Bird assemblages in remnant and revegetated habitats in an extensively cleared landscape, Wagga Wagga, New South Wales

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Extensive loss and degradation of native vegetation in the agricultural landscape of inland south-eastern Australia has resulted in significant losses in bird diversity and abundance. Native vegetation continues to be lost through the attrition of paddock trees, which constitute a large component of the remaining vegetation. The planting of native trees and shrubs is being undertaken as a means of halting the loss of biodiversity. However, the effectiveness of revegetation activities is still being assessed. A study in the Wagga Wagga area of New South Wales was undertaken to examine the relative value of remnant vegetation, farm plantings, paddock trees, and pasture for bird diversity. Species richness was highest in remnant vegetation, and was similar in planted vegetation and paddock trees. Relative abundance was similar across these three vegetation types. Species composition differed among all vegetation types, with planted and paddock tree sites having predominantly different sub-sets of the bird assemblage characteristic of remnant vegetation. The protection of remnant vegetation is essential for the conservation of the region's avifauna, but plantings and paddock trees also have important values for birds. However, plantings and paddock trees support different bird assemblages and complement each other. While important in their own right, the current plantings of native vegetation should not be considered as off-setting the continued loss of paddock trees. Retention of the avifauna of the Wagga Wagga area would be assisted if remnant vegetation and paddock trees were protected and integrated with appropriately designed revegetation.

Key words: Birds, Remnant Vegetation, Revegetation, Paddock trees, Agricultural landscapes

INTRODUCTION

THE agricultural landscape of south-eastern Australia has undergone extensive clearing and thinning of native vegetation, resulting in a landscape of remnant native vegetation and scattered paddock trees within a matrix of improved pasture and cultivated paddocks. Paddock trees are a significant component of the remaining native vegetation, but continue to be lost from the landscape through death, clearing, and lack of recruitment (Gibbons and Boak 2002; Gibbons *et al.* 2008). The existing network of remnant vegetation consists of small, scattered patches that are insufficient for long-term persistence of many bird populations (Saunders and Hobbs 1995; Kavanagh *et al.* 2007).

In recent years plantings of native woody vegetation, using indigenous or non-indigenous plant species, have become widespread. Such plantings have been undertaken for a variety of reasons including stock shelter, biodiversity conservation, and soil and water management. However, such plantings are frequently small in area. For example, in the Kyeamba Creek catchment east of Wagga Wagga, about 400 patches of replanted native vegetation were identified in surveys, with the total area of these plantings amounting to 582 ha, or 0.5% of the area of the catchment (Murray 2003). Apart from patch size, the value of planted vegetation for birds may be influenced by a number of factors including patch geometry (shape, width), floristic and structural complexity, age since establishment, position in the landscape, and surrounding landscape attributes (Kavanagh *et al.* 2007; Munro *et al.* 2007; Cunningham *et al.* 2008; Lindenmayer *et al.* 2010). The success of planting native vegetation may therefore vary among localities. Plantings designed to reduce land degradation do not always provide quality habitat for birds and small plantings may be limited in habitat value (Ryan 1999). However, such plantings do have value for some species (Biddiscombe 1985; Taws *et al.* 2001; Kinross 2004; Lindenmayer *et al.* 2007; Barrett *et al.* 2008; Kinross and Nicol 2008).

The combined values of remnant vegetation, plantings, and paddock trees for birds at the landscape level are recognized, although the relative value of different vegetation components in the landscape remain poorly understood (Fischer and Lindenmayer 2002b; Kavanagh *et al.* 2007; Cunningham *et al.* 2008; Lindenmayer *et al.* 2008; Montague-Drake *et al.* 2009).

Land management funding bodies direct significant amounts of on-ground funding towards revegetation, management of remnant vegetation and other environmental rehabilitation activities. These activities often include benefits for biodiversity as part of their objectives. However, there is limited information on the effectiveness of these activities for biodiversity, including birds, once they have

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been implemented (Murray 2003; Munro *et al.* 2007). Understanding the value of different vegetation components in the landscape to biodiversity is essential if management resources are to be directed most efficiently.

Here we report on a study which aimed to provide a snapshot of the avifauna of four vegetation types (remnants, planted patches, paddock trees, and cleared pasture) in an extensively modified agricultural landscape in the south-western slopes near Wagga Wagga, New South Wales. We aimed to determine the relative value of each vegetation type to local birds, in particular those considered to be declining or threatened, at a scale at which environmental management planning and funding allocations are frequently made (for example Kyeamba LWMP 1999).

METHODS

Study area

The study area was located within the mid-Murrumbidgee River catchment, part of the South-western Slopes Bioregion of New South Wales and centred on the city of Wagga Wagga (35°08'S, 147°21'E). Two physiographic regions cover the study area: the Kyeamba Creek Valley Plains consist of eroded piedmont plains near hills, gently undulating plains, small bedrock rises, and shallow incised drainage lines; while the Malebo–Mount Burngoogee region consists of undulating land and small hills. All valley floors in the area are formed of more recent alluvial sediments (Chen and McKane 1997).

