1				1			1												
			1		3																		
																							1
															1								
																							1
1	6	1	1	1	1	2		1	1	8	2	10	1	2	1	1	1						
			1														1		1		1		

SITES:										Blackbox										
Genus and species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Einadia nutans subsp. *linifolia*						3	1													
Einadia nutans subsp. *nutans*		1	12			10		10								1				
Eleocharis acuta										2										
Elymus scaber																				
Elymus scaber var. *scaber*																				
Enchylaena tomentosa		1	1	1										1		1		1		
Enneapogon intermedius																				
Enteropogon acicularis			1	1							1					2				
Epilobium hirtigerum										1										
Eragrostis setifolia																				
Eremophila longifolia																				
Erodium cicutarium		1		1							1		1						1	1
Erodium crinitum																				
Eucalyptus dumosa																				
Eucalyptus largiflorens	25	8	10	15	20	36	1	11	10	18	3	25	10	33	10	9	25	1	12	15
Eucalyptus leptophylla																				
Eucalyptus microcarpa																				
Eucalyptus populnea subsp. *bimbil*																6				
Eucalyptus socialis																				
Geijera parviflora																				
Glycine clandestina species complex																				
Gnaphalium gymnocephalum										1										
Gonocarpus elatus																				
Goodenia fascicularis			1																	
Goodenia glabra										1										
Goodenia glauca		1			1		1			1	1									
Goodenia pinnatifida																				
Goodenia sp.																				
Gynandriris setifolia																				
Hakea tephrosperma																				
Halgania cyanea																				
Haloragis aspera																				
Harmsiodoxa brevipes var. *brevipes*																				
Hedypnois rhagadioloides subsp. *cretic*																				
Helichrysum semipapposum																				
Helminthotheca echioides										1								1		
Hordeum leporinum	1	3	1	20	1	1		4			25	15	55	25	1		12	15	2	5
Hyalosperma glutinosum subsp. *glutinosa*																				
Hydrocotyle laxiflora																				
Hypericum perforatum																				
Hypochaeris glabra																				
Hypochaeris radicata								1								1				
Ixiolaena tomentosa			1																	
Juncus aridicola						1			1	8									1	
Juncus radula																		1		
Juncus usitatus									1											
Lactuca saligna																				
Lactuca serriola		1	1						1	8	1				1			1		1
Lamarckia aurea																				
Lavatera plebeia													1							
Lepidium africanum	1			1		1	1	1	1	1		1	1			1	1		1	1
Lepidium pseudohyssopifolium		1	1																	
Lolium loliaceum											5					1				
Lolium rigidum									1											
Lolium sp.		5	7	5	1	1		1		1		4	3	1	1		2	20	15	12
Lomandra filiformis																				
Lomandra multiflora subsp. *multiflora*																				
Lomandra sp.																				
Lycium ferocissimum	1			1			1					1		1		1			2	
Lythrum hyssopifolium										2										

Bimble Box–Pine													Boree						Rosewood–Belah			Mallee	
21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
1		1					2	1	1	1					1	8		8					
			1		1						1												
	1			1					1														
																10		2	15	5			
			2		1																		
	4			6	2	1	1	1		10		1	1	1	1	3						1	
						1									1								
								1	1														
							1		1				1			1						1	
																					1		
																						6	4
																						1	
																						3	
2				23		1	3	2	2	2	1	10											2
																						2	1
																			5		4		
			1		1				1														
					1																		
															1	1	2	1					
1		1	2		1																		
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		1			1																		
								1														1	
								1															
2			1					5															
																						1	1
					7																		
																		1					
			1		1												1	1			1	1	
																							1
						10				10		1	1			5	1	1			8		
															1							1	
																						1	
				1																			
			2								1												
1	1		1	1	1	1		1	1						1								
														1									
					1																		
										1						1		1					
						1		1		1						1		1			1		
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											1												
																	1						
					1	1		1		2		1	1	1		3		2		1	1		
											1												
			1																				
					1			1															1
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SITES:									Blackbox										
Genus and species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Maireana aphylla																				
Maireana brevifolia						1					1									
Maireana coronata																				
Maireana decalvans	1		1	1												2				
Maireana enchylaenoides														1		1				
Maireana eriantha																				
Maireana excavata																				
Maireana pentagona								1						1						
Maireana sp.																				
Malacocera tricornis					1															
Malva parviflora			1	1							1	1	1	1			1	1	1	1
Marrubium vulgare					1						1				1		1	1	1	20
Marsilea drummondii					1	1	1		8	6	1		1	1	1		1	1	2	1
Medicago laciniata											1									
Medicago minima			1					1		1	2									
Medicago polymorph		1		1					1	1			1						1	1
Medicago truncatula		1	1	1				1		1			1	1		1				
Melaleuca uncinata																				
Modiola caroliniana																			1	
Monachather paradoxa																				
Muehlenbeckia florulenta	8				1			1		15				3						
Myriocephalus pluriflorus																				
Onopordum acaulon													1		3					
Oxalis perenans		1	1	1	1	1			1	1			1	1	1		1	1	1	1
Panicum decompositum	1				1															
Panicum effusum																				
Parsonsia eucalyptophylla																				
Paspalidium gracile																				
Paspalum dilatatum									1	1					1					1
Persicaria lapathifolia										1										
Petrorhagia nanteuilii																				
Petrorhagia velutina																				
Phalaris aquatica															1				15	
Phalaris minor										1			1					1		
Phleum pratense								1												
Pimelea micrantha																				
Pittosporum phylliraeoides																				
Plantago drummondii										1										
Plantago turrifera								1												
Podolepis muelleri																				
Podospermum resedifolium		1																		
Polygonum aviculare	1												1	1					1	1
Pseudognaphalium pseudo-luteum										1										
Pterocaulon sphacelatum													1							
Ptilotus exaltatus var. *exaltatus*								1												
Ptilotus extenuatus																				
Ptilotus obovatus																				
Ptilotus semilanatus																				
Ptilotus spathulatus																				
Rapistrum rugosum												1	1					1		1
Rhagodia spinescens					1											13				
Rhodanthe corymbiflora		1	1		1			1						1						
Rhodanthe diffusa																				
Rhodanthe floribunda																				
Romulea rosea var. *australis*					1															
Rumex brownii				1							1						1			1
Rumex crispus									1		1				2				1	
Rumex crystallinus													1		1					1
Rumex sp.											1									
Rumex tenax										1										
Salsola kali var. *kali*	1		1	1	1		15	1								1				
Salvia verbenacea																				
Santalum lanceolatum																				

