Role of revegetation as habitat for birds: A case study of four revegetation localities in rural South Australia.

Karina Mercer and Clare Griffin

Land and Biodiversity Conservation Division
Department of Water, Land and Biodiversity Conservation

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Land and Biodiversity Conservation Division

Department of Water, Land and Biodiversity Conservation

Entry 4, Waite Road, Urrbrae

Telephone	National	(08) 8303 9645
	International	+61 8 8303 9645
Fax	National	(08) 8303 9555
	International	+61 8 8303 9555
Website	www.dwlbc.sa.gov.au	

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FOREWORD

South Australia's unique and precious natural resources are fundamental to the economic and social wellbeing of the State. It is critical that these resources are managed in a sustainable manner to safeguard them both for current users and for future generations.

The Department of Water, Land and Biodiversity Conservation (DWLBC) strives to ensure that our natural resources are managed so that they are available for all users, including the environment.

In order for us to best manage these natural resources it is imperative that we have a sound knowledge of their condition and how they are likely to respond to management changes. DWLBC scientific and technical staff continues to improve this knowledge through undertaking investigations, technical reviews and resource modelling.

Scott Ashby
CHIEF EXECUTIVE
DEPARTMENT OF WATER, LAND AND BIODIVERSITY CONSERVATION

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Paul Foster – undertook statistical analysis, prepared the original document and assisted in preparing this document

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SUMMARY

Degraded agricultural landscapes in South Australia have often been revegetated with a view to restoring habitat and enhancing biodiversity. Evaluation of the effectiveness of this strategy remains limited and unclear. This study examined the use, by bird species, of a number of revegetation sites in mallee areas of South Australia with the goal of investigating the usefulness of revegetation as bird habitat. The study aimed to determine:

- the species richness and abundance of birds present within the revegetated sites;
- whether any species of conservation significance are using the revegetated sites; and
- the complexity of the bird assemblages present.

Bird surveys were undertaken at a total of 12 sites at four localities, Port Wakefield, Murray Bridge, Rockleigh and Morella, all of which contain landscape revegetated within the past five to 15 years. Surveying followed the Birds Australia Atlas methodology which involves an approximate 70m radius meandering walk around a central point during a 20 minute period. Species and numbers of birds observed were recorded. The data for the multiple sites were pooled for each of the four localities.

Three key findings emerged from the study:

1. **A significant number of species (richness) and numbers of individual birds (abundance) were recorded at revegetated localities.**
2. **Birds representing a number of feeding guilds were recorded at vegetated localities indicating that they offer a diverse range of food sources.**
3. **Revegetated localities have the capacity to support species of conservation significance.**

Although points one and two are true for all localities, significant differences among localities were observed, particularly between Morella and Rockleigh. Morella had the highest species diversity (48 species), supported the greatest abundance (approximately 14 birds per 2ha) of birds and supported greatest guild complexity with birds represented in 12 feeding categories being recorded. Conversely Rockleigh had the lowest species diversity (22 species) and abundance (approximately 6 birds per 2ha) and displayed the lowest feeding guild complexity, with only seven guilds represented.

Site variations (both within and between localities), such as climate and revegetation method, make it difficult to relate these observed differences between Morella and Rockleigh to the 'type' of revegetation present. There are a myriad of possible reasons as to why these differences may exist. However parameters (such as plant growth and food available) were not measured as part of this project. Nevertheless, some general suggestions (based on observation only) can be made:

- The revegetation area as a whole is much larger at Morella (greater than 500 ha) than at Rockleigh (approximately 20 ha).
- Although younger than Rockleigh, the revegetation at Morella has exhibited larger growth and height while the revegetation at Rockleigh is not as pronounced either in height or width probably reflecting reduced cover;

- Morella is more species rich (combination of remnant, revegetation and regenerating plants) than Rockleigh; and
- Morella is adjacent to a water course, and hence there is most likely a great number and diversity of invertebrates available.

Therefore, Morella potentially offers a greater area of habitat and a more diverse and complex habitat for birds than Rockleigh in such things as structure, shelter types and food sources.

All of the revegetation localities occur directly adjacent to, or within close proximity to remnant vegetation. This also may be an important factor in promoting these revegetated areas as habitat.

Munro et al. (2007) reviewed the literature on fauna in revegetation in Australian agricultural areas and found that species richness of birds was greatest in revegetated areas that were large, structurally complex, containing old growth and near remnant vegetation. The recommendation was that revegetation should be in patches of large area with good width (ie not narrow strips) and structurally complex to maximise benefits to fauna.

The observation of a resident Malleefowl (*Leipoa ocellata*), listed as **Vulnerable** under the *Environment Protection and Biodiversity Conservation Act 1999,* at Murray Bridge, confirms the notion that the revegetation has capacity to support fauna of conservation significance.

Furthermore, the state **Rare** or **Vulnerable** (dependent on subspecies; under the *National Parks and Wildlife Act, 1974*) Southern Emu-wren (*Stipiturus malachurus*) was observed at Morella and a Brown Treecreeper (*Climacteris picumnus*), listed as **vulnerable** for the Adelaide and Mount Lofty Ranges (Willson and Bignall 2008) and South East (Croft et al. 1999) regions of South Australia, was observed at Rockleigh. These sightings indicate that these revegetation areas provide resources for species of conservation significance.

In conclusion, the findings indicate that revegetation of degraded landscapes provides opportunity for a potential biodiversity enhancement strategy in relation to Australian native bird species.

As such the key recommendation is:

That the provision of bird habitat (and fauna habitat in general) should be incorporated into revegetation design and technique / practices at the planning stage.

To build on the findings of this study, recommendations on possible further research are included in this report.

1. AIMS AND OBJECTIVES

The project was developed by the DWLBC Habitat Restoration group.

The main goal of the project was to determine if revegetated areas are providing habitat for bird species, in particular native birds.

To meet this goal a bird survey was undertaken at four localities within South Australia comprising degraded agricultural landscapes that had undergone a revegetation program. The objectives of the survey were to determine:

- the species richness and abundance of birds present within the revegetated sites;
- whether any species of conservation significance are using the revegetated sites; and
- the complexity of the bird assemblages present.