The area is part of the wheat-sheep zone and has been heavily cleared of native vegetation since the mid-1800s. The predominant land use is sheep and cattle grazing on exotic pastures, with some areas of cropping. Remaining native vegetation occurs mostly on steep ranges, along drainage lines, roadsides and small crown reserves. More than 85% of native vegetation has been cleared in the area (Chen and McKane 1997; Benson 2008), while in the Kyeamba Valley (the eastern section of the study area) only 3% tree cover remained by 1999 (Kyeamba LWMP 1999). Gibbons and Boak (2002) found that in an area slightly to the south of our study area, 54% of remaining tree cover occurred as patches of less than 1 ha and most of the remaining vegetation had been thinned and grazed. The original vegetation consisted mainly of woodlands dominated by White Box *Eucalyptus albens*, Grey Box *E. microcarpa*, Yellow Box *E. melliodora*, and Blakely's Red Gum *E. blakelyi*. Mugga Ironbark *E. sideroxylon* and Red Stringybark *E. macrorhyncha* woodlands and open forests occurred on skeletal soils of the hillier areas in the east of the study area. River Red Gums *E. camaldulensis* dominated along creek lines and along the Murrumbidgee River (Chen and McKane 1997). Planting of native vegetation has occurred in recent years on many properties using local and non-local native trees and shrubs. In the area covered by Kyeamba Valley Landcare Group, 75% of properties have undertaken some form of revegetation activity, although 60% of these are less than 1 ha in size and only 3.5% (14 patches) are greater than 5 ha (Murray 2003).

The climate is warm temperate, with hot, relatively dry summers and cold, relatively wet winters. The average annual rainfall varies from about 800 mm in the east (Kyeamba Valley) to 550 mm at Wagga Wagga (Chen and McKane 1997). During the study period, rainfall was below average with 488 mm in 2001, 376 mm in 2002, and 450 mm in 2003 (figures for Wagga Wagga; BOM 2010). Average temperatures at Wagga Wagga vary from a mean July minimum of 2.7°C to January maximum of 31.1°C (Chen and McKane 1997).

Survey sites

Twenty-one survey sites were located between Wagga Wagga and Tarcutta, 25 km to the east. Sites were allocated to one of four different vegetation types. Vegetation types in this study represent management history of the sites rather than specific floristic types, these being: (1) remnant native vegetation; (2) planted native vegetation; (3) paddock trees and (4) cleared paddocks.

Six sites were located in remnant native vegetation; four in travelling stock reserves, one in an old gravel extraction reserve (part of the reserve that had not been used for gravel extraction), and one in a crown reserve used for passive recreation. Although considered remnant vegetation, all sites have a history of human disturbance given that they occur in a relictual vegetation landscape. However sites were chosen as they had been reserved for a long period of time with no apparent extensive clearing of native vegetation having taken place. Two sites showed evidence of low levels of domestic stock grazing. The remaining four sites had been excluded from stock grazing. Vegetation in the remnant sites consisted of a mixture of mature and regrowth White Box, Yellow Box, Mugga Ironbark, and Blakely's Red Gum, with a sparse shrub layer (including Golden Wattle *Acacia pycnantha*, Native Blackthorn *Bursaria spinosa,* Bitter Pea *Daviesia daphnoides* and Bush Pea *Pultenaea foliolosa*) and a mixed ground layer of native and exotic grasses, litter, and bare soil. A few scattered logs were located in each site although much of the fallen timber had been removed.

Five sites were located in patches of planted native vegetation. Although this included a range of site sizes and shapes, in order to minimize confounding factors of planting age and landscape position, all were between 10 and 16 years of age and did not adjoin other established native vegetation. Each of the planted sites consisted of a mix of up to six endemic or non-endemic native species, including White Box, Blakely's Red Gum, Swamp Mahogany *E. botryoides*, Broadleaf Peppermint *E. dives*, Yellow Box, Ribbon Gum *E. viminalis*, River She-oak *Casuarina cunninghamiana,* and Bracelet Honey-myrtle *Melaleuca armillaris*, as well as shrub species, especially *Acacia* spp. and Native Blackthorn. Weeds such as Paterson's Curse *Echium plantagineum* and Phalaris *Phalaris* sp. were common within many planted patches, although heterogeneity of the ground cover was higher than in paddock tree or cleared sites, with increased coverage of bare ground and litter. Planted vegetation was not grazed during this study.

A further five sites were located in patches of paddock trees. Paddock trees were defined as mature trees that had established naturally, predominantly White Box, Grey Box, and Yellow Box trees. Paddock tree sites had widely spaced trees with no understorey of native shrubs and an intensively grazed ground cover of exotic pasture with little bare ground. All sites were grazed during this study. The remaining five sites consisted of open paddocks of exotic pastures and no tree or shrub cover. These sites were selected to represent the condition of planted sites prior to the planting of native trees and shrubs. All sites were grazed at the time of this study.

Sites were located in separate patches of vegetation but in similar topographical positions in the landscape (undulating valley floors or lower slopes). Survey sites were 1 ha. Where a survey site was situated within a larger patch of the same vegetation type the site dimensions were 100 m × 100 m, but where the patch was smaller and of dimensions that did not allow this (some of the planted sites were narrow strips), survey site dimensions were adjusted to suit while retaining a total area of 1 ha.

Survey method

Bird surveys were carried out between October 2001 and April 2003, with four surveys per site, one in each autumn and one in each spring. A fixed time and area search method (Loyn 1986) was used, with 20 minute counts for each 1 ha survey site. The number and species of all birds utilizing the site were recorded. Birds outside the site or flying over were recorded separately but not included in the analysis. All surveys were completed within 4 hours of sunrise or within 3 hours before sunset. To minimize bias in sampling due to varying bird activity at different times of day, the order and time of day within which surveys were undertaken was varied, with two surveys done in a morning session and two in an afternoon session for each site. Surveys were not conducted during periods of rain, moderate to strong wind (when calls could not be heard above background noise), or hot temperatures (above approximately 25°C) (Slater 1994). Calling birds were located to determine the number of individuals, so that all records were of birds seen. All surveys were conducted by the senior author. Scientific names of species are shown in Table 1. Taxonomy follows Christidis and Boles (2008).

