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Bird communities in mixed farming landscapes of the South Australian Murray–Mallee: The contribution of saltbush plantings

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Summary. Plantings of chenopod saltbushes (mainly *Atriplex* spp.) are increasing in South Australia to provide additional fodder for stock. The biodiversity benefits of these plantings were assessed by examining bird communities in two seasons (spring and autumn) at 16 sites, of four types: remnant native vegetation with adjacent saltbush, isolated remnant native vegetation, isolated saltbush, and conventionally managed agricultural land isolated from other vegetation in the South Australian Murray–Mallee. Sites with remnant native vegetation and adjacent saltbush showed the greatest bird abundance and species richness, as the adjacent saltbush plantings boosted bird species diversity at the patch level. Isolated saltbush sites supported mainly generalist and shrubland bird species. Bird communities were significantly different across the different site types, and abundances changed seasonally. Saltbush plantings provided improved habitat and biodiversity conservation value for birds over conventionally managed and cleared agricultural land. However, the simple structure of these monoculture plantings meant that they supported a significantly reduced suite of species compared with that in remnant native vegetation. Additional work is required to determine how birds use saltbush plantings—e.g. as permanent or supplementary habitat, or for use only by birds passing through.

Introduction

Excessive clearance of vegetation and associated habitat loss across Australia's southern agricultural landscapes have severely altered natural vegetation communities and caused widespread decline of biodiversity (Saunders & Curry 1990; Recher 1993a; Barrett *et al.* 2003; Attwood *et al.* 2009). As a result, many species are confined to an inadequate system of reserves and small patches of isolated remnant native vegetation, nested within a human-modified matrix (Ryan 1992; Margules & Pressey 2000).

In recent decades, the need to extend conservation and management efforts beyond reserve systems to encompass private land has become apparent (Law & Dickman 1998; Lindenmayer *et al.* 2010a). Revegetation has been the primary approach used to re-establish and extend habitats and restore ecosystem function (Recher 1993b; Saunders & Hobbs 1995; Vesk & Mac Nally 2006). However, efforts are constrained by trade-offs between agricultural production and conservation, size limitations and lack of multi-layered, structurally and floristically diverse vegetation (Recher 1993b; Bennett & Mac Nally 2004; Paton *et al.* 2004). As a result, current revegetation practices remain insufficient to effectively reduce the decline of biodiversity (McNeely & Schroth 2006; Vesk *et al.* 2008).

Recent research has recognised the potential for shrub- and tree-based perennial farming systems of native chenopod (saltbush *Atriplex* spp. or bluebush *Maireana* spp.*)* and mallee (*Eucalyptus* spp.) plant species to aid large-scale conservation of biodiversity (Lefroy & Smith 2004). Some constituents of these systems may connect and buffer existing remnant native vegetation and revegetated areas and increase available vegetation cover in extensively cleared regions (Haslem & Bennett 2008a; Fahrig *et al.* 2011).

Shrub-based plantings have been established in the wheat/sheep agricultural landscapes of southern Australia since the early 1990s (Lefroy 2002; Munro *et al.* 2011). In the drier zones there, saltbushes (principally Old Man Saltbush *Atriplex nummularia nummularia*) have been planted by many land managers as a fodder reserve for dry periods (Millsom 2002). As a result, many previously cleared landscapes are now interspersed with patches of shrub-level vegetation and, depending on the effects of grazing (see Dorrough *et al.* 2004), may increase diversity of birds and other taxa through greater landscape heterogeneity, improved food resources and increased complexity of vegetation (Lefroy *et al.* 2005; Collard *et al.* 2009; Prober & Smith 2009).

This study focusses on birds as they are the most conspicuous and numerous vertebrate fauna and are highly mobile, and therefore capable of exploiting newly available habitats (Hobbs *et al.* 2003; Loyn *et al.* 2007; Mac Nally 2007; Munro *et al.* 2011). However, many of the perceived benefits for birds of saltbush plantings remain speculative (Lefroy & Smith 2004; Lefroy *et al.* 2005; Collard & Fisher 2010), stemming from research on revegetation by mixed species (Palmer *et al.* 1997; Williams 2004). The few scientific investigations available examined isolated plantings relative to patches of native vegetation, and they identified small increases in species richness associated with saltbush plantings, relative to surrounding cleared land (e.g. Seddon *et al.* 2009; Collard *et al.* 2011). Research is required to further investigate trends in bird abundance, in addition to species richness, across landscapes containing saltbush plantings. Of particular importance is the need to also study the effects of adjacency to remnant native vegetation to determine whether plantings are capable of supporting bird communities in their own right, or simply supplement existing vegetation.

The aim of this study was to compare bird abundances and bird species richness across four different site types: remnant native vegetation with adjacent saltbush plantings, isolated remnant native vegetation, isolated saltbush plantings, and cleared previously vegetated land now under cropping or pasture. These data will allow the contributions of isolated and adjacent saltbush plantings to supporting bird species within fragmented mixed farming landscapes of the Murray–Mallee of South Australia (SA) to be assessed.

