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Planted saltbush (*Atriplex nummularia*) and its value for birds in farming landscapes of the South Australian Murray Mallee

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Summary In the fragmented agricultural landscapes of temperate southern Australia, broad-scale revegetation is underway to address multiple natural resource management issues. In particular, commercially-driven fodder shrub plantings are increasingly being established on non-saline land to fill the summer-autumn feed gap in grazing systems. Little is known of the contribution that these and other planted woody perennial systems make to biodiversity conservation in multifunctional landscapes. In order to address this knowledge gap, a study was conducted in the southern Murray Mallee region of South Australia. Selected ecological indicators, including plant and bird communities, were sampled in spring 2008 and autumn 2009 in five planted saltbush sites and nearby areas of remnant vegetation and improved pasture. In general, remnant vegetation sites had higher biodiversity values than saltbush and pasture sites. Saltbush sites contained a diverse range of plants and birds, including a number of threatened bird species not found in adjacent pasture sites. Plant and bird communities showed significant variation across saltbush, pasture and remnant treatments and significant differences between seasons. This study demonstrates that saltbush plantings can provide at least partial habitat for some native biota within a highly modified agricultural landscape. Further research is being conducted on the way in which biota, such as birds, use available resources in these dynamic ecosystems. An examination of the effects of grazing on biodiversity in saltbush would improve the ability of landholders and regional natural resource management agencies in making informed land management decisions.

Key words: *agricultural landscape,* Atriplex*, biodiversity, birds, farm management, fodder shrubs, saltbush.*

Introduction

Agricultural intensification across the temperate landscapes of southern Australia has resulted in the well-documented fragmentation and extensive degradation of natural vegetation systems, leading to biodiversity loss at local and landscape scales (Hobbs 1993). Efforts to restore habitat and ecosystem function within these landscapes often fall short of achieving the level that is required to meet regional restoration and land management targets. The shortfall may be due to constraints associated with costs, incompatibility with current (short rotation) farming practices, lack of direct economic benefits from habitat restoration activities and inadequate incentives for farmers to change their land management practices (Morrison *et al.* 2008). Limited uptake of revegetation by landholders is paralleled by increasing recognition by ecologists of the importance of elements of these managed production environments for native species (Attwood *et al.* 2009; Prober & Smith 2009).

In marginal farming areas of southern Australia, an increasing number of land managers are using alternative management systems, including perennial fodder shrubs such as saltbush to broaden the feed base over summer and autumn in grazing systems (McKenna *et al.* 2009). The production aspects of growing shrub-based systems such as saltbush in low to moderate rainfall areas are well documented (Bartel & Knight 2000; McKenna *et al.* 2009). However, such plantations also have the potential to play a role in achieving multiple NRM objectives for biodiversity conservation and sustainable land management (Lefroy & Smith 2004). In particular, Prober and Hobbs (2008) advocate a target of 30% of perennial production systems in degraded woodland landscapes, arguing that they can augment resources for native species and help restore viable farm incomes.

Fodder shrub plantings have the potential to enhance landscape-scale heterogeneity and local-scale habitat structural diversity, thus enhancing biodiversity conservation efforts and supplementing existing perennial plantings and stands of native vegetation (Collard & Fisher 2010). Across South Australia, over 7000 ha of saltbush (mostly Old Man Saltbush, *Atriplex nummularia*) was planted between 1999 and 2008 (DWLBC 2008). In the Murray Mallee region of South Australia, an estimated 7120 ha of woody revegetation was planted during the same period, of which 1700 ha (24%) comprised saltbush plantings. A short-term target of 4400 ha was set in 2001 for the establishment of fodder blocks across the Murray Mallee in the regional revegetation plan as part of the Mallee Futures Program (MMLAP 2001), with an overall target of 108 000 ha of newly established perennial vegetation considered necessary to address a variety of NRM issues in the region.