Analysis

The number of bird species was calculated for each site from the pooled survey data as a measure of species richness, and the numbers of individual birds recorded was averaged from all surveys to provide the mean number of individuals per survey as a measure of relative abundance for each vegetation type. Differences in species richness and relative abundance (the mean number of individual birds per survey) among vegetation types were tested using one-way ANOVA following $\log_{10}$ transformation. A post-hoc test (Tukey's HSD for unequal N) was used to determine which vegetation types were significantly different. Analysis was undertaken using STATISTICA (StatSoft 2004). To examine the composition of the bird assemblages, the 21 sites were ordinated using a constrained ordination technique (Canonical Analysis of Principal Coordinates (CAP); Anderson 2004) with Bray-Curtis dissimilarities. Canonical correlation analysis seeks the best discrimination of the bird assemblages between vegetation groups selected *a-priori*. Analysis of similarity (ANOSIM) and similarity percentages (SIMPER) were used to test for levels of difference in composition of the bird assemblage between each vegetation type. ANOSIM and SIMPER analyses were performed using PRIMER (Clarke and Gorley 2001).

Variation in the relative abundance of individual bird species between vegetation types was examined using non-parametric Kruskal-Wallis tests. Species recorded in only one survey were excluded from Kruskal-Wallis analysis. The degree of association of individual species with different vegetation types in this study was measured using Indicator Species Analysis (Dufrêne and Legendre 1997). Indicator values combine information on relative abundance and frequency of species. For example, when all individuals of a given species are restricted to a

Table 1. Relative abundance of birds (number of individuals per site per survey) in the four vegetation types. Data pooled for each vegetation type. Only species recorded in more than one survey have been included. Significance of differences in relative abundance calculated using Kruskal-Wallis test. ns = not significant at p = 0.05 level. 1. Conservation status: * = listed by Reid (1999) as declining in the sheep-wheat belt of Australia; v = listed as threatened under the *New South Wales Threatened Species Conservation Act 1995*.

Species		Conservation status[1]	Remnant	Planted	Paddock trees	Cleared	H	p
Number of sites			6	5	5	5		
Total species richness			53	33	34	10		
Stubble Quail	*Coturnix pectoralis*		0.0	0.0	0.2	0.0	6.48	ns
Common Bronzewing	*Phaps chalcoptera*		0.1	0.1	0.0	0.0	1.88	ns
Crested Pigeon	*Ocyphaps lophotes*		0.3	0.4	0.2	0.2	1.66	ns
Peaceful Dove	*Geopelia striata*		0.1	0.0	0.0	0.0	5.06	ns
Galah	*Eolophus roseicapillus*		0.3	0.1	1.6	0.0	5.74	ns
Sulphur-crested Cockatoo	*Cacatua galerita*		0.3	0.0	0.1	0.0	3.81	ns
Little Lorikeet	*Glossopsitta pusilla*	v	0.3	0.0	0.0	0.0	7.68	ns
Superb Parrot	*Polytelis swainsonii*	v	0.2	0.0	0.3	0.0	6.39	ns
Crimson (Yellow) Rosella	*Platycercus elegans*		0.2	0.1	0.1	0.0	1.69	ns
Eastern Rosella	*Platycercus eximius*		0.9	1.2	1.5	0.3	7.51	ns
Red-rumped Parrot	*Psephotus heamatonotus*		0.6	1.1	3.1	0.0	12.58	0.006
Sacred Kingfisher	*Todiramphus sanctus*		0.4	0.0	0.0	0.0	21.82	<0.001
White-throated Treecreeper	*Cormobates leucophaea*		0.4	0.0	0.0	0.0	21.80	<0.001
Brown Treecreeper	*Climacteris picumnus*	* v	0.8	0.0	0.0	0.0	44.91	<0.001
Superb Fairy-wren	*Malurus cyaneus*		0.1	2.7	0.0	0.0	39.95	<0.001
Weebill	*Smicrornis brevirostris*		0.2	0.8	0.0	0.0	10.26	0.016
Western Gerygone	*Gerygone fusca*		0.1	0.1	0.0	0.0	3.14	ns
Yellow Thornbill	*Acanthiza nana*		0.0	1.4	0.0	0.0	24.11	<0.001
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*		0.0	1.7	0.2	0.0	16.58	<0.001
Buff-rumped Thornbill	*Acanthiza reguloides*		0.0	0.1	0.3	0.0	2.23	ns
Spotted Pardalote	*Pardalotus punctatus*		1.3	0.1	0.2	0.0	19.75	<0.001
Striated Pardalote	*Pardalotus striatus*		0.4	1.3	2.0	0.0	27.90	<0.001
Yellow-tufted Honeyeater	*Lichenostomus melanops*		2.3	0.0	0.0	0.0	41.08	<0.001
Fuscous Honeyeater	*Lichenostomus fuscus*		1.7	0.1	0.0	0.0	15.67	0.001
White-plumed Honeyeater	*Lichenostomus penicillatus*		2.8	4.8	1.2	0.0	32.92	<0.001
Noisy Miner	*Manorina melanocephala*		1.0	0.4	2.9	0.2	21.74	<0.001
Red Wattlebird	*Anthochaera carunculata*		0.5	0.0	0.1	0.0	12.63	0.006
Black-chinned Honeyeater	*Melithreptus gularis*	v	0.3	0.0	0.1	0.0	3.16	ns
Brown-headed Honeyeater	*Melithreptus brevirostris*		0.5	0.0	0.0	0.0	7.68	ns
White-naped Honeyeater	*Melithreptus lunatus*		0.4	0.0	0.0	0.0	7.68	ns
Noisy Friarbird	*Philemon corniculatus*		0.6	0.0	0.0	0.0	10.37	0.016
Little Friarbird	*Philemon citreogularis*		0.1	0.1	0.0	0.0	1.87	ns
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*		0.1	0.2	0.1	0.0	3.82	ns
White-winged Triller	*Lalage sueurii*		0.0	0.2	0.0	0.0	6.48	ns
Crested Shrike-tit	*Falcunculus frontatus*	*	0.1	0.1	0.1	0.0	2.10	ns
Golden Whistler	*Pachycephala pectoralis*		0.1	0.0	0.1	0.0	3.14	ns
Rufous Whistler	*Pachycephala rufiventris*	*	0.7	0.5	0.1	0.0	17.68	<0.001
Grey Shrike-thrush	*Colluricincla harmonica*		0.6	0.7	0.0	0.0	33.51	<0.001
Dusky Woodswallow	*Artamus cyanopterus*	*	1.0	0.0	0.0	0.0	15.93	0.001
Australian Magpie	*Cracticus tibicen*		0.8	1.2	1.2	0.0	13.28	0.004
Grey Fantail	*Rhipidura albiscapa*		0.7	0.6	0.0	0.0	11.92	0.008
Willie Wagtail	*Rhipidura leucophrys*		1.0	1.5	0.3	0.5	30.19	<0.001