Bimble Box–Pine													Boree						Rosewood–Belah			Mallee	
21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
																				1			
																			1				
								1															
		1				1	1						1		2		1	1			1		
	1					1		1	1	1	1		1				1			1	1		
			1																				
1	2		1					1	1	1		1	2	1	4		1			1	1		
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				1	1							1				1							
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	1																						
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1	1	1				2	1	1		1		1		1	1	1	5	10			5	1	
	1				1			1	1				1	1			3	1			1		
																							13
			1		1																		
					1																		
1	1	1	1	1	1	1	1		1	1		1		1	1	1	1			1			
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30																	1	1			1	1	
			1																				
	1																						
																					1		
																1							
						1							1	1	1	2	1	1	1	1	1		
												1		1	1		1				1		
																							1

Genus and species	SITES:									Blackbox										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Scaevola aemula																				
Schismus barbatus														2						
Sclerolaena birchii			1																	
Sclerolaena diacantha	1				1						1					1				
Sclerolaena lanicuspis																				
Sclerolaena muricata																		1		
Sclerolaena muricata var. *muricata*	1	1	2	3	3	1		1			1	1		3		3				
Sclerolaena muricata var. *villosa*	1		2	1	1															
Sclerolaena stelligera	1		1	1	2		1	4					1							
Sclerolaena tricuspis					1															
Senecio quadridentatus										1				1						
Senecio runcinifolius										1										
Senna artemisioides nothosubsp. *coriacea*																				
Senna artemisioides subsp. *filifolia*																				
Sida ammophila																			1	
Sida corrugata	1	1		1			1									1		1		1
Sida cunninghamii																				
Sida fibulifera		1	2	2																
Sida trichopoda	1	1						1						1		1				
Silybum marianum											1		1							1
Sisymbrium erysimoides					1			1			1			25					1	
Sisymbrium irio		1			1	1					1		5					25		
Solanum elaegnifolium															1					
Solanum ellipticum									2											
Solanum esuriale																				
Solanum nigrum												1	1					1	1	1
Sonchus oleraceus		1	1							1		1	1	1		1		1	1	1
Spergularia rubra		1			1	1				1	1									
Sporobolus caroli		1	1		1			1						1						
Stackhousia monogyna																				
Tetragonia tetragonoides								1												
Teucrium racemosum			1	1				1		1				1						
Thyridolepis mitchelliana																				
Thysanotus patersonii																				
Tragopogon porrifolius										1	1							1		
Tricoryne elatior																				
Trifolium angustifolium																				
Trifolium arvense										1										
Trifolium campestre																				
Trifolium glomeratum									1	1	1		2	1						
Trifolium striatum																				
Trifolium subterraneum																				
Trifolium tomentosum														1						
Triodia scariosa subsp. *scariosa*																				
Tripogon loliiformis																				
Triptilodiscus pygmaeus																				
Urtica urens																			1	
Vicia sativa																			1	
Vittadinia condyloides														1						
Vittadinia cuneata	1	1		1			1	1												
Vittadinia cuneata var. *cuneata* *forma cuneata*			1		1		1													
Vittadinia gracilis																1				
Vulpia bromoides	1				1		1													
Vulpia myuros						1	1	1								1				
Wahlenbergia communis																				
Wahlenbergia fluminalis										1										
Wahlenbergia gracilis																				
Wahlenbergia luteola																				
Wahlenbergia sp.																				
Xanthium spinosum										1	1		1	1					1	
Zygophyllum sp.																				

Bimble Box–Pine													Boree						Rosewood–Belah			Mallee	
21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
																				1		1	1
																					1		
			1				3								2				2			3	
																			1				
																5	1	1		1	1		
																			1				
1							1	1							7				1			1	
	6	1		2	1	6	1	1	1	1	1	1	4	1	1	2	1	1		1	1	1	
			2								1												
												1											
						1				2		1						1		1	5	1	
							1		1									5	1				
													1			1	1						
				1				1										1					
				1	1				1			1		1					1			1	
																		1					
														1									
1																							1
			1																	1	1		
1		1	8	1	25	1			9														
			1																				
1			1		1				1														
	1		6	1	1			2			1												
1	1		1	1	1	1		1		1	1	1		1		1							
	1			1	1			1	1		1												
			1			1					1	1				1							
						1					1												
	1																						
																							1
		1			1				1														
1			1																				
			1	2		1	2	1			1			2									
1		1			1			1							1		1	1			1	1	
																1							
									1												1		
	1		1		1	2	1				1	1		1			1	1					
1			1		1		1				1				1								
									1														
																					1		
																	1						1
																						1