The increase in structural complexity resulting from the establishment of large areas of planted woody vegetation may provide important resources for native biota when considered at a regional level (Munro *et al.* 2007; Smith 2009; Collard & Fisher 2010). Despite its growing presence in the agricultural landscapes of temperate Australia, few published studies have assessed the value of planted saltbush for biodiversity. Exceptions are Norman *et al.* (2008) who examined plant and invertebrate assemblages in saltbush plantings on salt-affected land in south-western Western Australia and Seddon *et al.* (2009) who sampled bird species in planted saltbush alleys in western New South Wales. Despite a number of published articles that have identified the potential benefits of fodder shrub systems for biodiversity (e.g. Millsom 2002; Newton & Yunusa 2002; Lefroy *et al.* 2005), few studies demonstrate which species inhabit these plantings or which resources they are utilising.

This article presents findings from components of a preliminary investigation examining key indicators of biodiversity in Old Man Saltbush plantings. The aim of the study was to improve understanding of the biodiversity and resource values associated with planted saltbush compared with other landscape elements that exist along a gradient of structural complexity and agricultural management intensification. We sought to establish the structural and compositional features of the saltbush vegetation, to compare these features with those of other land uses and to determine which faunal taxa (birds) were associated with these different landscape elements.

Methods

Site selection

Study sites were located within a highly fragmented agricultural landscape near Pinnaroo (35°15′37.31″ S, 140°54′30.47″ E) in the southern Murray Mallee region of South Australia. Potential sites were identified using a combination of spatial imagery (aerial photos) and previously recorded locations of saltbush plantations from a range of databases. Further consultation with saltbush contractors and local farmers also helped to identify potential sites. Within the target area, fifteen study sites (>2 ha) were selected, comprising five replicates of three different land management 'treatments', namely: (i) saltbush plantation – fodder blocks of Old Man saltbush (*A. nummularia*) >3 years old, typically planted in a regular grid pattern with planted or volunteer native and exotic groundcover of grasses and herbs, grazed by sheep annually during late summer and autumn, (ii) improved pasture – areas of fallow cropping land adjacent to sampled saltbush patches, comprising a mix of native and exotic grasses and herbs, grazed by sheep year round, and (iii) remnant vegetation – isolated patches of native mallee vegetation with largely intact canopy and shrub layers and light to moderate grazing and disturbance of understorey and ground cover vegetation by rabbits and infrequently sheep.

Sampling protocols

Sampling was conducted to investigate differences in the structure and composition of the vegetation across treatments and to record the bird species using these respective treatments.

The indicators sampled were selected to represent aspects of biodiversity relevant to fragmented, multiple-use agricultural landscapes. Plants were selected as a measure of local-scale biodiversity and functional values, while birds were chosen as a measure of landscape-scale ecological processes and for their ability to use spatially and temporally variable resources.

All sites were sampled for vegetation and birds across two seasons, spring (October 2008) and autumn (March 2009), coinciding with times of low and high grazing intensity in saltbush.

Vegetation structure and community composition

A modified form of the Bushland Condition Monitoring methodology devised for mallee vegetation associations of the Southern Mount Lofty Ranges (Croft *et al.* 2005) was used to assess vegetation characteristics. Briefly, a representative 30 m by 30 m quadrat was selected within each of the treatments (remnant, saltbush, pasture) at each of the replicate sites in spring 2008. Quadrat locations were recorded using a GPS and marked permanently so that they could be relocated and surveyed again in autumn 2009 to quantify temporal variation in vegetation attributes. Photo points were established at one corner of each vegetation quadrat. The modified vegetation indicators selected from Croft *et al.* (2005) were:

Plant species richness

The plant species present in each quadrat (native and exotic) were recorded, with voucher specimens collected for each species for correct identification.

Structural diversity (Ground cover)

The percentage cover of leaf litter, exposed rock, microphytic crust, native ground cover, exotic ground cover and bare ground was estimated.

Structural diversity (Plant life forms)

The percentage cover of the different plant life forms present in each quadrat was estimated. Life form attributes assessed included trees, shrubs, herbs, mat plants, grasses, tussocks, vines and climbers, mistletoe and ferns.