Table 1 — continued

Species		Conservation status[1]	Remnant	Planted	Paddock trees	Cleared	H	P
Australian Raven	*Corvus coronoides*		0.1	0.2	0.3	0.0	4.05	ns
Restless Flycatcher	*Myiagra inquieta*	*	0.3	0.0	0.0	0.0	13.12	0.004
Magpie-lark	*Grallina cyanoleuca*		0.5	0.0	0.2	0.1	11.87	0.007
White-winged Chough	*Corcorax melanorhamphos*		0.3	0.0	0.0	0.0	5.06	ns
Jacky Winter	*Microeca fascinans*	*	0.2	0.0	0.1	0.0	7.20	ns
Eastern Yellow Robin	*Eopsaltria australis*	*	0.4	0.0	0.0	0.0	21.80	<0.001
Rufous Songlark	*Cincloramphus mathewsi*		0.5	0.9	0.3	0.3	4.28	ns
Welcome Swallow	*Hirundo neoxena*		0.3	0.0	0.6	0.5	9.96	0.019
Common Blackbird	*Turdus merula*		0.2	0.2	0.0	0.0	4.99	ns
Common Starling	*Sturnus vulgaris*		0.3	1.0	2.5	0.4	12.36	0.006
Mistletoebird	*Dicaeum hirundinaceum*		0.3	0.0	0.1	0.0	9.93	0.019

Species recorded in only one survey during the study and therefore not used in the above species analysis include: Brown Quail *Coturnix ypsilophora*, Black-shouldered Kite *Elanus axillaris*, Painted Button-quail *Turnix varius* (*); Cockatiel *Nymphicus hollandicus*, Australian Ringneck *Barnardius zonarius*, Southern Boobook *Ninox novaeseelandiae*, Laughing Kookaburra *Dacelo novaeguineae*, White-browed Babbler *Pomatostomus superciliosus* (*), White-browed Woodswallow *Artamus superciliosus* (*), Grey Butcherbird *Cracticus torquatus*, Scarlet Robin *Petroica boodang* (v), Silvereye *Zosterops lateralis*, Fairy Martin *Petrochelidon ariel*, Diamond Firetail *Stagonopleura guttata* (* v).

particular vegetation type (e.g., remnant vegetation), and all samples from remnant vegetation sites contain an occurrence of that species, then the indicator value is maximal (IV%=100). Species data were randomized among the four vegetation type treatments and a Monte Carlo randomization procedure was performed with 1000 iterations in order to determine the statistical significance of the indicator values. Indicator Species Analysis was performed using PC-ORD (McCune and Mefford 1999).

RESULTS

Sixty-seven bird species were recorded. Within remnant vegetation sites, 53 species (79% of the total) were recorded, while the planted sites had 33 species (49%) and paddock tree sites had 34 species (51%). Only five species (7%) were recorded in cleared sites.

Bird species richness differed significantly among vegetation types (One-way ANOVA, $F_{3,17} = 89.2$, $P < 0.001$) and was highest in remnant vegetation with a mean of 24.3 species per site. Species richness was lowest in cleared vegetation (pasture dominated sites) with a mean of 4.0. Planted vegetation (mean of 15.6) and paddock trees (mean of 14.8) were intermediate in species richness (Fig. 1). *Post-hoc* tests indicated that all vegetation types were significantly different from each other with the exception of planted and paddock tree sites, which did not differ significantly from each other (Fig. 1). The most frequently recorded species (percentage of surveys) were Willie Wagtail (49%), White-plumed Honeyeater (46%), Striated Pardalote (42%), Australian Magpie (37%), Eastern Rosella (37%), Noisy Miner (32%), Grey Shrike-thrush (31%), Rufous Songlark (30%), Common Starling (25%), Rufous Whistler (21%) and Red-rumped Parrot (21%).

Relative abundance did not differ significantly among remnant vegetation (25.8 birds per survey), planted vegetation (23.4) and paddock trees (19.6), however all were significantly higher than cleared vegetation sites (2.2) ($F_{3,17} = 49.2$, $P < 0.001$; Fig. 1). The 10 most abundant species were White-plumed Honeyeater, Red-rumped Parrot, Noisy Miner, Common Starling, Eastern Rosella, Striated Pardalote, Australian Magpie, Willie Wagtail, Superb Fairy-wren and Yellow-tufted Honeyeater.