Methods

Study region

The study was conducted at 16 sites in the northern Murray–Mallee of SA (Figure 1). This region is typical of southern Australian broadacre wheat/sheep agricultural landscapes, having experienced wide-scale clearance of vegetation but now characterised by large tracts of cleared land interspersed with small patches of remnant native vegetation dominated by

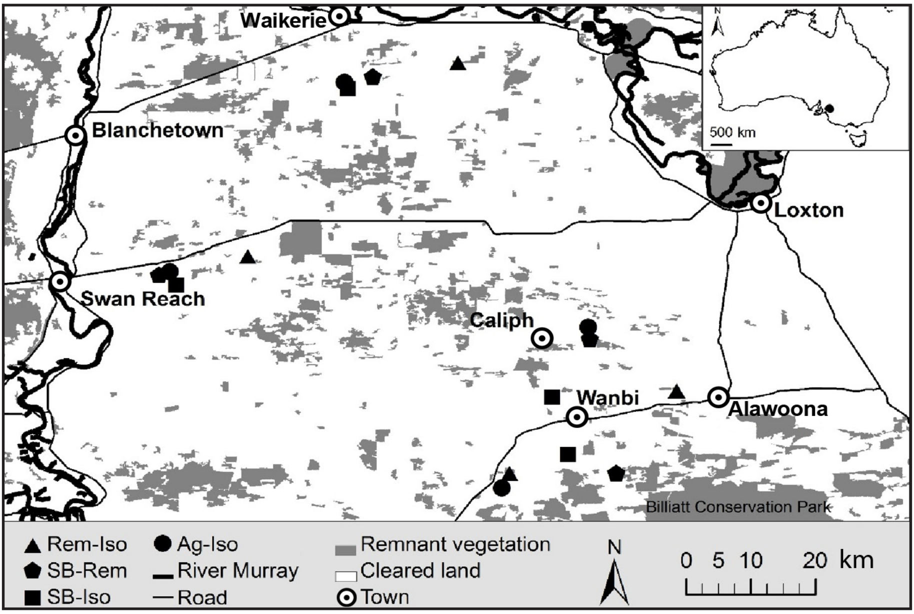

Figure 1. Study region in the northern Murray–Mallee of South Australia. Study site types are Rem-Iso (isolated remnant native vegetation), SB-Rem (remnant native vegetation with adjacent saltbush), SB-Iso (isolated saltbush) and Ag-Iso (agricultural land isolated from other vegetation) (see methods).

mallees *Eucalyptus* spp. (Specht 1972; Foulkes & Gillen 2000). Saltbush has been planted in the region since the 1990s, and is predominantly Old Man Saltbush with a variety of introduced ground-covers. In this region summers are warm to hot (mean maximum temperature 31.1°C) and winters are cool to cold (mean maximum temperature 16.2°C), and the mean annual rainfall is 268.8 mm (recorded at Caliph: Bureau of Meteorology 2012). Soils are principally sandy with little heavy clay and are derived from fluviatile and lacustrine beds overlying marine tertiary deposits (Prescott & Piper 1932; Newell 1961).

Site selection

After examination from the ground, sixteen study sites were selected from a potential 20 identified from aerial photography. They represented four replicates of each of four different types: remnant native vegetation with adjacent saltbush (SB-Rem), isolated remnant native vegetation (Rem-Iso), isolated saltbush (SB-Iso), and agricultural land isolated from other vegetation (Ag-Iso) (Figure 1). All sites were isolated from surrounding vegetation by a minimum of 400 m except for one SB-Iso site that was 150 m from nearby vegetation. Patches of remnant native vegetation ranged from 45.9 to 582.9 ha in area and were dominated by mallee eucalypts, including Lerp Mallee *Eucalyptus incrassata,* Giant Mallee *E. oleosa,* and Red Mallee *E. socialis,* with sparse subcanopy and very sparse shrub layers of tea-trees *Melaleuca,* acacias *Acacia* and spinifex *Triodia* species with minimal herbaceous and grassy ground-cover (Specht 1972; Foulkes & Gillen 2000). Saltbush plantings were between 10 and 20 years old and ranged from 6.1 to 52.1 ha in area, with the saltbushes planted in rows and evenly spaced. All were composed of Old Man Saltbush and ground-covers of introduced grasses and weeds. Agricultural land consisted of pasture (introduced grasses) or wheat crops. Study sites were sampled using survey areas measuring

500 m × 500 m (25 ha), strategically placed to cover the vegetation type(s) to be surveyed and a portion of the edge to capture any bird movements to or from the survey area.

Bird surveys

Each study site was surveyed four times during both spring (September/October) 2010 and autumn (March/April) 2011, at weekly intervals. Bird surveys took place in fine weather between sunrise and midday to maximise the detection of birds (Conner & Dickson 1980). Birds were recorded along seven equidistantly spaced 500-m transects. Transects were walked in alternate directions, beginning and ending in diagonally opposite corners of each 25-ha survey area to minimise double-counting of individual birds. To reduce the effect of observer interference and increase the chance of detecting less conspicuous species, transect direction was rotated each survey. Transects ran north–south during Surveys 1 and 2, with Survey 1 beginning in the north-eastern corner of the survey area and Survey 2 in the south-western corner. During Surveys 3 and 4, transects ran east–west, with Survey 3 beginning in the north-western corner and Survey 4 in the south-eastern corner. Five transects were walked at Ag-Iso sites, as the very sparse and low vegetation allowed birds to be seen easily at a distance. All birds seen and heard were recorded, with deviations from the transect line made to confirm species visually. Flying birds were recorded only if they landed within the survey area.

Vegetation surveys

Each 25-ha survey area was divided into 25 m × 25 m quadrats, 120 of which were selected to serve as vegetation survey quadrats in SB-Rem, Rem-Iso and SB-Iso sites using a stratified, evenly distributed layout. Sixty of these quadrats, spaced equally across the site, were surveyed at each site during spring 2010, with the remaining 60 surveyed during autumn 2011. Because of the uniform nature of Ag-Iso sites, a total of 60 quadrats was selected, with 30 surveyed during each season. At the centre-point of each quadrat, visual estimates were made of percentage cover and average height of strata of vegetation: canopy (>4 m), subcanopy (2–4 m), understorey (0.5–1.9 m), and ground-cover (adapted from Martin *et al.* 2004). In addition, the percentage cover of leaf-litter was estimated within each quadrat. Plants were identified to genus.