Bird diversity and community composition

All study sites were surveyed three times in both the spring and autumn seasons for bird abundance and community composition. Surveys were conducted in the morning in fine conditions between 30 min and 4 h after sunrise and consisted of a 2 ha, 20 min survey [based on the 'Birds Australia Atlas' protocol of Barrett *et al.* (2003)]. Bird activity was recorded within a 2 ha area in the habitat of interest, with deviations from a central transect to identify birds. Species presence and abundance were recorded, as well as behavioural observations where possible. During sampling, birds that flew across the transect were considered in the analyses only if they were observed flying in close association with the vegetation of the transect area.

Data analysis

Plant species richness data (native and exotic species combined) and bird abundance and species richness data were compared across seasons and treatments with two-way crossed analysis of variance (ANOVA) using 'Statistix' version 8. Plant and bird species richness data were log $(x + 1)$ transformed to address the distributional and variance assumptions required for linear models.

Analyses of the plant and bird community data (native and exotic species combined) were conducted using routines within the multivariate statistical package PRIMER v6 (Clarke & Gorley 2006). Plant data were in presence/absence form and required no transformation. Bird abundance data were pooled across the three repeat surveys within each season and 4th root transformed to reduce the influence of the abundant species.

Analyses for both plant and bird data were conducted on a resemblance matrix of Bray–Curtis similarity measures (Clarke & Gorley 2006). Graphical analyses of the relationships between replicate samples within the three treatments and across the two seasons were examined using the non-metric multi-dimensional scaling (nMDS) routine.

To determine if there were differences in plant and bird composition and abundance resulting from treatment and/or seasonal effects, the data were analysed using the PERMANOVA+ procedure within PRIMER v6. PERMANOVA+ is a permutational multivariate analysis of variance that is free from the assumptions of traditional parametric ANOVA procedures and allows analysis of complex experimental designs (Anderson 2001; McArdle & Anderson 2001). The data were analysed as a 2-factor fixed model design, with season and treatments as factors. The Monte Carlo permutation procedure within PERMANOVA+ was used to calculate the significance in each analysis. Where differences were identified, pairwise comparisons were conducted for treatments within each season, and seasons within each treatment.

Where PERMANOVA+ revealed significant differences between treatments or seasons, the bird species most responsible for these differences were then identified using the Similarity Percentage (SIMPER) routine (Clarke & Gorley 2006).

Results

Vegetation composition and structure

Overall, 89 plant species were recorded across all sites during spring and autumn sampling combined (Appendix S1). Of the 82 species that were able to be identified, 35 were native and 47 were exotic (Table 1). Purple Crassula (*Crassula peduncularis*) is listed as 'Rare' in South Australia and was recorded in three of the remnant sites in spring. Eighty-one species were recorded across all sites in spring 2008 and 35 species were recorded in autumn 2009. A total of 58 species was recorded in remnant sites (39 were exclusively in remnants), 38 species in saltbush sites (10 were exclusively in saltbush) and 35 species in pasture sites (11 were exclusively in pasture) across both seasons (Table 1).

Mean plant species richness (native + exotic) ranged from 23.4 per quadrat in remnant vegetation treatments in spring 2008 to 3.4 per quadrat in saltbush treatments in autumn 2009 (Table 1). There were significant differences in species richness (ANOVA, $P < 0.05$) between treatments across seasons and between seasons across all treatments, although there was no significant interaction between main effects.

Mean plant species richness was significantly higher in remnants than in saltbush or pasture in both seasons. Mean species richness in saltbush was significantly higher than that in pasture in spring 2008, but not significantly different in autumn 2009 (*a priori* contrasts, $P < 0.05$).

Changes in the vegetation structure (ground cover and plant life form cover) are evident from photo point images taken in spring 2008 and autumn 2009 (Fig. 1). Grazing of the saltbush sites in late summer and early autumn led to almost complete defoliation of the saltbush plants and the removal of most of the 'volunteer' herbaceous ground cover components between saltbush rows.

In spring 2008, the type and relative amount of ground cover varied between treatments (Table 1). Remnants had a higher proportion of microphytic crust and a lower proportion of introduced ground cover compared with saltbush and pasture treatments.

In autumn 2009, the relative cover of leaf litter increased in all treatments and the amount of exotic cover in saltbush and pasture treatments diminished compared with cover in spring 2008 (Table 1). Microphytic crust was present only in remnant sites in autumn.