2. METHODOLOGY

2.1 SURVEY LOCALITIES AND SITES

Four localities, Rockleigh, Port Wakefield, Murray Bridge and Morella (see Figure 1 for locations), were chosen in which to set up survey sites. The localities all contain degraded agricultural landscape revegetated with predominantly mallee species within the past four to 15 years.

Figure 1: Locations of the four revegetation localities (Port Wakefield, Rockleigh, Murray Bridge and Morella) in South Australia.

Each locality was further divided into a number of survey sites, with a total of 12 survey sites being established. Survey sites were located in an area of revegetation representative of the type of vegetation in the immediate vicinity. Differences exist between sites both within a locality and between localities, in terms of the age of the revegetation and the type of revegetation implemented (species of plants and method of planting). Descriptions of the revegetation within each site and locality are shown in Table 1.

Table 1. Broad descriptions of revegetation localities and their sites.

*not measured as part of this study and therefore only based on what was planted in the revegetation. May not be a true indication of food sources available (e.g. invertebrates would be present).

Locality – Rockleigh

Privately owned – revegetated land previously degraded by grazing and cropping. SA Murray-Darling Basin Natural Resource Management Region.

Site Descriptions	*Possible food sources available
Site 1 **Approximate Age:** 5-10 years **Revegetation Method:** Tube stock **Dominant Revegetation Type:** Mix of indigenous spp. (local and non-local) **Description:** On a hill slope with rocky outcrops, some remnants including *Lomandra* spp. and numerous grasses. Heavily grazed prior to planting. Natural regeneration of *Senna artemisioides* and *Allocasuarina verticillata* on eastern hill face.	Variety of seeds from soft or fine to hard coated, from very small to medium sized. Large berries.
Site 2 **Approximate Age:** 5 years **Revegetation Method:** Direct seeded **Dominant Revegetation Type:** *Acacia* spp., *Eucalyptus* spp. **Description:** Rows relatively dense, with some large open areas left amongst lines. Abundant regenerating native grasses.	

Locality - Port Wakefield

Pt Wakefield Proof and Experimental Establishment (Australian Department of Defence) - portions have undergone various revegetation activities over the past decade and more. Northern and Yorke Natural Resource Management Region.

Site Descriptions	*Possible food sources available
Site 1 **Approximate Age:** 12 years **Revegetation Method:** Direct seeded **Dominant Revegetation Type:** *Eucalyptus* spp., *Callitris gracilis, Acacia* spp. **Remnant Vegetation:** Remnant adjoins western edge **Description:** Rows run N-S. Revegetation is all canopy species. Ground flora and several shrub layers have regenerated, predominantly *Enchylaena tomentosa*, *Nitraria billardierei* and *Maireana* spp., but sparse. Tall mallee *Eucalyptus* spp. on southern edge of site, smaller mallee *Eucalyptus* spp. on eastern fringe, Chenopod shrubs scattered throughout middle section.	Variety of seeds from soft or fine to hard coated, from small to medium sized. Small and large berries. A variety of fruit sources from papery, fleshy, small and woody, and soft and persistent.
Site 2 **Approximate Age:** 12 years **Revegetation Method:** Tube stock **Dominant Revegetation Type:** *Eucalyptus* spp., *Melaleuca lanceolata, Maireana brevifolia (Regeneration)* **Remnant Vegetation:** Remnant adjoins western edge **Description:** Revegetation is all canopy species. Open site. Ground flora and several shrub layers have regenerated, predominantly *Enchylaena tomentosa*, *Nitraria billardierei* and *Maireana* spp., but sparse.	
Site 3 **Approximate Age:** 10 years **Revegetation Method:** Direct seeded **Dominant Revegetation Type:** *Eucalyptus* spp., *Melaleuca lanceolata , Acacia* spp. **Description:** Revegetation is all canopy species. Ground flora and several shrub layers have regenerated, predominantly *Enchylaena tomentosa*, *Nitraria billardierei* and *Maireana* spp., but sparse.	

Locality – Murray Bridge

Murray Bridge Training Area (Australian Department of Defence) - portions have undergone various revegetation activities over the past decade and more. SA Murray-Darling Basin Natural Resource Management Region.

Site Descriptions	*Possible food sources available
Site 1 **Approximate Age:** 15 years **Revegetation Method:** Direct seeded **Dominant Revegetation Type:** *Eucalyptus* spp., *Melaleuca lanceolata, Acacia* spp. **Remnant Vegetation:** Large remnant block adjacent **Description:** Revegetation is all canopy species. Ground flora and mid-storey species have regenerated or colonised.	Variety of seeds from soft or fine to hard coated, from small to medium sized. Variety of fruit from papery, hard, or fleshy, small to medium in size (provided by regenerating and colonising species).
Site 2 **Approximate Age:** 14 years **Revegetation Method:** Direct seeded **Dominant Revegetation Type:** *Eucalyptus* spp., *Acacia* spp. **Description:** Revegetation is all canopy species. Vegetation quite dense.	
Site 3 **Approximate Age:** 12 years **Revegetation Method:** Direct seeded **Dominant Revegetation Type:** *Eucalyptus* spp., *Melaleuca lanceolata, Acacia* spp. **Description:** Revegetation is all canopy species. Narrow linear strip of revegetation with road on one side and open grazed paddock on the other.	

Locality - Morella

Owned by Department for Environment and Heritage, SA - previously a privately owned agricultural property.

South East Natural Resource Management Region.