Analysis of similarity showed that vegetation type was a significant discriminator of bird composition, with all types being significantly different from each other (Table 2). The CAP ordination of vegetation types revealed that based on bird assemblage, there was a high level of separation among vegetation types (85.7% correct fit) (Fig. 2). As with richness and relative abundance, cleared vegetation sites were most

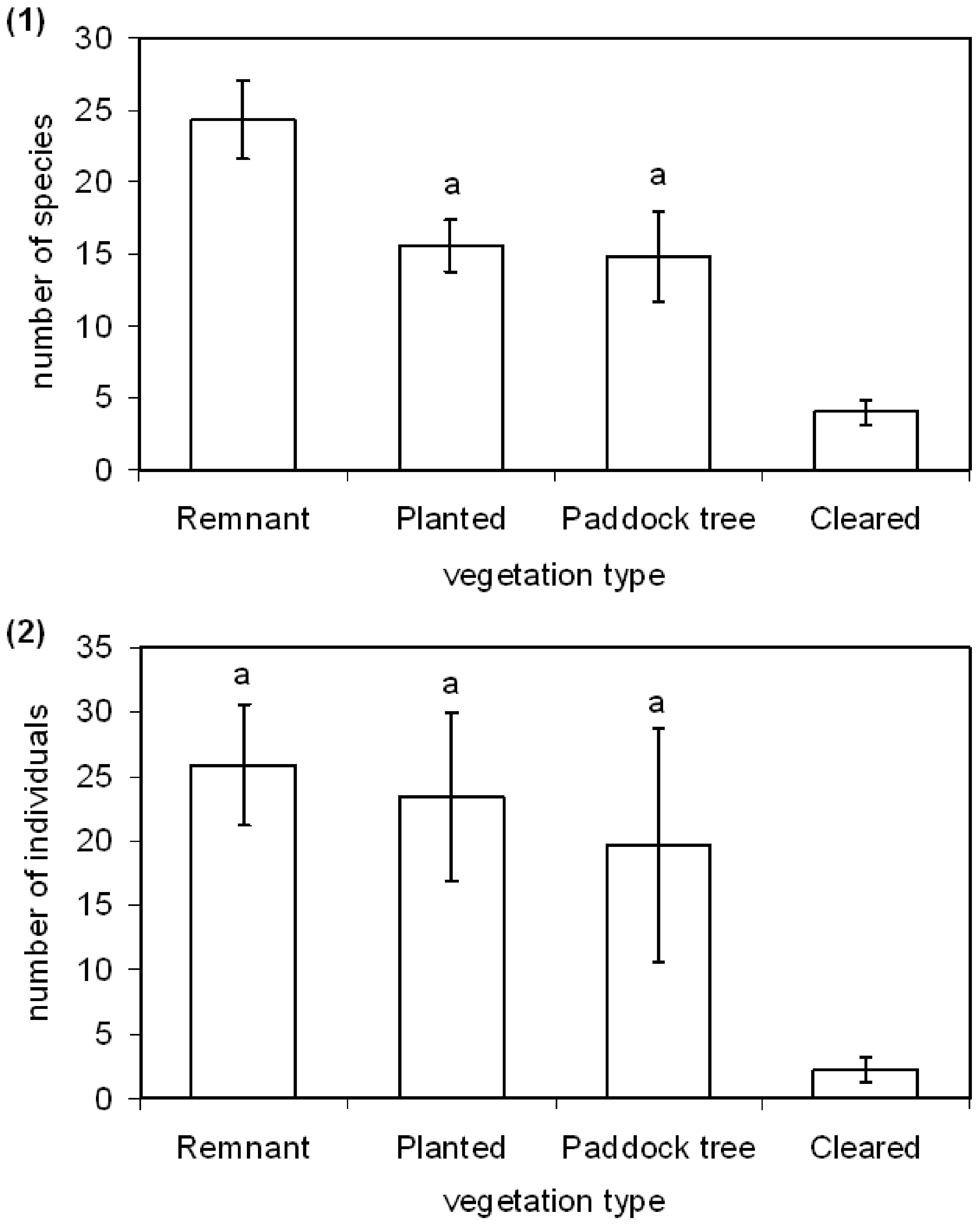

Fig. 1. (1) Mean species richness and (2) relative abundance (mean number of individuals per survey) per site across vegetation types. Bars represent 95% confidence intervals. Letter a above bars represent vegetation types for which no significant difference was found using Tukey's HSD for unequal N.

dissimilar to remnant, planted and paddock tree sites. Unlike species richness and relative abundance however, planted vegetation and paddock trees were significantly different from each other in terms of bird composition (70.2% dissimilarity) (Table 2) indicating that although planted and paddock tree sites had similar numbers of species and individuals, the composition of the bird fauna between the vegetation types was different. Similarly, there was no differences in relative abundance between remnant vegetation, planted and paddock tree types, but there were differences in composition (Table 2).

Table 2. Pair-wise statistical differences between bird assemblages occupying the different vegetation types, assessed by ANOSIM.