More plant life forms were present in remnant sites than saltbush or pasture in both spring 2008 and autumn 2009 (Table 1). The reduction in total cover in saltbush and pasture sites in autumn 2009 was largely due to a reduction in cover of herbs and low grasses. Tall shrubs made up the highest proportion of plant life form cover in remnants in both spring and autumn and were absent from all other treatments.

The analysis of the vegetation data using nMDS revealed that the vegetation assemblages were generally well separated across treatments with the pasture being most dissimilar to the remnant vegetation and the saltbush intermediate to the two (Fig. 2). There was also evidence of differences in vegetation assemblages across seasons within each of the treatments and a close similarity between the saltbush and pasture treatments in the spring season (Fig. 2).

The two-way crossed PERMANOVA+ analysis confirmed the pattern evident in the nMDS. There were significant differences between treatments ($F = 7.47$, $P = 0.0001$) and seasons ($F = 10.61$, $P = 0.0001$), although the significant interaction term ($F = 2.07$, $P = 0.0193$) suggested that these differences are dependent on which treatment and season combination is examined.

Subsequent pair-wise tests revealed that within the autumn season all treatments were significantly different from one another. In the spring season, the remnants were different from both the saltbush and pasture, but the saltbush and pasture treatments were not significantly different. The pair-wise tests across

Table 1. Summary of vegetation data recorded from five replicate sites (30 × 30 m) in remnant, saltbush and pasture treatments in spring 2008 and autumn 2009

Cumulative plant species richness									
Treatment	**Remnant**		**Saltbush**		**Pasture**		**All treatments†**		
Season	**Spring 08**	**Autumn 09**	**Spring 08**	**Autumn 09**	**Spring 08**	**Autumn 09**	**Spring 08**	**Autumn 09**	**Grand Total**
Native species	31	17	4	2	3	2	33	19	35
Exotic species	19	2	32	6	23	11	41	15	47
Unknown	7	1	1	0	1	0	7	1	7
All species	57	20	37	8	27	13	81	35	–
Total species richness (spring + autumn)‡	58 [39]		38 [10]		35 [11]			89	
Mean species richness§	23.4 (1.5)^{a}	7.8 (0.6)^{b}	17.0 (1.1)^{c}	3.4 (0.4)^{d}	10.0 (2.5)^{e}	4.0 (1.3)^{d}	–	–	–
Ground cover¶									
Leaf litter	16.2 (3.7)	36.0 (6.0)	21.2 (10.8)	32.8 (14.6)	15.8 (6.3)	29.4 (13.0)	–	–	–
Microphytic crust	28.8 (6.7)	32.0 (5.1)	1.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0)	–	–	–
Native cover	2.2 (0.8)	2.4 (1.1)	1.0 (0.0)	0.2 (0.2)	1.0 (0.0)	4.0 (4.0)	–	–	–
Exotic cover	11.8 (4.7)	1.6 (0.9)	38.0 (8.6)	1.8 (0.8)	57.6 (14.6)	10.2 (8.7)	–	–	–
Plant life forms									
Tall mallee	13.8 (4.4)	18.6 (6.9)					–	–	–
Small mallee	10.5 (2.1)	10.5 (1.7)					–	–	–
Tall shrubs	17.8 (6.0)	27.2 (10.5)					–	–	–
Medium shrubs	3.5 (1.5)	1.6 (0.7)	34.0 (9.1)	34 (9.8)			–	–	–
Small shrubs	1.0 (0)		7.0 (0.0)	2.2 (2.0)			–	–	–
Herbs	8.3 (2.9)	1.8 (0.9)	17.0 (1.2)	1.8 (0.8)	30.2 (8.0)	8.2 (4.1)	–	–	–
Mat plants	1.0 (0)						–	–	–
Low grasses	6.8 (3.5)	1.6 (0.9)	17.4 (4.2)	0.8 (0.2)	38.0 (3.4)	6.4 (5.9)	–	–	–
Low tussocks	1.5 (0.5)	0.4 (0.2)	2.0 (1.0)				–	–	–
Vines, Climbers	1.0 (0)	0.8 (0.2)	1.0 (0)				–	–	–
Count of plant life forms	10	8	6	4	2	2	–	–	–

†This column contains cumulative totals of species recorded across all treatments. ‡This row contains cumulative totals of species recorded in both spring 2008 and autumn 2009. Values in square parentheses [ ] are the number of plant species recorded exclusively in each treatment. §Species richness is given as mean of five samples per treatment (±1 standard error). Values sharing the same letter are not significantly different ¶Ground cover components are given as mean percentage cover of five samples per treatment (±standard error).