Site Descriptions	*Possible food sources available
Site 1 **Approximate Age:** 6 years **Revegetation Method:** Direct seeded **Dominant Revegetation Type:** *Melaleuca* spp. in swampy depression, surrounded by *Eucalyptus* spp. and *Acacia* spp. on sandy rises. **Remnant Vegetation:** *Melaleuca* sp. fringing wetland basin 100 m south. **Description:** Dense low understorey on clay flat of a few remnant *Melaleuca halmaturorum*, revegetated and regenerated *Melaleuca* shrubs and weedy Tall Wheat Grass. Dense revegetation on surrounding sandy rises consisting mainly of *Eucalyptus fasciculosa* over *Acacia* spp. and other revegetated and regenerated shrub species. Few scattered remnant eucalypts (mainly *E. fasciculosa*). Groundcover dominated by weedy grasses and herbs. Little bare ground.	Variety of seeds from soft or fine to hard coated, from small to medium sized. Small and large berries. Variety of fruit from fleshy, small and woody, or soft and persistent.
Site 2 **Approximate Age:** 5 years **Revegetation Method:** Direct seeded **Dominant Revegetation Type:** *Acacia* spp., *Dodonaea* spp. and some *Eucalyptus* spp. on sandy east-facing slope. **Remnant Vegetation:** *Eucalyptus camaldulensis* fringing wetland 150 m east. **Description:** Patchy revegetation consisting of mainly *Eucalyptus fasciculosa, E. diversifolia, E. leucoxylon* and *Allocasuarina verticillata* over *Acacia* spp., *Dodonaea viscosa* and other revegetated and regenerated shrub species. Groundcover dominated by weedy grasses and herbs. Little bare ground.	
Site 3 **Approximate Age:** 4 years **Revegetation Method:** Direct seeded **Dominant Revegetation Type:** *Acacia* spp., *Dodonaea* spp. and *Eucalyptus* spp. on sandy east-facing slope. **Remnant Vegetation:** *Eucalyptus camaldulensis* and *Melaleuca* spp. fringing wetland 150 m east. Scattered *Eucalyptus fasciculosa* and *E. diversifolia* nearby. **Description:** Patchy revegetation consisting of mainly *E. fasciculosa, E. diversifolia, E. leucoxylon* and *Allocasuarina verticillata* over *Acacia* spp., *Dodonaea viscosa* and other revegetated and regenerated shrub species. Groundcover dominated by weedy grasses and herbs. Little bare ground.	
Site 4 **Approximate Age:** 4 years **Revegetation Method:** Direct seeded **Dominant Vegetation Type:** *Eucalyptus* spp., *Acacia* spp., *Dodonaea* spp. and some *Callistemon* spp. on gently sloping loamy clay. **Remnant Vegetation:** Remnant *Eucalyptus camaldulensis* fringing wetland 100 m north. Martin Washpool Conservation Park 1 km east. **Description:** Patchy revegetation consisting of mainly *Eucalyptus diversifolia, E. leucoxylon* and *Allocasuarina verticillata,* over *Acacia* spp, *Dodonaea viscosa, Callistemon rugulosus* and other revegetated and regenerated shrub species. Groundcover dominated by weedy grasses and herbs. Little bare ground.	

2.2 SURVEY METHODOLOGY

The bird survey methodology followed the standard Birds Australia ATLAS methodology (Barrett et al. 2003) and was based on a two hectare area (circular quadrat) search. Surveys were conducted approximately 70m out from a central marker in a circular direction for a period of 20 minutes. The central marker was marked by a dropper and a GPS location reading. A photo-point marker was set up at the central marker to collect photo-records.

In order to attempt to record bird species active at different times of the day and at different times of the year, surveys were undertaken both in the morning and late afternoon, repeated on consecutive days and repeated each season for one year. Surveys commenced in winter 2006 through to autumn 2007. During the survey the bird species and number of each species observed, were noted. Opportunistic sightings of bird species within the revegetation but outside of the survey plots or outside of the survey time allocation were also recorded.

2.3 DATA ANALYSIS

Each bird species recorded was assigned to a feeding guild based on combined diet and substrate guilds as defined by Slater (1995) (Table 2).

Table 2. Bird feeding guilds based on diet and substrate guilds, Slater (1995)

Guild	Description
n	Mainly nectar/pollen and invertebrates
f	Mainly fruit (frugivores)
sg	Mainly seeds at or near ground level
st	Seeds
v	Mainly vertebrates or large invertebrates
i	Invertebrates at all levels
ic	Invertebrates in the canopy
*lb	Invertebrates on trunks and branches
id	Invertebrates in dense understorey and ground
lg	Invertebrates from bare ground
ia	Invertebrates from air
is	Invertebrates from shrubs
pd	Mainly plant material from shrub layer but also sometimes from ground

*No representatives recorded during this survey

A basic statistical analysis was undertaken of bird abundance, bird species diversity and bird feeding guilds, both within and between localities. For the analysis; since the purpose of surveying at different times of the day and different times of the year was purely to maximise the number of species recorded, within each survey site, the data from the morning and evening surveys and the seasonal surveys were combined to provide a total number of bird species observed and total abundance of each species for that site. Then within each locality, the data for the multiple survey sites (within that locality) were combined. This provided a single total for number of species and abundance of each species for that locality. A mean estimate of species abundance for each of the four localities was then calculated.

3. RESULTS

3.1 BIRD DIVERSITY AND ABUNDANCE

3.1.1 SUMMARY FOR EACH LOCALITY

A total of 48 bird species were recorded at Morella with a mean abundance of approximately 14 birds per two hectares, 45 species (mean abundance of approximately 11 birds) were observed at Murray Bridge, 32 species (mean abundance of approximately 12 birds) were recorded at Port Wakefield and 19 bird species (mean abundance of approximately six birds) were recorded at Rockleigh (Table 3). The majority of birds recorded at each location were native, although introduced species were observed at all localities (see Appendix 1 for a full species list for each locality).

Table 3. Number of species and mean abundance (per 2 hectares) of birds recorded during the survey at each locality.

		Morella	Rockleigh	Murray Bridge	Port Wakefield
Number of species	Native	45	18	43	30
	Introduced	3	1	2	2
	Total	**48**	**19**	**45**	**32**
Mean abundance of species		**14.2**	**5.6**	**10.6**	**11.6**

3.1.2 COMPARISON BETWEEN LOCALITIES

Variations in mean species diversity and mean abundance were observed between localities. Morella was the most species rich, supporting significantly more species than each of the other localities (Figure 2). Port Wakefield and Murray Bridge were relatively rich in species but did not differ markedly from each other. Rockleigh recorded least species richness and differed significantly from all other localities.

Rockleigh contained significantly less birds than both Port Wakefield and Morella (Figure 3). There was little difference between the localities of Port Wakefield, Murray Bridge and Morella in mean numbers of birds found.