Data analysis

Bird abundances (number of birds), species richness (number of species), incidence values and species diversity indices were calculated for each site and season. Incidence values (*I*) describe the reporting rate or fidelity of bird species at a site and were determined by the proportion of surveys in which a species was encountered (Dawson 1981). Incidences were calculated according to the methods of Watson (2003) for all birds at all sites during autumn and spring separately and across the entire study.

Species diversity indices incorporate both species richness and abundance data to produce an index value representative of both the number of species (richness) and equitability or evenness of their abundances (Lloyd & Ghelardi 1964; Tramer 1969; McCune & Grace 2002). Shannon & Weaver (1963) and Simpson (1949) diversity indices were chosen to analyse bird survey data as both are suited to measuring infinite populations (McCune & Grace 2002). The Shannon diversity index measures evenness of a sample with the minimum value zero, obtained when one species is present, whereas the Simpson diversity index is the likelihood that two randomly selected individuals will be different species, with a maximum likelihood of 1 (McCune & Grace 2002). To correct for the counter-intuitive inverse relationship of the true Simpson index with diversity, values were subtracted from their maximum value of 1 (Berger & Parker 1970).

Both bird and vegetation data were analysed using the statistical software package SPSS version 19.0 (SPSS Inc. Chicago, Illinois, USA) and were tested for normality using Kolmogorov-Smirnov tests before analysis. Bird abundance and bird species richness data were first analysed using two-way Analysis of Variance (ANOVA) to detect significant differences between seasons and site types. These were followed by least significant difference (LSD) *post-hoc* tests to identify where differences lay and to allow multiple comparisons between sites and types (George & Mallery 2006).

Vegetation data

Data on the percentage cover of vegetation were compared separately for saltbush, remnant native vegetation and agricultural land sections across sites (e.g. remnant native vegetation between SB-Rem and Rem-Iso sites). To identify similarities in vegetation structures, percentage cover data for each stratum were averaged, and habitats at each site were analysed with non-metric multi-dimensional scaling (NMDS) ordinations constructed with PC-ORD software (version 5) using the slow and thorough speed and thoroughness method and Sorenson (Bray-Curtis) distance measurement. This method was chosen as NMDS is generally the most effective ordination method for non-parametric ecological data (McCune & Grace 2002).

Results

Bird communities

A total of 67 bird species was recorded across all sites in spring 2010 and autumn 2011 combined (Appendix 1), with 52 in spring and 60 in autumn. Six species (Southern Boobook *Ninox novaeseelandiae*, Rainbow Bee-eater *Merops ornatus*, Dusky Woodswallow *Artamus cyanopterus,* Eurasian Skylark *Alauda arvensis*, Tree Martin *Petrochelidon nigricans* and Common Starling *Sturnus vulgaris*) were recorded only during spring, and 15 (Emu *Dromaius novaehollandiae*, Diamond Dove *Geopelia cuneata*, Australian Owlet-nightjar *Aegotheles cristatus*, Wedge-tailed Eagle *Aquila audax*, Little Eagle *Hieraaetus morphnoides*, Nankeen Kestrel *Falco cenchroides*, Cockatiel *Nymphicus hollandicus*, Mulga Parrot *Psephotus varius*, Elegant Parrot *Neophema elegans*, Pallid Cuckoo *Cacomantis pallidus*, Weebill *Smicrornis brevirostris*, Buff-rumped Thornbill *Acanthiza reguloides*, Varied Sittella *Daphoenositta chrysoptera*, White-browed Woodswallow *Artamus superciliosus* and Grey Fantail *Rhipidura albiscapa*) only during autumn. Sites with remnant native vegetation with adjacent saltbush (SB-Rem) had the greatest bird species richness (54 species/25-ha site per survey) and mean abundance (60.8 ± standard deviation 4.9 birds/25-ha site per survey) in spring and autumn combined, whereas isolated agricultural sites (Ag-Iso) had the lowest richness (9 species) and abundance (3.8 ± 0.7 birds/site per survey) (Table 1). Six species (Diamond Dove, Mulga Parrot, Splendid Fairy-wren *Malurus splendens*, Weebill, Buff-rumped Thornbill and Grey Fantail) were recorded only at SB-Rem sites, six (Australian Owlet-nightjar, Wedge-tailed Eagle, Cockatiel, Pallid Cuckoo, Southern Boobook and Tree Martin) only at Rem-Iso sites, and three (Little Eagle, Nankeen Kestrel and Elegant Parrot) only at SB-Iso sites. No species were recorded solely at Ag-Iso sites, but six (Crested Pigeon *Ocyphaps lophotes*, Black-shouldered Kite *Elanus axillaris*, Blue Bonnet *Northiella*

Table 1. Bird species richness (total species), mean bird abundance (number of individual birds ± standard deviation per 25-ha site per survey), and species diversity indices at study sites in the northern Murray–Mallee, SA, in spring 2010 and autumn 2011. The species diversity index given is the Shannon diversity index (Shannon & Weaver 1963), with the Simpson index (Simpson 1949) in parenthesis; each Simpson index is the true Simpson index subtracted from 1 (Berger & Parker 1970) (see methods).

	Site type			
	SB-Rem	*Rem-Iso*	*SB-Iso*	*Ag-Iso*
Spring				
Total species	43	37	21	7
Mean abundance	50.7 ± 5.7	42.6 ± 4.5	23.5 ± 1.4	2.8 ± 0.6
Species diversity index	3.51 (0.92)	2.85 (0.90)	1.87 (0.88)	1.14 (0.71)
Autumn				
Total species	47	45	22	5
Mean abundance	71.9 ± 7.2	66.4 ± 6.7	36.5 ± 4.2	4.8 ± 1.2
Species diversity index	5.41 (0.94)	4.05 (0.89)	2.27 (0.86)	1.12 (0.24)
Spring + autumn combined				
Total species	54	53	28	9
Mean abundance	60.8 ± 4.9	54.5 ± 4.5	30.0 ± 2.5	3.8 ± 0.7
Species diversity index	3.84 (0.94)	3.17 (0.91)	1.72 (0.89)	1.11 (0.61)

haematogaster, Australian Magpie *Cracticus tibicen*, Australian Raven *Corvus coronoides* and Australasian Pipit *Anthus novaeseelandiae*) were found at all the site types (Appendix 1).