Figure 1. Photo point of the same saltbush planting prior to grazing (Spring 2008) and after grazing (Autumn 2009). The right hand photo taken in 2009 shows that an almost complete defoliation of saltbush plants and a reduction in volunteer groundcover occured following grazing.

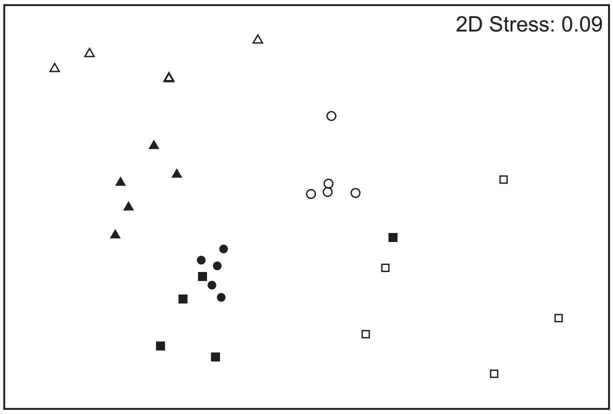

Figure 2. Two-dimensional ordination (non-metric multi-dimensional scaling) of plant presence/absence data showing spring (shaded) and autumn (open) samples within each treatment. ▲/Δ = remnant, ●/○ = saltbush, ■/□= pasture.

seasons within each treatment revealed significant seasonal differences ($P < 0.05$) in vegetation from spring to autumn in all treatments.

Bird community composition and structure

A total of 57 bird species was observed during spring and autumn surveys (Appendix S2). Of these species, 52 were recorded in spring 2008 and 35 species were recorded during autumn 2009 surveys (Table 2). Remnant, saltbush and pasture treatments contained a total of 50, 24 and 12 species respectively across both seasons. Five species that were recorded in the autumn surveys were not recorded in spring and 22 species that were recorded during spring surveys were not recorded during autumn (Table 2).

Thirty-two bird species were recorded only in remnant sites, four bird species: the Elegant Parrot (*Neophema elegans*), Singing Honeyeater (*Lichenostomus virescens*), Magpie-Lark (*Grallina cyanoleuca*) and Australian Kestrel (*Falco cenchroides*) were found only in saltbush sites and one bird species, the Brown Songlark (*Cinclorhamphus cruralis*) was found only in pasture sites across both seasons. Nine species were recorded in at least one site across all three treatments (Appendix S2).

Table 2. Number of bird species (native and introduced) recorded in all remnants, saltbush and pasture sites in spring 2008 and autumn 2009. Numbers in parentheses indicate the number of species found exclusively in each treatment. Row and column totals are cumulative

	Remnant	Saltbush	Pasture	Total (cumulative)
Spring 2008	45 (33)	17 (4)	10 (1)	52 (22)
Autumn 2009	29 (19)	15 (3)	6 (1)	35 (5)
Total (spring and autumn)	50 (32)	24 (4)	12 (1)	57

Four species listed as 'Rare' under Schedule 9 of the South Australian *National Parks and Wildlife Act 1972* were recorded during the survey period. The Elegant Parrot was recorded in two of the saltbush sites in spring; the Hooded Robin (*Melanodryas cucullata cucullata*) was recorded in one remnant site in spring and in one saltbush site in autumn; the Restless Flycatcher (*Myiagra inquieta*) was recorded in one remnant site in spring and autumn and one saltbush site in spring; and the White-winged Chough (*Corcorax melanorhamphos*) was recorded in only one remnant site in autumn (Appendix S2). Two introduced bird species, the Common Starling (*Sturnus vulgaris*) and the House Sparrow (*Passer domesticus*) were recorded infrequently across all treatments in both seasons.