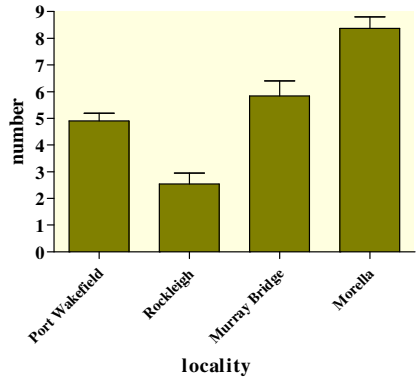

Figure 2: Mean species richness (± sem) by locality

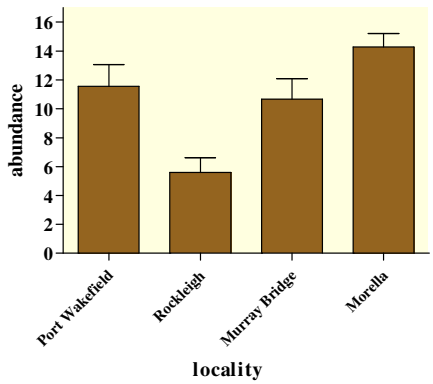

Figure 3:Mean total abundance (± sem) by locality

3.1.3 SUMMARY

Each locality supported populations of varying numbers of birds from a variety of species. Rockleigh supported the least diversity and the least abundance, whereas all other localities supported considerable numbers and diversity of birds.

3.2 COMPOSITION OF BIRD FEEDING ASSEMBLAGES

The assemblage of birds at each locality can be assessed by grouping species into feeding guilds, which provides an assessment of bird species in association with food availability and food diversity. The presence or absence of a food related grouping suggests whether or not a site is providing a diverse or narrow range of food to bird species.

3.2.1 SUMMARY FOR EACH LOCALITY

Table 3 shows the number of feeding guilds represented at each locality and the dominant guild present.

Table 4. Feeding guilds (number and dominant) represented at each locality.

	Morella	Rockleigh	Murray Bridge	Port Wakefield
Number of guilds represented**	12	7	10	9
Dominant guild(s)	Insectivores	Nectivores & Insectivores	Insectivores	Frugivores

** Based on guild classification of Slater (1995)

Birds belonging to all of the 12 represented feeding guilds were observed at Morella with the dominant guild being insectivores. Port Wakefield featured nine guilds, dominated by frugivores, and Murray Bridge featured 10 guilds, dominated by insectivores. Seven guilds were represented at Rockleigh with nectarivores and insectivores being dominant.

3.2.2 COMPARISON BETWEEN LOCALITIES

Comparison of the feeding guilds present at the four localities indicates that food resources varied between some localities. Morella (Figure 7) recorded the greatest guild complexity with guilds being mostly represented in similar proportions but a dominance of insectivores. Conversely, Rockleigh (Figure 5) displayed less feeding guild complexity with nectarivores and insectivores being the most prominent. Murray Bridge (Figure 6) and Port Wakefield (Figure 4) represented similar number of guilds but differed in that Port Wakefield was dominated by frugivores and Murray Bridge was dominated by insectivores.

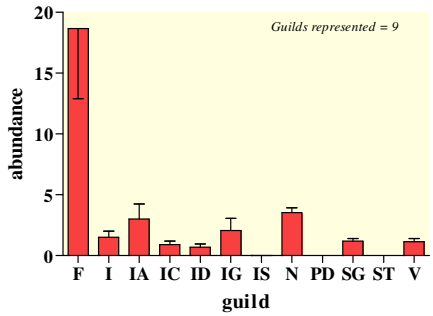

Figure 4: Bird abundance within each feeding guild * Port Wakefield (n=42)

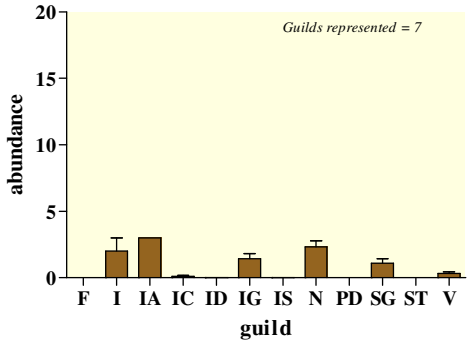

Figure 5: Bird abundance within each feeding guild * Rockleigh (n=28)

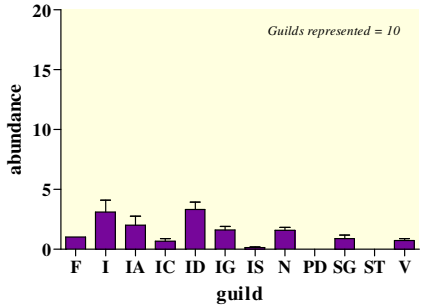

Figure 6: Bird abundance within each feeding guild * Murray Bridge (n=42)

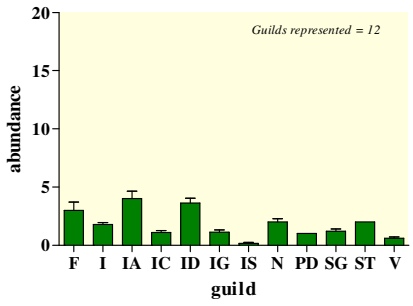

Figure 7: Bird abundance within each feeding guild * Morella (n=60)

***** Guilds based on combined diet + substrate guilds, by Slater (1995) (shown in Table 2): pd = additional by Stokes. NB guild ib was not represented at any of the localities and therefore not included in analysis.

3.2.3 SUMMARY

Morella provided the greatest range of food resources for birds, while Rockleigh provided the least complexity.

3.3 SPECIES OF CONSERVATION SIGNIFICANCE

Malleefowl (*Leipoa ocellata*) which is listed as **Vulnerable** both nationally under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and at the state level under the *National Parks and Wildlife Act* 1972 (NPW Act), Schedule 8, was observed at Murray Bridge during the survey. During a follow-up survey in spring 2007 an active nest mound was found between sites 1 and 2, and a tending adult (presumably the male) observed within 50 metres of the nest. Malleefowl have been regularly recorded in old growth mallee and in previously burnt regrowth mallee to the east of the revegetated areas at this locality in recent times (ADF 2007). The nearest recorded active mound, the nearest cluster of active and inactive mounds and the location where the greatest number of Malleefowl recordings have previously been made are less than 2km, 3.5km and 8km (respectively) from the active mound found in the revegetation. The finding of the nest within the revegetation presumably represents dispersal and colonisation of the species to suitable habitat as the revegetation ages and develops.

A single sighting of the Southern Emu-wren, (*Stipiturus malachurus*) was recorded at Morella in revegetation site 1. This species had a state rating of **Rare** or **Vulnerable** (under the *National Parks and Wildlife Act, 1974* (the NPW Act)) depending on the subspecies. As the record was by passive observation and not by active trapping or photography the subspecies was not identified. This species was recorded as an opportunistic sighting and not verified as either resident or transient (passing through en route to a more permanent site).