Site comparison		% Dissimilarity	*R* value	*P* value
remnant	planted	72.1	0.43	0.019
remnant	paddock tree	78.0	0.56	0.004
remnant	cleared	92.9	0.79	0.002
planted	paddock tree	70.2	0.62	0.008
planted	cleared	90.5	0.74	0.008
paddock tree	cleared	85.8	0.62	0.008

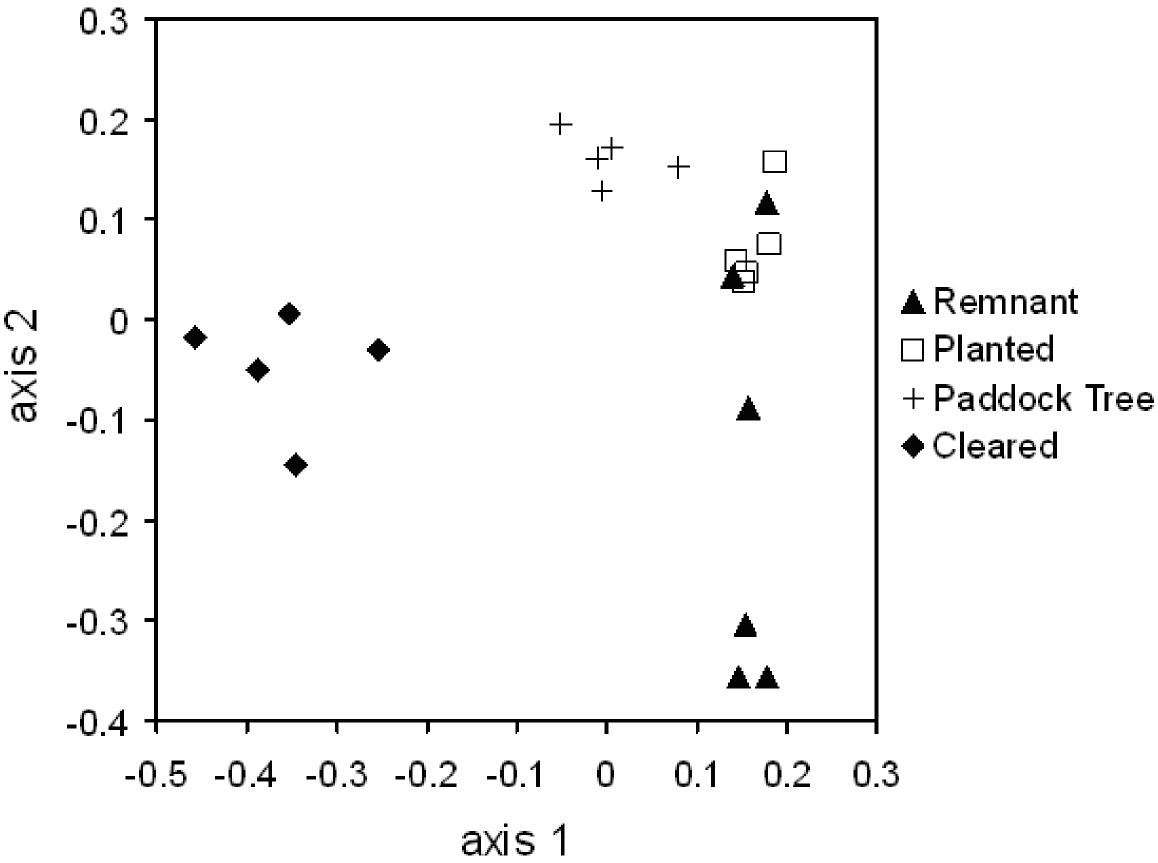

Fig. 2. Two dimensional canonical analysis of principal coordinates of the bird using sample sites categorized by vegetation type. Diagnostics indicate an 85.7% correct fit of the bird assemblages using *a-priori* determined vegetation groups.

The Kruskal-Wallis tests on relative abundance of individual species (excluding fourteen species recorded in only one survey) showed that there was a significant difference between one or more vegetation types for 28 species (Table 1). Thirteen species were most abundant in remnant vegetation, including Sacred Kingfisher, White-throated Treecreeper, Brown Treecreeper, Spotted Pardalote, Yellow-tufted Honeyeater, Fuscous Honeyeater, Red Wattlebird, Noisy Friarbird, Dusky Woodswallow, Restless Flycatcher, Magpie-lark, Eastern Yellow Robin and Mistletoebird (Table 1). Species most abundant in planted vegetation included Superb Fairy-wren, Weebill, Yellow Thornbill, Yellow-rumped Thornbill and White-plumed Honeyeater. Grey Fantail, Willie Wagtail, Grey Shrike-thrush and Rufous Whistler were most abundant on both remnant and planted sites (Table 1). Species most abundant in paddock trees included Red-rumped Parrot, Striated Pardalote, Noisy Miner and Common Starling (Table 1). Although no species was more abundant in cleared vegetation, Welcome Swallows were most abundant in the open vegetation of the cleared and paddock tree sites (Table 1). Australian Magpies were most abundant in remnant, paddock tree and planted sites, but were not found in cleared sites without trees. There was no difference in the abundance of 25 species among vegetation types (Table 1).

Table 3. Birds found to be significant indicator species (using Indicator Species Analysis) for each of the four vegetation types. No species were found to be significant indicators of cleared sites.