Abundance

In total, 4778 birds were recorded, 1926 in spring 2010 and 2857 in autumn 2011. Mean bird abundance (number of birds/site per survey) was significantly different between these seasons ($P < 0.001$, $F = 20.458$) at all sites except for Ag-Iso sites ($P = 0.063$, $F = 3.803$, two-way ANOVA). Analysis showed no significant interaction between season and site type ($P = 0.097$, $F = 2.156$). Mean abundance per site did not differ significantly between SB-Rem and Rem-Iso sites during either spring or autumn ($P > 0.05$, both seasons), but both had significantly higher mean abundances than SB-Iso sites ($P < 0.001$, both seasons), which in turn were significantly higher than Ag-Iso sites ($P < 0.001$, both seasons). When seasonal data were compared for individual site types, mean bird abundance was greater during autumn at SB-Rem ($P = 0.032$, $F = 5.168$), Rem-Iso ($P = 0.003$, $F = 11.203$) and SB-Iso sites ($P < 0.001$, $F = 17.974$, one-way ANOVA). No significant seasonal difference was detected at Ag-Iso sites ($P = 0.063$, $F = 3.803$, Figure 2).

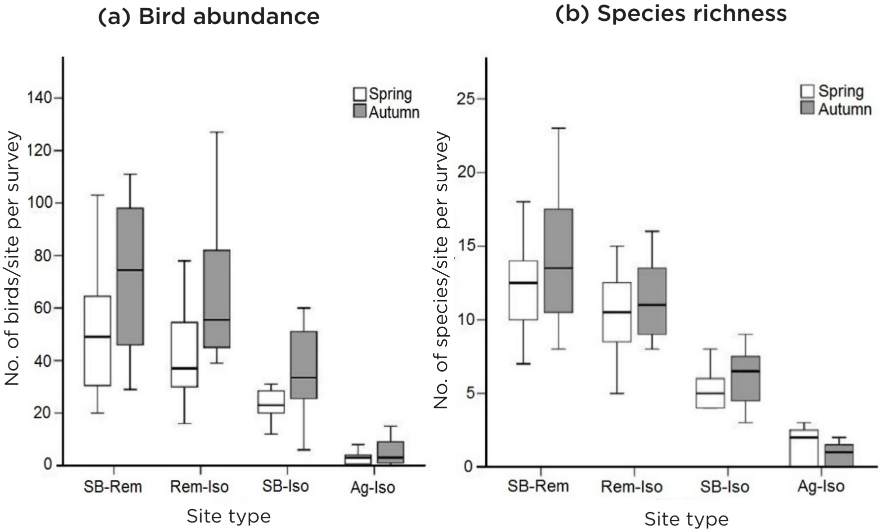

Figure 2. (a) Bird abundance (number of birds/25-ha site) and (b) species richness (number of species/25-ha site) per survey at the four study site types (see methods) during spring 2010 and autumn 2011. Each box indicates the median (line), 25% and 75% quartiles; whiskers indicate minima and maxima.

Bird species richness

Mean bird species richness (number of species/site per survey) was significantly different between all site types (P <0.05), but not between spring and autumn seasons (P = 0.96, F = 2.818, two-way ANOVA). It was highest for SB-Rem sites, followed by Rem-Iso, SB-Iso and Ag-Iso sites. There was no significant interaction between season and site type (P = 0.248, F = 1.393).

Incidence and species diversity indices

Open-country generalist birds were present in the highest number in all surveys. The Australian Magpie was recorded most frequently across all surveys, followed by the Australian Ringneck *Barnardius zonarius* and Galah *Eolophus roseicapillus*. These species comprised 5.94, 9.27, and 7.73% of total bird abundance at SB-Rem sites; 8.78, 9.53 and 7.81% at Rem-Iso; 10.63, 0.52 and 1.46% at SB-Iso; and 57.81, 0 and 0% at Ag-Iso sites, respectively. At SB-Rem sites, Chestnut-rumped Thornbills *Acanthiza uropygialis* were most frequent during spring (I = 0.94) whereas Magpies and Yellow-rumped Thornbills *A. chrysorrhoa* were most frequent in autumn (I = 0.94 in both cases). During both seasons, the Ringneck (I = 0.88, spring; I = 0.94, autumn) and Magpie (I = 0.88, both seasons) were most frequent at Rem-Iso sites. The Singing Honeyeater *Lichenostomus virescens* (I = 0.75, spring; I = 1.0, autumn) and Variegated Fairy-wren *Malurus lamberti* (I = 0.75, spring; I = 0.94, autumn), both shrubland species, were most common at SB-Iso sites throughout the study, along with the