A further species worth noting was not recorded during the survey under discussion, but was observed during a follow-up survey in revegetation site 2 at Rockleigh in 2007. The Brown Treecreeper (*Climacteris picumnus*), not currently listed under the EPBC Act or the NPW Act but listed as **vulnerable** for the Adelaide and Mount Lofty Ranges (Willson and Bignall 2008) and South East (Croft et al. 1999) regions of South Australia, was observed feeding in revegetation site 2, but considered to have the majority of its territory within nearby degraded remnant vegetation on an adjacent property.

4. DISCUSSION

Due to site variations (both within and between localities), such as climate and revegetation method and landscape context, it is difficult to relate observed differences between localities to the 'type' of revegetation present, as these site differences influence the presence and abundance of bird species and hence interpretation of findings. There are a myriad of possible reasons as to why these differences may exist. However parameters (such as plant growth and food available) were not measured as part of this project. Nevertheless, if we examine Morella (which recorded the highest number of bird species and the greatest number of feeding guilds of the four localities) and Rockleigh (which recorded the lowest number of bird species and the lowest number of feeding guilds of the four localities) some general suggestions (based on observation only) can be made:

- The revegetation area as a whole is much larger at Morella (greater than 500 ha) than at Rockleigh (approximately 20 ha);
- Although younger than Rockleigh, the revegetation at Morella has exhibited greater growth and height while the revegetation at Rockleigh is not as pronounced either in height or width, probably reflecting reduced cover;
- Morella has greater plant species richness (combination of remnant, revegetation and regenerating plants) than Rockleigh; and
- Morella is adjacent to a watercourse, and hence there is most likely a great number and diversity of invertebrates available.

Therefore, Morella potentially offers birds a greater area of habitat of greater diversity and complexity in such things as structure, shelter types and food sources than Rockleigh.

All of the revegetation localities occur directly adjacent to, or within close proximity to remnant vegetation. This also may be an important factor in revegetated areas providing habitat.

Munro et al. (2007) reviewed the literature on fauna in revegetation in Australian agricultural areas and found that species richness of birds was greatest in revegetated areas that were large, structurally complex, containing old growth and near remnant vegetation. The recommendation was that revegetation should be in patches of large area with good width (ie not narrow strips) and structurally complex to maximise benefits to fauna.

To build on the value of this study and to be able to make more concise interpretations of the differences among localities (to work towards designing revegetation that maximises its value as bird / fauna habitat) more research is required including:

- Replicating the survey in a remaining bare paddock site and at an adjacent remnant vegetation site, as well as investigating how bird species are moving both within revegetated areas and between revegetated areas and other habitats (i.e. movement within a landscape).

  A comparison in bird use can then be made to determine whether or not the bird diversity observed in the revegetated sites is consistent with remnant vegetation sites in the same locality, and also whether bird diversity is enhanced in the revegetation compared to the degraded pastureland.

- The collection of quantitative data (for each of the surveyed sites) on attributes such as vegetation growth since planting, vegetation diversity, food source diversity and vegetation structure, as well as observations of how birds are using the sites. This could include; what birds are feeding on (e.g. nectar or fruit) and how they use the area (e.g. just flying through or nesting). This will provide an indication of how available resources within the revegetated areas are being utilised by birds.

5. CONCLUSIONS AND RECOMMENDATIONS

This study contributes meaningfully to our understanding of biodiversity in relation to revegetation as a landscape and ecosystem rehabilitation strategy. A significant number of bird species (richness), significant numbers of individual birds (abundance) and birds across a number of feeding guilds were recorded at the revegetated localities.

The finding of the active Malleefowl nest suggests that revegetated areas have the capacity to support species of conservation significance and highlights the biodiversity value of the revegetation sites at Murray Bridge, and more generally to revegetation as a biodiversity enhancement strategy. The sightings of the Southern Emu-wren and the Brown Treecreeper also suggest that revegetated areas may provide valuable resources for species of conservation significance.

This study demonstrates that even small scale revegetation can provide habitat for a range of bird species, including species of conservation significance, highlighting the importance of such restoration projects for enhancing biodiversity in agricultural landscapes.

As such, the following recommendations are made:

- That the **provision of bird habitat** (and fauna habitat in general) **should be incorporated into biodiversity focused revegetation design** and technique at the planning stage. For example, it's important to determine what birds occur (or are likely to occur) in the surrounding area (either as transients or residents) where the revegetation is to be undertaken and factor their resource requirements into the revegetation design.
- Further **research** needs to be undertaken into **what factors** (e.g. implementation method, vegetation age, growth and development, proximity to remnant vegetation) or combination of factors may **make revegetation more successful in providing habitat for birds**.
- There is a need for continuing **research on habitat, foraging and reproductive requirements in addition to dispersal and movement patterns of all native fauna** to inform biodiversity focussed revegetation work.