Despite the coarse seasonal differences evident from Table 2, there were no statistically significant differences between seasons (across all treatments) for bird species richness (ANOVA, $F = 2.45$, $P > 0.05$). However, using combined seasonal data, there were significant differences across all treatments for species richness (ANOVA, $F = 26.04$, $P < 0.05$). Mean species richness was significantly higher in remnant sites than in saltbush or pasture. Saltbush sites had significantly higher mean bird species richness than pasture sites ($P < 0.05$, Fig. 3).

There was a significant difference in overall bird abundance between seasons (ANOVA, $F = 6.89$, $P < 0.05$) and across all treatments (ANOVA, $F = 8.88$, $P < 0.05$). There was no significant difference in total bird abundance between remnant and saltbush sites and remnant and pasture sites in spring 2009 ($P > 0.05$). In spring, pasture sites had significantly lower total bird abundance than saltbush sites ($P < 0.05$), with similar trends apparent across treatments in autumn 2009.

The analysis of the avian data using nMDS revealed that the bird assemblages were generally separated across land

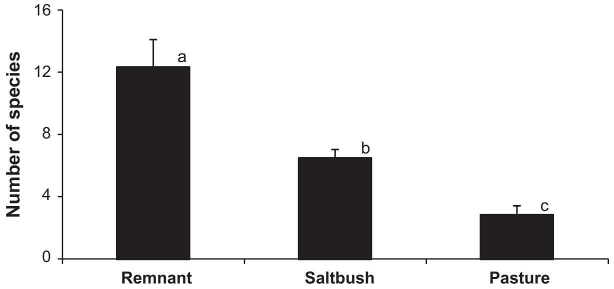

Figure 3. Mean (±1 standard error) values for bird species richness (combined seasonal data) in remnant, saltbush and pasture treatments. Means sharing the same letter are not significantly different (*a priori* contrasts $P > 0.05$).

management treatments. There was however, no strong indication of differences across seasons within each treatment (Fig. 4).

PERMANOVA+ confirmed the general pattern displayed in the nMDS, revealing significant differences between bird assemblages in the different land use treatments ($F = 6.47$, $P = 0.0001$) but no seasonal differences ($F = 0.77$, $P = 0.18$). There was however, a significant treatment by season interaction term ($F = 1.82$, $P = 0.0185$), indicating that differences in treatments were dependent on the season in which the surveys were conducted.

Pairwise tests of the levels of treatment within season revealed that the bird assemblages in the saltbush and pasture treatments were not significantly different in autumn ($P > 0.05$). Bird assemblages in all other treatments were significantly different in both the spring and autumn seasons ($P < 0.05$).

A similar suite of bird species contributed to a large proportion of the dissimilarity between sites in the different treatments and seasons (Appendix S3). Species contributing most to the dissimilarity between two treatments were typically present in both treatments, with differences due to higher or lower average abundance. Exceptions to this pattern were those species restricted to remnant sites such as the Yellow Thornbill (*Acanthiza nana*), Common Bronzewing (*Phaps chalcoptera*), Spotted Pardalote (*Pardalotus punctatus*) and Red Wattlebird (*Anthochaera carunculata*).

Discussion

Potential biodiversity values of saltbush

Naturally occurring chenopod shrublands in semi-arid areas provide habitat and resources for a diverse range of native fauna. For example, biological surveys of the Olary Plains in South Australia found mammal, bird and reptile groups that are associated with different types of chenopod shrubland (Forward & Robinson 1996; Playfair *et al.* 1997). The dependence of some native species on shrubby vegetation systems suggests that planting such systems in agricultural areas may at least partially satisfy the habitat and resource requirements of these species. Changes to less intensive land management, coupled with predicted climate variability, may also provide opportunities for new species to colonise or move through the landscape.