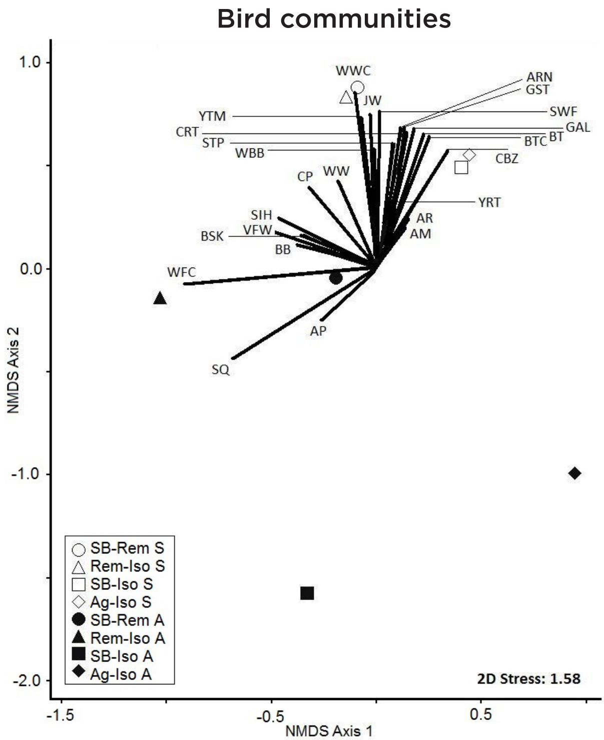

Figure 3. Two-dimensional non-metric multi-dimensional scaling (NMDS) ordination of bird community distribution across survey site types for the 25 most commonly occurring species based on incidence (*I*) values for both spring and autumn. Distances between sample units approximate strength of bird species association with site types (McCune & Grace 2002). Data were collected during spring (S) 2010 and autumn (A) 2011. Bird species: AM = Australian Magpie, AP = Australasian Pipit, AR = Australian Raven, ARN = Australian Ringneck, BB = Blue Bonnet, BSK = Black-shouldered Kite, BT = Brown Thornbill, BTC = Brown Treecreeper, CP = Crested Pigeon, CRT = Chestnut-rumped Thornbill, CBZ = Common Bronzewing, GAL = Galah, GST = Grey Shrike-thrush, JW = Jacky Winter, SIH = Singing Honeyeater, SQ = Stubble Quail, STP = Striated Pardalote, SWF = Southern Whiteface, VFW = Variegated Fairy-wren, WBB = White-browed Babbler, WFC = White-fronted Chat, WW = Willie Wagtail, WWC = White-winged Chough, YRT = Yellow-rumped Thornbill, and YTM = Yellow-throated Miner.

Magpie (*I* = 0.56, spring; *I* = 0.50, autumn) and Crested Pigeon (*I* = 0.50, spring; *I* = 0.69, autumn). The Australasian Pipit (*I* = 0.50, spring; *I* = 0.13, autumn) and Magpie (*I* = 0.19, spring; *I* = 0.63, autumn) were recorded most often at Ag-Iso sites (Figure 3, Appendix 1).

Shannon and Simpson diversity indices revealed that SB-Rem sites had the highest bird species diversity in both spring and autumn, marginally higher than Rem-Iso sites. Species diversity was markedly lower at SB-Iso sites compared with SB-Rem and Rem-Iso sites, and at Ag-Iso sites species diversity was lowest

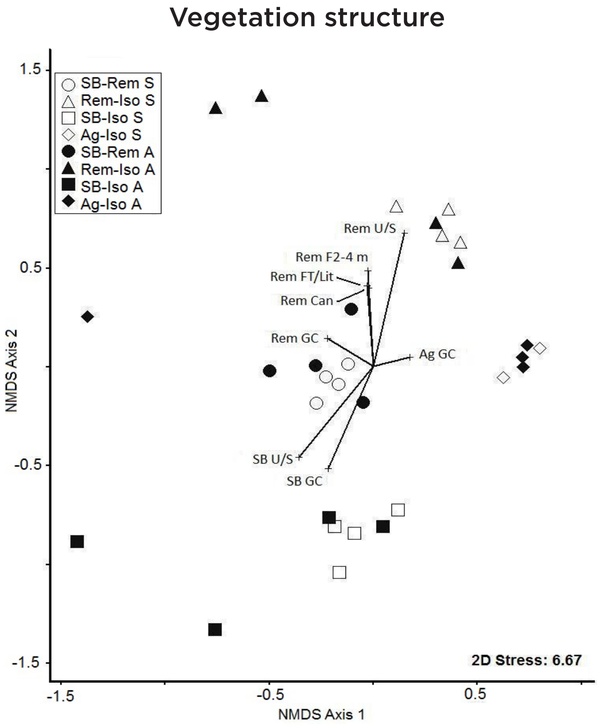

Figure 4. Two-dimensional non-metric multi-dimensional scaling (NMDS) ordination based on percentage cover of canopy (Rem Can), sub-canopy (Rem F2–4 m), understorey (Rem U/S), fallen timber/leaf-litter (Rem FT/Lit), and ground-cover (Rem GC) within remnant vegetation; understorey (SB U/S) and ground-cover (SB GC) in saltbush plantings; and ground-cover (Ag GC) in agricultural land across the four study site types: SB-Rem, Rem-Iso, SB-Iso, Ag-Iso. Distances between sample units approximate dissimilarity in site composition and the angles and lengths of the radiating lines (vectors) indicate the direction and strength of relationships of the variables with the ordination scores (McCune & Grace 2002). See methods for site types. Data were collected during spring (S) 2010 and autumn (A) 2011.

throughout the study. Simpson indices were only slightly different across SB-Rem, Rem-Iso and SB-Iso sites compared with greater differences in Shannon indices (Table 1).