APPENDICES

1. OBSERVED BIRD SPECIES LIST

Common name	*Scientific name*	Cons. Significance AUS	Cons. Significance SA	Port Wakefield	Rockleigh	Murray Bridge	Morella
Australian Magpie	*Cracticus tibicen*			y	y	y	y
Australian Raven	*Corvus coronoides*			y	y	y	y
Australian Ringneck	*Barnardius zonarius*					y	y
Beautiful Firetail	*Stagonopleura bella*						y
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*			y	y		y
Black-shouldered Kite	*Elanus axillarus*			y	y	y	y
Brown Goshawk	*Accipiter fasciatus*						y
Brown Songlark	*Cincloramphus cruralis*			y	y		
Brown Thornbill	*Acanthiza pusilla*					y	y
Brown Treecreeper	*Climacteris picumnus*		V		***		
Brown-headed Honeyeater	*Melithreptus brevirostris*					y	
Common Bronzewing	*Phaps chalcoptera*				y	y	y
Crested Pigeon	*Ocyphaps lophotes*			y	y	y	y
Crimson Rosella	*Platycercus elegans*				y		
Emu	*Dromaius novaehollandiae*						y
Galah	*Eolophus roseicapillus*			y	y	y	y
Gilbert's Whistler	*Pachycephala inornata*		R			y	
Golden Whistler	*Pachycephala pectoralis*					y	y
Grey Butcherbird	*Cracticus torquatus*			y		y	y
Grey Currawong	*Strepera versicolor*				y	y	y
Grey Fantail	*Rhipidura albiscapa*					y	y
Grey Shrike-thrush	*Colluricincla harmonica*			y	y	y	y
Jacky Winter	*Microeca fascinans*					y	
Little Button-quail	*Turnix velox*			y			
Little Wattlebird	*Anthochaera chrysoptera*						y
Magpie Lark	*Grallina cyanoleuca*			y	y	y	y
Malleefowl	*Leipoa ocellata*	V	V			y	
Masked Woodswallow	*Artamus personatus*			y			
Musk Lorikeet	*Glossopsitta concinna*						y
Nankeen Kestrel	*Falco cenchroides*			y			
New Holland Honeyeater	*Phylidonyris novaehollandiae*					y	y
Noisy Miner	*Manorina Melanocephala*			y			y
Peaceful Dove	*Geopelia striata*					y	y
Peregrine Falcon	*Falco peregrinus*				y		
Purple-gaped Honeyeater	*Lichenostomus cratitius*			y	y	y	y
Red Wattlebird	*Anthochaera carunculata*			y	y	y	y
Red-rumped Parrot	*Psephotus haematonotus*						y
Shy Heathwren	*Calamanthus cautus*					y	
Silvereye	*Zosterops lateralis*			y		y	y
Singing Honeyeater	*Lichenostomus virescens*			y	y	y	y
Southern Emu-wren	*Stipiturus malachurus*		R/E				**

Southern Scrub-robin	*Drymodes brunneopygia*					y	

Common name	*Scientific name*	Cons. Significance AUS	Cons. Significance SA	Port Wakefield	Rockleigh	Murray Bridge	Morella
Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*			y		y	y
Spotted Pardalote	*Pardalotus punctatus*			y		y	
Striated Pardalote	*Pardalotus striatus*			y	y	y	y
Striated Thornbill	*Acanthiza lineata*			y		y	y
Stubble Quail	*Coturnix pectoralis*					y	y
Superb Fairy-wren	*Malurus cyaneus*					y	y
Tawny-crowned Honeyeater	*Phylidonyris melanops*						y
Tree Martin	*Petrochelidon nigricans*			y		y	y
Variegated Fairy-wren	*Malurus lamberti*					y	
Wedge-tailed Eagle	*Aquila audax*						y
Weebill	*Smicrornis brevirostris*			y		y	y
Welcome Swallow	*Hirundo neoxena*			y		y	y
Whistling Kite	*Haliastur sphenurus*			y			
White-browed Babbler	*Pomatostomus superciliosus*			y		y	y
White-browed Scrubwren	*Sericornis frontalis*						y
White-fronted Chat	*Epthianura albifrons*						y
White-plumed Honeyeater	*Lichenostomus penicillatus*				y		
White-winged Chough	*Corcorax melanorhamphos*		R			y	
Willie Wagtail	*Rhipidura leucophrys*			y		y	y
Yellow Thornbill	*Acanthiza nana*			y		y	y
Yellow-faced Honeyeater	*Lichenostomus chrysops*					y	y
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*			y		y	y
Zebra Finch	*Taeniopygia guttata*					y	
*Common Blackbird	*Turdus merula*					y	y
*Common Starling	*Sturnus vulgaris*			y	y	y	y
*European Goldfinch	*Carduelis carduelis*						y
*House Sparrow	*Passer domesticus*			y			
Total number species	Native			30	19	43	46
	Introduced			2	1	2	3
	Overall			32	20	45	49

* Introduced species, ** opportunistic sighting (current survey), *** 2007 sighting (at same survey site but during alternate survey)

V = Vulnerable; R = Rare

Nomenclature is consistent with Christidis and Boles (2008).

2. REVEGETATION SPECIES LIST – MURRAY BRIDGE

Botanical name	**Common Name**	**Fruit type**
Acacia argyrophylla	Silver Mulga-bush	Hard Coated Seed
Acacia brachybotrya	Grey Mulga-bush	Hard Coated Seed
Acacia calamifolia	Wallowa	Hard Coated Seed
Acacia pycnantha	Golden Wattle	Hard Coated Seed
Acacia rigens	Nealie	Hard Coated Seed
Allocasuarina verticillata	Drooping Sheoak	Soft seed disappears quickly after release
Callitris gracilis	Southern Cypress Pine	Medium Seed, remains in litter for some time
Callitris verrucosa	Scrub Cypress Pine	Medium Seed, remains in litter for some time
Dodonaea viscosa var. angustissima	Hop Bush	Hard Coated Seed
Eucalyptus gracilis	Yorrell	Fine seed, very small
Eucalyptus incrassata	Ridge-fruited Mallee	Fine seed, medium size
Eucalyptus leptophylla	Narrow-leaf Red Mallee	Fine seed, very small
Eucalyptus porosa	Mallee Box	Fine seed, medium size
Eucalyptus socialis	Beaked Red Mallee	Fine seed, medium size
Melaleuca acuminata	Mallee Honey-myrtle	Fine seed, very small
Melaleuca lanceolata	Dryland Teatree	Fine seed, very small

3. REVEGETATION SPECIES LIST – PORT WAKEFIELD

Botanical name	**Common Name**	**Fruit type**
Acacia hakeoides	Hakea Wattle	Hard Coated Seed
Acacia oswaldii	Umbrella Wattle	Hard Coated Seed
Acacia pycnantha	Golden Wattle	Hard Coated Seed
Acacia notabilis	Notable Wattle	Hard Coated Seed
Acacia nyssophylla		Hard Coated Seed
Acacia rigens	Nealie Wattle	Hard Coated Seed
Acacia sclerophylla	Hard-leaf Wattle	Hard Coated Seed
Allocasuarina verticillata	Drooping Sheoak	Soft seed disappears quickly after release
Callitris gracilis	Southern Cypress Pine	Medium Seed, remains in litter for some time
Dodonaea viscosa var. angustissima	Hop Bush	Hard Coated Seed
Eucalyptus gracilis	Yorrell	Fine seed, very small
Eucalyptus incrassata	Ridge-fruited Mallee	Fine seed, medium size
Eucalyptus lansdowneana	Pt Lincoln Gum	Fine seed, very small
Eucalyptus leptophylla	Narrow-leaf Red Mallee	Fine seed, very small
Eucalyptus porosa	Mallee Box	Fine seed, medium size
Eucalyptus socialis	Beaked Red Mallee	Fine seed, medium size
Melaleuca lanceolata	Dryland Teatree	Fine seed, very small
Pittosporum angustifolium	Native Apricot	Large berry
Senna artemisioides ssp	Senna	Hard Coated Seed