Despite the fact that the study area lies approximately 100 km south of the natural distribution of Old Man Saltbush, a number of native bird species were recorded in saltbush plantings that were not observed in adjacent areas of pasture. It is uncertain whether these species are resident in the saltbush patches or if they are opportunistically and/or temporarily using resources provided by the saltbush. The current findings suggest that elements of these planted systems may provide at least partial habitat for native bird species, compared with more structurally simple and/or complex landscape elements.

Of particular interest was the observation of nesting Orange and White-fronted Chats in only saltbush sites during the spring 2008 survey, providing evidence of the potential value of these areas for native bird species that are naturally associated with shrub-layer vegetation. Seddon *et al.* (2009) also observed two species of chat (Orange and Crimson) feeding and sheltering in planted saltbush alleys in non-saline areas of the NSW Central Western Plains. The high abundance of such eruptive bird species is likely to change seasonally and annually, depending on climatic conditions in the study landscape and in surrounding areas. Conditions during sampling were typical of the seasonal climatic patterns of the region.

Most of the bird species recorded in saltbush were also recorded in one or both of the other two land uses, suggesting a degree of plasticity in their

Figure 4. Two-dimensional ordination (non-metric multi-dimensional scaling) of fourth root transformed bird abundance data showing each treatment. ▲/△ = remnant, ●/○ = saltbush, ■/□ = pasture. Shaded shapes are spring 2008 surveys and unshaded shapes are autumn 2009 surveys.

behaviour and resource requirements in relation to the agricultural matrix. A large proportion of these species (42%) were habitat 'Generalists' (*sensu* Attwood *et al.* 2009) with very few 'Woodland specialists' observed in saltbush sites. The habitat requirements of the latter species are unlikely to be met by a grazed, monoculture of saltbush. Similarly, the small, isolated and modified remnants sampled in this study contained fewer species than could be expected in larger and less disturbed vegetation remnants in the landscape (e.g. Billiat or Ngarkat Conservation Parks).

The observations of three threatened bird species (the Elegant Parrot, Hooded Robin and Restless Flycatcher) and a range of other native birds in saltbush plantings in this study support the notion that these 'novel' ecosystems (*sensu* Hobbs *et al.* 2008) may also complement existing fragmented vegetation communities and thus potentially contribute to regional biodiversity conservation. These threatened species are not generally associated with shrubland habitat, rather they are typically found in habitat containing trees. Their presence in saltbush sites and complete absence from adjacent pasture sites, suggests that the saltbush may be providing them resources in the form of food, shelter or structure for perching. These threatened bird species exhibit features and behaviours consistent with 'Woodland generalists' proposed by Attwood *et al.* (2009).

Our findings are similar to those of Seddon *et al.* (2009) who showed higher species richness of birds in remnant vegetation compared with three year old saltbush alley plantings in central western New South Wales. Unlike these authors who found no difference in the number of bird species between saltbush and crop rotation (conventional) sites, we found significantly higher bird species richness in saltbush than in pasture treatments. Seddon *et al.* (2009) also sampled saltbush alleys (i.e. 15 m wide saltbush strips, alternating with 50 m wide strips of pasture), whereas contiguous blocks greater than 2 ha were sampled in the present study. The floristic diversity and structural complexity of the saltbush plantings compared with adjacent areas of pasture is likely to be the reason for this difference (Collard *et al.* 2009a).

Resources available to birds in planted saltbush at different spatial and temporal scales

The preliminary observations from this study suggest that planted saltbush vegetation may play a role in providing resources for a range of native bird species, some of which are of conservation significance. Collard and Fisher (2010) propose some potential mechanisms by which planted fodder shrub systems can provide benefits to native fauna at different spatial scales. These benefits depend on the sheltering, foraging and nesting requirements of individual species at a site scale and the mobility, phenotypic plasticity and resilience of populations at a landscape scale. On-going investigations are underway on the specific resources that planted saltbush offers to different bird species and whether the plantings provide more than just an opportunistic resting stop or stepping stone between preferred habitats. Furthermore, seasonal differences in bird community composition suggest temporal variability and it is unclear how individual species respond to this.