Vegetation structure

Ordination analysis of vegetation variables illustrated clear separation of sites according to vegetation structure (Figure 4). Remnant native vegetation at Rem-Iso sites was characterised by greater canopy cover (Rem Can), fallen timber/leaf-litter (Rem FT/Lit), and understorey cover (Rem U/S) compared with SB-Rem sites. Cover of remnant native vegetation foliage between 2 and 4 m (Rem F2–4 m) was similar at Rem-Iso and SB-Rem sites, but SB-Rem sites had greater ground-cover within remnant native vegetation (Rem GC). Sites with remnant native vegetation and adjacent saltbush plantings (SB-Rem) clustered between Rem-Iso and SB-Iso sites. Isolated saltbush sites (SB-Iso) were clearly separated from other sites by their lack of higher strata of vegetation, and by their saltbush understorey cover (SB U/S) and greater ground-cover within saltbush plantings (SB GC) compared with SB-Rem sites. Isolated agricultural land sites (Ag-Iso) were well separated from all other sites as they were composed exclusively of agricultural ground-covers (Ag GC). Several sites were also markedly separated during autumn, largely by the removal of agricultural ground-cover post harvest.

Discussion

The present study highlights the potential of saltbush plantings to provide improved habitat and biodiversity conservation value for birds over conventional cropping and pasture. However, the simple monoculture structure of these plantings means that they supported a significantly reduced suite of species compared with that present in remnant native vegetation, and one dominated by generalist and shrubland bird species. Several bird species found only in isolated saltbush plantings were not present at agricultural sites, suggesting that these species would be otherwise absent from tracts of cropping/grazing land. The significantly greater richness and abundance of species associated with remnant native vegetation highlights the importance of these remnants in supporting avifauna within fragmented agricultural landscapes. Despite potential inter-annual variability issues with the short timeframe of this study (see Maron *et al.* 2005), the documented species richness and abundance patterns are reflected in numerous similar but longer-term studies (e.g. Hobbs *et al.* 2003; Kavanagh *et al.* 2007; Loyn *et al.* 2007; Seddon *et al.* 2009; Paton *et al.* 2010), making these results robust and applicable in the longer term.

The richness and abundance of bird species in isolated saltbush plantings (SB-Iso) fell between those found in sites with remnant native vegetation (SB-Rem and Rem-Iso) and agricultural (Ag-Iso) sites. The differences in richness and abundance between sites with remnant native vegetation [SB-Rem (54 species, 60.8 ± 4.9 birds/site/survey) and Rem-Iso (53 species, 54.5 ± 4.5 birds/site/survey)] and isolated saltbush sites [SB-Iso (28 species, 30.0 ± 2.5 birds/site/survey)] were substantial, but of equal note are the differences between the latter (isolated saltbush) and conventional cleared agricultural land (9 species, 3.8 ± 0.7 birds/site/survey) (see Table 1). Such findings match those of Collard *et al.* (2011), who also documented significant differences in the bird assemblage between saltbush plantings and conventional pasture sites, and Seddon *et al.* (2009), who found more diverse bird communities within alley-planted saltbush compared with adjacent paddocks, although the differences were not statistically significant. Various studies (e.g. Arnold 2003; Hobbs *et al.* 2003; Martin *et al.* 2004; Kavanagh *et al.* 2007; Smith 2009) illustrate that perennial farming systems can support markedly greater species richness than conventional land uses, although less than in remnant native vegetation. Furthermore, the use of Shannon and Simpson diversity indices, representing both the number of species and the equitability or evenness of their abundances, confirmed that these patterns were not due simply to high abundances of particular species. Some species may be more detectable than others (Buckland *et al.* 1993), especially in saltbush plantings where dense foliage may obscure some birds, but in the present study repeated visits to sites and surveying in different directions increased the chance of detecting inconspicuous species, thus reducing bias toward more conspicuous birds.

Bird community composition differed substantially between SB-Rem, Rem-Iso, SB-Iso and Ag-Iso sites, a finding parallelled in other studies comparing commercial tree-based habitats (e.g. Burgess 1999; Sanchez-Zapata & Calvo 1999; Hobbs *et al.* 2003). Nearly all bird species recorded in saltbush plantings were recorded also in other vegetation types, and those that were recorded only in saltbush were mostly large, open-country generalists. This suggests that saltbush plantings do not add to bird species richness within the study region, but simply provide habitat for species with relatively flexible resource requirements that are already prevalent in the landscape. This is highly likely, as the most abundant birds within saltbush plantings were generalist species (such as the Australian Magpie and Crested Pigeon) and shrubland species (including the Singing Honeyeater, Variegated Fairy-Wren and White-browed Babbler *Pomatostomus superciliosus*) already widespread throughout the region (Higgins *et al.* 2001; Higgins & Peter 2002; Barrett *et al.* 2003). Similar associations are evident from studies of commercial tree plantations. For example, Munro *et al.* (2011) compared commercial 'woodlot' plantings with mixed-species 'ecological' revegetation, and found that generalists dominated the more simply structured woodlot plantations, but ecological plantings supported a range of more specialised species. Many studies identify generalists as the dominant species in simple-structured plantings such as eucalypt (Fisher & Goldney 1998; Ryan 1999) and pine (Gepp 1976) plantations. Such associations and lack of more specialised (particularly woodland) species are generally indicative of plantings that provide little benefit to native fauna (Munro *et al.* 2011), and this is likely in the present study. Saltbush plantings are therefore of little benefit to many declining woodland species, which are rarely found in simple-structured plantings and require specialised intervention for their recovery (Fisher & Goldney 1998; Kinross 2004; Lindenmayer *et al.* 2010b; Paton *et al.* 2010).

At SB-Rem sites, the Singing Honeyeater and White-browed Babbler showed similar abundances in both the adjacent saltbush and the remnant native vegetation. Because of grazing, the remnant native vegetation at SB-Rem sites was largely devoid of understorey vegetation, a stratum plentiful in saltbush. In addition, several disused White-browed Babbler nests were discovered in adjacent saltbush at two SB-Rem sites. These results suggest that these species may supplement the lack of understorey in remnant native vegetation by using adjacent saltbush plantings. The lack of understorey in the remnant native vegetation at these sites may also have affected the bird assemblage there as species associated with the understorey may have been less abundant as a result.