4. REVEGETATION SPECIES LIST – ROCKLEIGH

Botanical name	**Common Name**
Acacia argyrophylla	Silver Mulga-bush
Acacia brachybotrya	Grey Mulga-bush
Acacia calamifolia	Wallowa
Acacia hakeoides	Hakea Wattle
Acacia ligulata	Umbrella Bush
Acacia microcarpa	Manna Wattle
Acacia oswaldii	Umbrella Wattle
Acacia pycnantha	Golden Wattle
Acacia rigens	Nealie
Acacia sclerophylla	Hard-leaf Wattle
Allocasuarina muelleriana ssp.	Common Oak-bush
Allocasuarina verticillata	Drooping Sheoak
Atriplex semibaccata	Berry Saltbush
Atriplex vesicaria ssp.	Bladder Saltbush
Callitris canescens	Scrubby Cypress Pine
Callitris preissii	Southern Cypress Pine
Dodonaea viscosa ssp. angustissima	Narrow-leaf Hop-bush
Dodonaea viscosa ssp. cuneata	Wedge-leaf Hop-bush
Eucalyptus 'anceps'	Sessile-fruit White Mallee
Eucalyptus brachycalyx	Gilja
Eucalyptus calycogona var.	Square-fruit Mallee
Eucalyptus camaldulensis var. camaldulensis	River Red Gum
Eucalyptus dumosa	White Mallee
Eucalyptus gracilis	Yorrell
Eucalyptus incrassata	Ridge-fruited Mallee
Eucalyptus largiflorens	River Box
Eucalyptus oleosa	Red Mallee
Eucalyptus porosa	Mallee Box
Eucalyptus socialis	Beaked Red Mallee
Melaleuca acuminata	Mallee Honey-myrtle
Melaleuca brevifolia	Short-leaf Honey-myrtle
Melaleuca lanceolata ssp. lanceolata	Dryland Tea-tree
Melaleuca uncinata	Broombush
Pittosporum phylliraeoides var. microcarpa	Native Apricot
Rhagodia parabolica	Mealy Saltbush
Senna artemisioides	

5. REVEGETATION SPECIES LIST – MORELLA

Native Species Present at Morella	Common Name	Present as Remnant (within overall site)	Present as Revegetated Plant(s) (within overall site)	Naturally Regenerated (year first observed)	General Overall Abundance at Morella, in 2007	Site 1 (2 ha)	Site 2 (2 ha)	Site 3 (2 ha)	Site 4 (2 ha)
Acacia cupularis	Coastal Umbrella Bush		✓		Common	✓	✓	✓	
Acacia leiophylla	Limestone Wattle		✓		Common		✓	✓	
Acacia longifolia sophorae	Coastal Wattle	**?**		✓ **(2004)**	Common	✓			✓
Acacia myrtifolia	Myrtle Wattle		✓		Isolated individuals		✓		
Acacia pycnantha	Golden Wattle		✓	✓ **(2006)**	Common	✓	✓	✓	✓
Acacia spinescens	Spiny Wattle		✓		Isolated individuals				
Acaena novae-zelandiae	Sheep's Burr	**?**		✓ **(2005)**	Isolated individuals			✓	
Adriana quadripartita	Coastal Bitter Bush	**?**	✓	✓ **(2001)**	Scattered clumps				
Allocasuarina muelleriana	Slaty Sheoak		✓		Scattered individuals		✓		
Allocasuarina verticillata	Drooping Sheoak	✓	✓		Common		✓	✓	✓
Amyema melaleucae	Mistletoe	**?**		**? (2006)**	Isolated individuals	✓			
Amyema miquellii/pendula [ID?]	Box or Drooping Mistletoe	**?**		**? (2006)**	Isolated individuals				
Arthropodium strictum	Chocolate Lily	**?**		✓ **(2006)**	Isolated individuals				
Austrodanthonia setacea[1]	Bristly Wallaby Grass	✓			Scattered individuals				
Austrodanthonia sp. [ID?]	Wallaby Grass	✓		✓ **(2005)**	Common				✓
Austrostipa mollis	Soft Spear-grass	**?**		**? (2004)**	Scattered individuals				
Austrostipa sp. 2 [ID?]	Spear-grass	**?**		**? (2004)**	Scattered individuals			✓	✓
Bursaria spinosa	Christmas Bush	✓	✓		Isolated individuals				
Callistemon rugulosus	Scarlet Bottlebrush		✓		Scattered individuals				✓
Carpobrotus rossii	Pigface			✓ **(2006)**	Isolated individuals				
Cassytha sp. [ID?]	Snottygobble			✓ **(2007)**	Isolated individuals				
Chenopodium pumilio	Clammy Goosefoot			✓ **(2007)**	Scattered clumps	✓			
Clematis microphylla[1]	Old Man's Beard	✓	**?**	✓ **(2004)**	Scattered individuals				
Crassula colligata colligata	Australian Stonecrop	**?**		✓ **(2006)**	Scattered individuals				