Site-level attributes and wider landscape context are both important determinants of species' occurrence in agricultural landscapes (Lindenmayer & Hobbs 2004; Collard *et al.* 2009b). In particular, structural complexity is an important factor affecting the occurrence and abundance of different fauna species (Fischer *et al.* 2004; Munro *et al.* 2007). Findings from the present study suggest that the higher structural complexity of saltbush plantings (when compared with surrounding intensively managed pastures) and changes to vegetation structure caused by seasonal and/or management influences may have a significant effect on bird communities. As identified by other authors (e.g. Fischer *et al.* 2004; Munro *et al.* 2007), more information is needed on landscape factors as well as the habitat and resource requirements of different species to better inform the placement of planted woody perennial systems in farming landscapes.

Management considerations

Saltbush plantings are primarily established by land managers on non-saline lands in southern Australia as fodder crops. Intense grazing in these systems, typically during late summer and early autumn, is reflected in the large seasonal differences shown by plant and bird communities in the present study. Some of these differences may be due to the effects of season alone, rather than grazing management or a combination of both. Saltbush plants are able to recover from this annual heavy grazing pressure, however the prolonged reduction in vegetative structure and groundcover may affect other plant and animal species in different ways. For example, bird species associated with dense, shrubby vegetation (e.g. Inland Thornbill, *Acanthiza apicalis*) may be displaced or unable to survive while those favouring more open structure (e.g. Australian Magpie, *Cracticus tibicen*) may benefit. The timing and intensity of grazing in saltbush could be managed to better suit the requirements of some of these species, particularly those of higher conservation significance.

We have shown that saltbush plantings can enhance vegetation structural complexity compared with existing pasture systems and thus potentially provide resources for native fauna. Furthermore, 'volunteer' or planted groundcover components between saltbush rows have the potential to improve stock-carrying capacity, reduce soil erosion and enhance floristic diversity (Norman *et al.* 2008). The majority of the volunteer species present in the sampled saltbush plantings, including Old Man Saltbush, was exotic in origin and a number of them were declared weeds in South Australia. Whilst they may provide some resources for native fauna, consideration needs to be given to the possible consequences of weeds and potentially other vertebrate and invertebrate pests in saltbush plantings and the impacts of pest management on biodiversity values at local and regional scales.

Environmental benefits of saltbush plantings may be enhanced by other management improvements such as changes to the timing and intensity of grazing or by incorporating more than one fodder shrub species. For example, mixed shrub-based forage systems are currently being explored as viable enterprises that are potentially more resilient in the face of climate change (Hobbs *et al.* 2009). The high productivity of saltbush on low fertility soils also makes it a potentially useful species for biosequestration in the light of emerging carbon markets (Hobbs 2009).

Conclusion and future directions

The results presented here contribute to a greater understanding of the value of planted saltbush systems for biodiversity, compared with other better known landscape elements. We sampled only five sites in each land management treatment over the course of a year within a relatively small area of the South Australian Murray Mallee. There was also considerable variation in grazing management of saltbush and pasture sites, as well as differences in time since establishment for saltbush. Despite these experimental inconsistencies, statistically significant differences between treatments and seasons were detected for both plant and bird communities.

Opportunities exist to further quantify the biodiversity values of saltbush plantings in the study landscape and elsewhere. Subsequent work in the Murray Mallee is beginning to uncover details about how birds are actually using the resources on offer in these saltbush systems (e.g. food, shelter, feeding substrates, nesting material). Combining data on local-scale attributes (e.g. groundcover, plant life forms, grazing intensity) with landscape context information (e.g. composition and configuration of surrounding landscape elements), may also help to explain the observed patterns in faunal communities in planted saltbush systems. Such information would be useful to guide future decisions made by land owners and regional natural resource management bodies on the strategic placement and on-ground management of perennial fodder shrubs.

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Supporting Information

Additional Supporting Information may be found in the online version of this article.

Appendix S1. Plant species recorded in each land use treatment.

Appendix S2. Bird species recorded across all sampled land uses and seasons.

Appendix S3. Average dissimilarity between treatments and the average abundance of the bird species contributing up to 30% of the dissimilarity between treatments. Species are listed in decreasing order of their importance in discriminating between the two sets of samples.