Shannon and Simpson species diversity indices highlighted a greater diversity of bird species at sites with saltbush plantings adjacent to remnant native vegetation compared with sites where native remnant or planted saltbush vegetation was surrounded by agricultural land. When adjacent to remnant native vegetation, saltbush may increase habitat heterogeneity beyond either remnant native vegetation or saltbush alone, potentially providing habitat and resources for a greater suite of bird species (Benton *et al.* 2003; Haslem & Bennett 2008b). Furthermore, diversity indices at SB-Iso sites were mostly considerably below those at Rem-Iso sites, but significantly higher than at Ag-Iso sites. This indicates that, when isolated from remnant native vegetation, saltbush plantings can provide habitat for a small number of generalist and shrubland birds.

This study shows that birds occur in saltbush (both isolated plantings and those adjacent to remnant native vegetation), but the composition of the bird communities there differs from that in remnant native vegetation. Research is required to determine whether the species in saltbush reside within the plantings or use them as supplementary foraging habitat or as refuges for transient birds. It must focus on comparing birds' foraging behaviours and the resources used, as well as reproduction and survival, in saltbush and native remnant vegetation, as recommended for commercial tree plantings (Hobbs *et al.* 2003; Kavanagh *et al.* 2007). Knowledge of birds' patterns of spatial use is required to determine the degree to which saltbush plantings are used relative to remnant native vegetation.

Conclusions

This study shows that plantings of Old Man Saltbush can at best support a portion of bird species—dominated by open-country generalists and shrubland species—that are typically found in fragmented agricultural landscapes. In addition, it has illustrated the small gains in species richness and abundance that saltbush plantings can yield when planted adjacent to existing remnant native vegetation. Like many similar investigations (e.g. Hobbs *et al.* 2003; Loyn *et al.* 2007), however, this research highlights that remnant native vegetation has the greatest biodiversity value and needs to be conserved in agricultural landscapes.

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Appendix 1. Birds of the northern Murray–Mallee, SA. Mean abundance (*A*, mean number of birds/25-ha site per survey) and incidence (*I*, proportion of surveys in which a bird species was observed) at different site types (in spring 2010 and autumn 2011 combined) for all 67 species documented. Study site types are SB-Rem (remnant native vegetation with adjacent saltbush), Rem-Iso (isolated remnant native vegetation), SB-Iso (isolated saltbush), and Ag-Iso (agricultural land isolated from other vegetation) (see methods).

Species	*Site type*							
	SB-Rem		*Rem-Iso*		*SB-Iso*		*Ag-Iso*	
	A	*I*	*A*	*I*	*A*	*I*	*A*	*I*
Emu *Dromaius novaehollandiae*	0.06	0.00	0.13	0.03	0.00	0.00	0.00	0.00
Stubble Quail *Coturnix pectoralis*	0.00	0.00	0.00	0.00	0.44	0.28	0.13	0.09
Common Bronzewing *Phaps chalcoptera*	0.22	0.13	1.25	0.72	0.00	0.00	0.00	0.00
Crested Pigeon *Ocyphaps lophotes*	2.59	0.59	0.88	0.41	2.38	0.59	0.06	0.03
Diamond Dove *Geopelia cuneata*	0.09	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Australian Owlet-nightjar *Aegotheles cristatus*	0.00	0.00	0.13	0.09	0.00	0.00	0.00	0.00
Black-shouldered Kite *Elanus axillaris*	0.09	0.09	0.03	0.06	0.13	0.09	0.03	0.06
Wedge-tailed Eagle *Aquila audax*	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00
Little Eagle *Hieraaetus morphnoides*	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.00
Nankeen Kestrel *Falco cenchroides*	0.00	0.00	0.00	0.00	0.06	0.03	0.00	0.00
Galah *Eolophus roseicapillus*	4.72	0.78	4.25	0.72	0.44	0.16	0.00	0.00
Cockatiel *Nymphicus hollandicus*	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00
Australian Ringneck *Barnardius zonarius*	5.66	0.08	5.19	0.91	0.16	0.06	0.00	0.00
Blue Bonnet *Northiella haematogaster*	0.13	0.03	0.41	0.03	0.63	0.19	0.06	0.03
Mulga Parrot *Psephotus varius*	0.28	0.06	0.00	0.00	0.00	0.00	0.00	0.00

Appendix 1 continued

Species	*SB-Rem*		*Rem-Iso*		*SB-Iso*		*Ag-Iso*	
	A	*I*	*A*	*I*	*A*	*I*	*A*	*I*
Elegant Parrot *Neophema elegans*	0.00	0.00	0.00	0.00	0.19	0.03	0.00	0.00
Pallid Cuckoo *Cacomantis pallidus*	0.00	0.00	0.09	0.03	0.00	0.00	0.00	0.00
Southern Boobook *Ninox novaeseelandiae*	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00
Rainbow Bee-eater *Merops ornatus*	0.06	0.03	0.31	0.16	0.00	0.00	0.00	0.00
Brown Treecreeper *Climacteris picumnus*	0.69	0.31	1.41	0.31	0.00	0.00	0.00	0.00
Superb Fairy-wren *Malurus cyaneus*	0.34	0.09	0.06	0.03	0.19	0.03	0.00	0.00
Splendid Fairy-wren *Malurus splendens*	0.50	0.16	0.00	0.00	0.00	0.00	0.00	0.00
Variegated Fairy-wren *Malurus lamberti*	1.56	0.41	0.47	0.09	4.31	0.84	0.00	0.00
Weebill *Smicrornis brevirostris*	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Yellow Thornbill *Acanthiza nana*	0.09	0.06	0.22	0.13	0.00	0.00	0.00	0.00
Yellow-rumped Thornbill *Acanthiza chrysorrhoa*	7.88	0.91	8.03	0.78	1.72	0.19	0.00	0.00
Chestnut-rumped Thornbill *Acanthiza uropygialis*	5.69	0.91	6.69	0.69	0.00	0.00	0.00	0.00
Buff-rumped Thornbill *Acanthiza reguloides*	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Inland Thornbill *Acanthiza apicalis*	0.19	0.09	0.09	0.06	0.00	0.00	0.00	0.00
Brown Thornbill *Acanthiza pusilla*	0.22	0.13	0.38	0.13	0.00	0.09	0.00	0.00
Southern Whiteface *Aphelocephala leucopsis*	1.34	0.41	0.44	0.09	0.03	0.03	0.00	0.00
Spotted Pardalote *Pardalotus punctatus*	0.19	0.13	0.28	0.06	0.00	0.00	0.00	0.00
Striated Pardalote *Pardalotus striatus*	1.13	0.22	1.00	0.25	0.00	0.00	0.00	0.00