Species		Site type	Indicator value (%)	p value
Brown Treecreeper	*Climacteris picumnus*	remnant	100.0	0.001
Spotted Pardalote	*Pardalotus punctatus*	remnant	87.0	0.001
Sacred Kingfisher	*Todiramphus sanctus*	remnant	83.3	0.001
White-throated Treecreeper	*Cormobates leucophaeus*	remnant	66.7	0.005
Yellow-tufted Honeyeater	*Lichenostomus melanops*	remnant	66.7	0.005
Eastern Yellow Robin	*Eopsaltria australis*	remnant	66.7	0.005
Restless Flycatcher	*Myiagra inquieta*	remnant	66.7	0.005
Fuscous Honeyeater	*Lichenostomus fuscus*	remnant	64.7	0.010
Little Lorikeet	*Glossopsitta pusilla*	remnant	50.0	0.042
Noisy Friarbird	*Philemon corniculatus*	remnant	50.0	0.042
Superb Fairy-wren	*Malurus cyaneus*	planted	76.4	0.001
Yellow Thornbill	*Acanthiza nana*	planted	60.0	0.028
White-plumed Honeyeater	*Lichenostomus penicillatus*	planted	54.1	0.020
Willie Wagtail	*Rhipidura leucophrys*	planted	49.9	0.013
Common Starling	*Sturnus vulgaris*	paddock trees	59.9	0.009
Striated Pardalote	*Pardalotus striatus*	paddock trees	53.2	0.017
Noisy Miner	*Manorina melanocephala*	paddock trees	51.9	0.043

Of the 40 species found in planted vegetation or paddock trees, all but five species, Stubble Quail, Yellow Thornbill, Yellow-rumped Thornbill, Buff-rumped Thornbill, and White-winged Triller, were recorded in remnant vegetation (Table 1). Eleven species occurred in planted vegetation but not in paddock trees, while 10 species occurred in paddock trees but not planted sites (Table 1). Nineteen species were found in both planted and paddock tree vegetation (Table 1), indicating that the assemblage of birds in these two vegetation types formed different, albeit overlapping, subsets of the birds found in remnant vegetation.

Ten species were indicators of remnant vegetation sites, four were indicators of planted vegetation sites and three of paddock tree sites (Table 3). No species were indicators of cleared vegetation sites.

DISCUSSION

Bird species richness was significantly higher in remnant native vegetation than planted vegetation and paddock trees, and significantly lower in cleared paddocks. This broadly supports the findings of other studies of birds in agricultural landscapes (Kinross 2004; Martin *et al.* 2004; Barrett *et al.* 2008; Cunningham *et al.* 2008). Kinross (2004), Kavanagh *et al.* (2007), and Barrett *et al.* (2008) recorded a higher proportion of total species in planted sites (64%, 79% and 70% respectively), compared to this study (49%). This may have been due to the small size of planted sites in this study, and their isolation from both remnant vegetation and mature paddock trees, compared to Kavanagh *et al.* (2007) and Barrett *et al.* (2008) who included a number of larger sites (over 5–10 ha) closer to remnant patches of woodland. Revegetation sites in Barrett *et al.* (2008) were also frequently undertaken around existing large paddock trees. In the Kyeamba Valley part of our study area, of 400 patches of planted vegetation that were identified by Murray (2003), the average size was 1.5 ha and 79% were less than 2 ha. Only two patches were larger than 10 ha. Habitat structure is also a significant determinant of species richness (MacArthur and MacArthur 1961; Recher 1969). Remnant vegetation sites had a higher structural diversity compared to planted and paddock tree sites. Planted sites lacked mature trees, while the paddock tree sites consisted of mature trees but lacked a shrub layer and a diverse ground-cover.

The lack of a significant difference in relative abundance between remnant vegetation, planted and paddock trees sites was largely due to the presence of a few species in higher numbers in the vegetation types with lower species richness. For example, Superb Fairy-wren and White-plumed Honeyeater were present in relatively high numbers in planted sites, and Red-rumped Parrot, Noisy Miner and Common Starling were present in relatively high numbers in the paddock tree sites. Revegetated sites increase in structural complexity with age (Munro *et al.* 2007), resulting in a corresponding increase in bird richness (Biddiscombe 1985; Taws *et al.* 2001; Martin *et al.* 2004). The increase in structural complexity and bird richness with vegetation age is also reflected in an increase in relative abundance of birds.

The composition of bird assemblages is a more important measure of the value of the different vegetation types than measures based on richness or relative abundance (see Munro *et al.* 2007). In our study, the composition of the bird assemblage differed significantly among the four vegetation types. Although planted sites and paddock tree sites had a similar species richness and relative abundance, the relative makeup of species differed. In terms of species diversity, planted and paddock tree sites were predominantly two different sub-sets of the assemblage characteristic of remnant vegetation. Paddock trees were dominated by birds favouring mature trees and an open understorey (e.g., Galah, Red-rumped Parrot, Striated Pardalote, Australian Raven and Mistletoebird), while plantings were dominated by birds favouring dense foliage and shrubs (e.g., Superb Fairy-wren, Yellow Thornbill, Grey Shrike-thrush, Grey Fantail and Willie Wagtail), reflecting the structure of each vegetation type.

Attributes of planted sites, such as isolation, size, geometry and plant species composition and density, affect the bird assemblage composition and abundance (e.g., Kavanagh *et al.* 2007; Lindenmayer *et al.* 2007, 2010; Kinross and Nicol 2008). Lindenmayer *et al.* (2010) and Priday (2010) showed that for some species it is not the characteristics of a patch of woody vegetation alone that determines habitat suitability, but that the characteristics of adjacent vegetation types may also be important. Paddock tree and planted sites in this study were isolated from other patches of woody vegetation, being surrounded by exotic pastures. Remnant sites typically adjoined areas of paddock trees, which may have influenced the occurrence of species by increasing the patch area for birds requiring mature trees and creating a continuum of woodland types (McIntyre and Barrett 1992).