APPENDICES

Native Species Present at Morella	Common Name	Present as Remnant (within overall site)	Present as Revegetated Plant(s) (within overall site)	Naturally Regenerated (year first observed)	General Overall Abundance at Morella, in 2007	Site 1 (2 ha)	Site 2 (2 ha)	Site 3 (2 ha)	Site 4 (2 ha)
Cynoglossum australe	Australian Hounds-tongue	**?**		✓ **(2006)**	Common				
Dianella brevicaulis	Small-flower Flax-lily			✓ **(2006)**	Isolated individuals				
Dianella revoluta [ID?] *(white flowers)*	Black-anther Flax-lily			✓ **(2007)**	Isolated individuals				
Dichondra repens [ID?]	Kidney Weed	**?**		✓ **(2005)**	Scattered clumps				
Distichlis distichophylla	Emu Grass	✓		✓ **(2001)**	Common	✓	✓		
Dodonaea viscosa spatulata	Sticky Hop Bush		✓		Common	✓	✓		✓
Enchylaena tomentosa	Ruby Saltbush			✓ **(2004)**	Scattered individuals				
Eucalpytus incrassata subsp incrassata	Ridge-fruited Mallee		✓		Isolated individuals			✓	
Eucalyptus camaldulensis	Red Gum	✓	✓	✓ **(2001)**	Common				✓
Eucalyptus diversifolia	Coastal Mallee	✓	✓	✓ **(2006)**	Common	✓	✓	✓	✓
Eucalyptus fasciculosa	Hill (Pink) Gum	✓	✓	✓ **(2005)**	Common	✓	✓	✓	
Eucalyptus leucoxylon	SA Blue Gum	✓	✓		Common		✓	✓	✓
Exocarpos cupressiformis	Native Cherry			✓ **(2006)**	Isolated individuals				
Frankenia pauciflora gunnii	Sea Heath			✓ **(2007)**	Scattered individuals				
Gahnia deusta	Limestone Saw-sedge	✓		✓ **(2001)**	Scattered clumps				
Goodia medicaginea	Golden Tip			✓ **(2001)**	Isolated clumps				
Haloragis aspera	Rough Raspwort			✓ **(2006)**	Scattered individuals				
Halosarcia pergranulata	Samphire	✓		**?**	Scattered individuals	✓			
Hakea muelleriana [ID?]	Desert Hakea		✓		Isolated individuals				
Hydrocotyle sp.	Pennywort	✓			Isolated individuals				
Isolepis nodosa	Knobby Clubrush			✓ **(2006)**	Scattered individuals				
Kennedia prostrata	Running Postman		**(✓)**		-				
Kunzea pomifera	Muntries		✓	✓ **(2006)**	Scattered individuals	✓			
Leucopogon parviflorus	Coastal Beard Heath			✓ **(2007)**	Isolated individuals				
Malva preissiana	Australian Hollyhock			✓ **(2005)**	Isolated individuals				
Melaleuca brevifolia	Small-leaved Honey-	**?**	✓		Scattered individuals				
Melaleuca halmaturorum	Saltwater Paperbark	✓	✓	✓ **(2002)**	Common	✓			

APPENDICES

Native Species Present at Morella	Common Name	Present as Remnant (within overall site)	Present as Revegetated Plant(s) (within overall site)	Naturally Regenerated (year first observed)	General Overall Abundance at Morella, in 2007	Site 1 (2 ha)	Site 2 (2 ha)	Site 3 (2 ha)	Site 4 (2 ha)
Melaleuca lanceolata	Dryland Tea-tree	✓	✓	✓ **(2005)**	Common			✓	✓
Muehlenbeckia adpressa [ID?]	Climbing Lignum			✓ **(2006)**	Scattered individuals				
Muehlenbeckia gunnii[1]	Coastal Lignum	✓		✓ **(2003)**	Common				
Myoporum insulare	Boobialla			✓ **(2005)**	Scattered individuals	✓			
Myoporum parvifolium	Creeping Boobialla	✓		✓ **(2003)**	Common	✓			
Olearia axillaris	Coastal Daisy		✓		Scattered individuals				
Caladenia carnea	Pink Fingers	✓			Isolated individuals				
Oxalis perennans	Native Wood-sorrel	✓		✓ **(2005)**	Isolated individuals				
Pelargonium australe [ID?]	Native Storks Bill			✓ **(2005)**	Scattered individuals			✓	✓
Pimelea serpyllifolia	Desert Riceflower			✓ **(2007)**	Isolated individuals				
Poa tenera	Slender Tussock-grass			**? (2006)**	Scattered individuals				
Pteridium esculentum	Bracken Fern	✓		✓ **(2001)**	Isolated clumps				
Pultenaea tenuifolia [ID?]	Bush Pea			✓ **(2005)**	Isolated individuals				
Restionaceae sp. (Apodasmia brownii?				✓ **(2007)**	Isolated clumps				
Rhagodia candolleana ssp candolleana	Seaberry Saltbush			✓ **(2005)**	Scattered individuals				
Sarcocornia quinqueflora [ID?]	Beaded Glasswort	**?**		✓ **(2002)**	Common				
Senecio pinnatifolius	Variable Groundsel			✓ **(2006)**	Isolated individuals				
Samolus repens	Creeping Brookweed	**?**		✓ **(2006)**	Common (wet flats)				
Solanum laciniatum	Kangaroo Apple			✓ **(2002)**	Scattered individuals		✓		
Suaeda australis	Austral Seablite	**?**		✓ **(2001)**	Common				
Tetragonia implexicoma	Bower Spinach	**?**		✓ **(2005)**	Common				
Thomasia petalocalyx	Paper-flower			✓ **(2007)**	Isolated individuals				
Threlkeldia diffusa	Coast Bonefruit			✓ **(2006)**	Scattered individuals				
Vittadinia cuneata	New Holland Daisy	**?**		✓ **(2005)**	Scattered clumps				
Wahlenbergia communis	Bluebell	**?**		**? (2004)**	Isolated individuals				
Wilsonia rotundifolia	Round-leaved Wilsonia	**?**		✓ **(2005)**	Common (wet flats)				
Xanthorrhoea caespitosa	Sand-heath Yacca	✓		✓ **(2005)**	Common				

UNITS OF MEASUREMENT

Units of measurement commonly used (SI and non-SI Australian legal)

Name of unit	Symbol	Definition in terms of other metric units	Quantity
Hectare	ha	10^4 m^2	Area
Metre	m		length

GLOSSARY

Biodiversity — (1) The number and variety of organisms found within a specified geographic region. (2) The variability among living organisms on the earth, including the variability within and between species and within and between ecosystems

Biological diversity — See 'biodiversity'

Diversity — The distribution and abundance of different kinds of plant and animal species and communities in a specified area

DWLBC — Department of Water, Land and Biodiversity Conservation (Government of South Australia)

Ecosystem — Any system in which there is an interdependence upon, and interaction between, living organisms and their immediate physical, chemical and biological environment

Frugivores — Fruit-eating

Guild — A group of organisms that use the same ecological resource in a similar way

Habitat — The natural place or type of site in which an animal or plant, or communities of plants and animals, live

Native species — Any animal and plant species originally in Australia; see also 'indigenous species'

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