Appendix 1 continued

Species	*SB-Rem*		*Rem-Iso*		*SB-Iso*		*Ag-Iso*	
	A	*I*	*A*	*I*	*A*	*I*	*A*	*I*
Singing Honeyeater *Lichenostomus virescens*	2.75	0.66	0.25	0.09	5.00	0.88	0.00	0.00
Yellow-plumed Honeyeater *Lichenostomus ornatus*	0.25	0.09	0.41	0.19	0.00	0.00	0.00	0.00
Noisy Miner *Manorina melanocephala*	0.22	0.09	0.22	0.09	0.06	0.03	0.00	0.00
Yellow-throated Miner *Manorina flavigula*	2.19	0.31	0.50	0.13	0.16	0.06	0.00	0.00
Spiny-cheeked Honeyeater *Acanthagenys rufogularis*	0.25	0.16	0.16	0.06	0.00	0.00	0.00	0.00
Red Wattlebird *Anthochaera carunculata*	0.16	0.09	0.19	0.16	0.00	0.00	0.00	0.00
White-fronted Chat *Epthianura albifrons*	0.28	0.06	0.00	0.00	5.50	0.41	0.00	0.00
Brown-headed Honeyeater *Melithreptus brevirostris*	0.56	0.25	0.03	0.03	0.00	0.00	0.00	0.00
White-browed Babbler *Pomatostomus superciliosus*	4.38	0.59	2.41	0.38	1.63	0.25	0.00	0.00
Varied Sittella *Daphoenositta chrysoptera*	0.28	0.06	0.06	0.03	0.00	0.00	0.00	0.00
Black-faced Cuckoo-shrike *Coracina novaehollandiae*	0.03	0.00	0.13	0.06	0.00	0.00	0.00	0.00
Rufous Whistler *Pachycephala rufiventris*	0.31	0.16	0.13	0.09	0.00	0.00	0.00	0.00
Grey Shrike-thrush *Colluricincla harmonica*	0.91	0.44	0.97	0.50	0.06	0.03	0.00	0.00
Masked Woodswallow *Artamus personatus*	0.13	0.09	0.06	0.06	0.00	0.00	0.00	0.00
White-browed Woodswallow *Artamus superciliosus*	0.75	0.03	8.19	0.16	0.00	0.00	0.00	0.00
Dusky Woodswallow *Artamus cyanopterus*	0.03	0.00	0.13	0.09	0.00	0.00	0.00	0.00
Grey Butcherbird *Cracticus torquatus*	0.19	0.09	0.13	0.13	0.00	0.00	0.00	0.00
Australian Magpie *Cracticus tibicen*	3.63	0.84	4.78	0.88	3.19	0.53	2.31	0.41

Appendix 1 continued

Species	*SB-Rem*		*Rem-Iso*		*SB-Iso*		*Ag-Iso*	
	A	*I*	*A*	*I*	*A*	*I*	*A*	*I*
Grey Currawong *Strepera versicolor*	0.16	0.16	0.06	0.03	0.00	0.00	0.00	0.00
Grey Fantail *Rhipidura albiscapa*	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Willie Wagtail *Rhipidura leucophrys*	0.91	0.44	1.06	0.50	0.94	0.22	0.00	0.00
Australian Raven *Corvus coronoides*	0.41	0.25	0.81	0.28	0.13	0.06	0.28	0.09
Restless Flycatcher *Myiagra inquieta*	0.13	0.06	0.22	0.16	0.00	0.00	0.00	0.00
White-winged Chough *Corcorax melanorhamphos*	5.47	0.66	0.03	0.03	0.00	0.00	0.00	0.00
Jacky Winter *Microeca fascinans*	0.94	0.31	0.28	0.19	0.03	0.03	0.00	0.00
Red-capped Robin *Petroica goodenovii*	0.06	0.06	0.19	0.13	0.00	0.00	0.00	0.00
Hooded Robin *Melanodryas cucullata*	0.47	0.19	0.13	0.09	0.00	0.00	0.00	0.00
Eurasian Skylark *Alauda arvensis*	0.09	0.00	0.00	0.00	0.03	0.03	0.00	0.00
Brown Songlark *Cincloramphus cruralis*	0.03	0.03	0.03	0.03	0.00	0.00	0.00	0.00
Welcome Swallow *Hirundo neoxena*	0.28	0.09	0.00	0.00	0.13	0.00	0.09	0.03
Tree Martin *Petrochelidon nigricans*	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00
Common Starling *Sturnus vulgaris*	0.00	0.00	0.06	0.03	0.06	0.03	0.06	0.06
House Sparrow *Passer domesticus*	0.91	0.13	0.00	0.00	0.09	0.03	0.00	0.00
Australasian Pipit *Anthus novaeseelandiae*	0.09	0.03	1.00	0.34	2.31	0.53	0.97	0.31

■