Of the ten species that were significantly associated with remnant vegetation (Table 3), four are declining or threatened woodland species in the wheat-sheep regions of Australia – Little Lorikeet, Brown Treecreeper, Eastern Yellow Robin and Restless Flycatcher (Reid 1999; NSW Threatened Species List) — highlighting the importance of remnant patches of native vegetation in this highly modified agricultural landscape. Dusky Woodswallow was also recorded only in remnant vegetation, but not frequently enough to determine if it was significantly associated with this vegetation type alone. A further five species (Superb Parrot, Black-chinned Honeyeater, Crested Shrike-tit, Rufous Whistler, and Jacky Winter) listed as threatened in NSW, or declining by Reid (1999), were found to occur in remnant vegetation, but also occurred in other vegetation types.

The Crested Shrike-tit and Rufous Whistler were found in remnant, planted and paddock tree sites, suggesting that resources for these species were available in all three vegetation types. Superb Parrot, Black-chinned Honeyeater and Jacky Winter were found in remnant vegetation as well as paddock trees. For mobile species such as these, the combination of remnant vegetation and paddock trees are likely to be important as part of the total matrix of vegetation available in the landscape (Manning *et al.* 2006). Increased planting of native vegetation will add to the total vegetation matrix and benefit many of these species.

The Brown Treecreeper has been shown to be strongly associated with remnant vegetation, and missing from, or rare, in planted vegetation (Kinross 2004; Martin *et al.* 2004; Kavanagh *et al.* 2007; Cunningham *et al.* 2008). Our study found a similar pattern for this species, which was found only in remnants (Indicator Value = 100%). Cooper and Walters (2002) found that Brown Treecreepers declined in fragmented habitats due to low female recruitment and lack of dispersal between fragments. Given the small size of plantings and their isolation from remnant vegetation in this landscape, colonization of plantings by Brown Treecreepers is unlikely. Cunningham *et al.* (2008) also suggest that planted vegetation may not provide necessary foraging habitat for Brown Treecreepers, at least while the vegetation is relatively young, nor has sufficient fallen timber. Except for remnant sites, fallen timber was absent from the vegetation types in this study, including the paddock tree sites where fallen branches had previously been removed from the ground as part of pasture management activities.

Although only three species (Striated Pardalote, Noisy Miner and Common Starling) were significantly associated with paddock tree sites alone, mean species richness was relatively high (34 species). This is despite the widespread presence of the aggressive Noisy Miner which is known to exclude other birds (Grey *et al.* 1998; Clarke and Oldland 2007). Our data therefore reinforce the notion that paddock trees form an important component of the total native vegetation matrix of the study area. Four species of conservation concern were recorded on paddock tree sites, as well as in remnant vegetation, including Superb Parrot, Black-chinned Honeyeater, Crested Shrike-tit and Jacky Winter, reflecting the value of this vegetation type to birds. Paddock trees may be of value as a provision of resources (Superb Parrot and Black-chinned Honeyeater were observed feeding in seeding and flowering trees), or as stepping-stones while moving through the landscape. Fischer and Lindenmayer (2002a) found that small habitat features such as single paddock trees were valuable for some bird species usually thought to be associated with remnant woodland. Paddock trees therefore form an important component of the native vegetation matrix in the Wagga Wagga region, complementing remnant patches and plantings. Their continued loss from the landscape will result in a reduction in the area of treed habitat and increasing isolation of remaining remnants, adversely affecting the local avifauna (Fischer and Lindenmayer 2002a, 2002b; Gibbons and Boak 2002).

Management implications

Given that they support a number of species not found in either paddock trees or plantings, the management of patches of remnant vegetation in a manner sympathetic to birds is important. Both plantings and paddock trees have important values for birds, but support different assemblages, and should be seen as complementary to each other. The planting of native vegetation should not be seen as an offset for the loss of old paddock trees, especially as important habitat attributes of paddock trees will take many years to develop in planted vegetation (Vesk *et al.* 2008). We concur with Fischer and Lindenmayer (2002a) that paddock trees, in addition to remnant vegetation patches, should be important components of conservation strategies.

Given that many of the plantings in this area are small and often consist of strips along fencelines (Murray 2003), increasing the size and width of plantings would increase their value to birds. Wherever possible, planted native vegetation should ideally incorporate paddock trees to include attributes of both vegetation types. Timber plantations that have maintained existing trees have been found to support more bird species and higher numbers of individuals than even aged younger plantings alone, by providing increased diversity of foraging sites (Kavanagh and Turner 1994). In locations where ground foraging birds occur (such as the Jacky Winter and Brown Treecreeper) and utilize existing large paddock trees and fallen timber, care should be taken to ensure that plantings do not compromise existing habitat values for these species. Very high stem densities may reduce the suitability of the habitat through loss of access and reduction in diversity of foraging substrates (Recher *et al.* 2002; Antos and Bennett 2005). High stems densities resulting in a dense shrub canopy may be beneficial to some species however, through a reduction in the impact of the aggressive Noisy Miner (Clarke and Oldland 2007; Lindenmayer *et al.* 2010).

Planted vegetation sites in this study appeared to be developed on sites where the ground cover was dominated by exotic pasture grasses. Barrett *et al.* (2008) and Montague-Drake *et al.* (2009) found that sites with a scarcity of annual grasses and a cover of native grasses and forbs are important determinants of site occupancy for a number of birds in the south-west slopes of NSW, especially declining ground foraging species. Therefore, when establishing native trees and shrubs, attention should be paid to either controlling exotic grasses and establishing native ground cover (see Gibson-Roy *et al.* 2010), or focusing replanting efforts on areas not dominated by exotic grasses and weeds. The retention or addition of fallen timber to planted sites would further enhance the value of plantings in the Wagga Wagga area (Mac Nally *et al.* 2002).

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