# DWLBC Technical Report

## Biodiversity value of saltbush (*Atriplex nummularia*) plantings in mixed farming landscapes of the Southern Mallee, South Australia

Government of South Australia
Department of Water, Land and Biodiversity Conservation

DWLBC Technical Report 2009/27

# Biodiversity value of saltbush (*Atriplex nummularia*) plantings in mixed farming landscapes of the Southern Mallee, South Australia

**Stuart Collard, Andrew Fisher, David McKenna**

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

**November 2009**

**DWLBC Technical Report 2009/27**

NRM Research Alliance

Government of South Australia
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**Land and Biodiversity Conservation Division**

Department of Water, Land and Biodiversity Conservation

GPO Box 2834, Adelaide SA 5001

| | | |
|---|---|---|
| Telephone | National | (08) 8303 9531 |
| | International | +61 8 8303 9531 |
| Fax | National | (08) 8303 9555 |
| | International | +61 8 8303 9555 |
| Website | www.dwlbc.sa.gov.au | |




ISBN 978-1-921528-62-0

**Preferred way to cite this publication**

Collard, S.J., Fisher, A.M. and McKenna, D.J. (2009). Biodiversity value of saltbush (*Atriplex nummularia*) plantings in mixed farming landscapes of the Southern Mallee, South Australia. DWLBC Technical Report 2009/27, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Adelaide.

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# FOREWORD

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

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

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

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

# ACKNOWLEDGEMENTS

We are grateful to the following people: landholders who allowed access to sampling sites; Rowena Danks (Murray-Mallee Local Action Planning Group), Ray O'Malley, Greg Sweeney (SARDI) and Mike Bennell for assistance with site selection; Department for Environment and Heritage for supplying aerial photography; Ann-Marie Mabarrack and Kate Willing (Rural Solutions SA) for GIS and mapping support and Zita Stokes, Rob Wallace, Patricia Hill and Melanie Carson for reviewing the document. Thanks to staff from the Land and Biodiversity Conservation Division, DWLBC for their support and technical assistance. Thanks also to Richard Glatz, Glenys Wood and Helen De Graaf from SARDI Entomology for technical support and identification of invertebrates.

This work was supported through funding from the Complementary State NRM Program 2008/2009 as one of a suite of projects coordinated by the NRM Research Alliance.

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# SUMMARY

In the highly 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 pilot study was conducted in the southern Murray Mallee region of South Australia. Selected ecological indicators, including plant, bird and invertebrate communities were sampled in spring 2008 and autumn 2009 in five planted saltbush sites and nearby areas of remnant vegetation and improved pasture.

Plant and bird communities showed significant variation across saltbush, pasture and remnant treatments and significant differences between seasons. In general, remnant vegetation sites had higher biodiversity values than saltbush and pasture sites. Saltbush sites contained a diverse range of plant, bird and invertebrate taxa, including a number of threatened bird species not found in adjacent pasture sites. Invertebrates captured in saltbush sites included a mix of species known to be beneficial to agriculture as well as a number of known pest species.

This pilot study demonstrates that saltbush plantings can provide at least partial habitat for some native biota within a highly modified agricultural landscape. Further work is needed on the way in which biota such as birds use resources in these ‘novel’ ecosystems. An examination of the effects of grazing on biodiversity in saltbush would assist landholders and regional NRM groups in making informed land management decisions.

# 1. INTRODUCTION

The temperate landscapes of southern Australia have undergone extensive transformation to agriculture following European settlement. Subsequent intensive land use has resulted in widespread habitat loss and degradation leading to a loss of biodiversity at local and landscape scales (Hobbs 1993). Efforts to restore habitat and ecosystem function within these landscapes using ‘Landcare-style’ plantings are falling short of achieving the level of landscape transformation 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 (Ward et al. 2005; 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 (Craig et al. 2000; Hobbs et al. 2008; Attwood et al. 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 and 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 and 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. Across South Australia, over 7 000 hectares of saltbush (mostly Old Man Saltbush, *Atriplex nummularia*) was planted between 1999 and 2008 (Cheers 2009). In the Murray Mallee region of South Australia alone, an estimated 7 120 hectares of woody revegetation was planted during the same period, of which 5 010 ha (70%) comprised mixed native species and 1 700 ha (24%) comprised saltbush plantings (Table 1). A short-term target of 4 400 ha was set for the establishment of fodder blocks across the Murray Mallee in the regional revegetation plan as part of the Mallee Futures Program (http://www.malleefutures.org.au/), 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.

**Table 1. Revegetation activities in the South Australian Murray Mallee region, adapted from Cheers (2009). Areas are cumulative totals from data collected annually from 1999-2008.**

| Type of revegetation | Total (ha) | % |
|---|---|---|
| Native/ Indigenous | 5010 | 71 |
| Farm forestry | 200 | 3 |
| Saltbush | 1700 | 24 |
| Tagasaste | 80 | 1 |
| Product species | 20 | <1 |
| Softwood forestry | 80 | 1 |
| Total | 7120 | 100 |

The increase in structural complexity that results from large areas of planted woody vegetation may provide important resources for native biota when considered at regional level (Munro et al. 2007). Evident from Table 1 is the relative importance of saltbush fodder plantings in the Murray Mallee landscape, compared with other types of perennial planting. However, despite its growing presence in the landscape, few published studies have assessed the value of planted saltbush for biodiversity (but in WA, Norman et al. 2008; and in NSW, Seddon et al. 2009 have explored these factors). While a number of published articles identify the potential benefits of these systems for biodiversity (e.g. Millsom 2002; Newton and Yunusa 2002; LeFroy et al. 2005), few studies demonstrate which species are actually found in these plantings.

This report presents findings of a pilot study examining selected indicators of biodiversity in Old Man Saltbush plantings. The aim of the study was to improve our understanding of the biodiversity and ecological functions associated with planted saltbush compared with other land uses 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 other land uses and to determine which bird species and invertebrate taxa are associated with these different landscape elements.

# 2. METHODS

## 2.1 SITE SELECTION

The target area for this study was the southern Murray Mallee region (Figure 1). 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 were selected, comprising five replicates of three different land management "treatments". The treatments were selected to reflect different levels of structural complexity and land management intensity and comprised 'saltbush plantation', 'improved pasture' and 'remnant vegetation'. It was important to have each of the treatment areas in excess of 2 ha in order to accommodate the survey protocols outlined below. Several sites were ruled out following ground-truthing because this criterion could not be satisfied. It was particularly difficult to find remnant vegetation patches in the same landform as the saltbush of suitable size and quality to be included in the study.

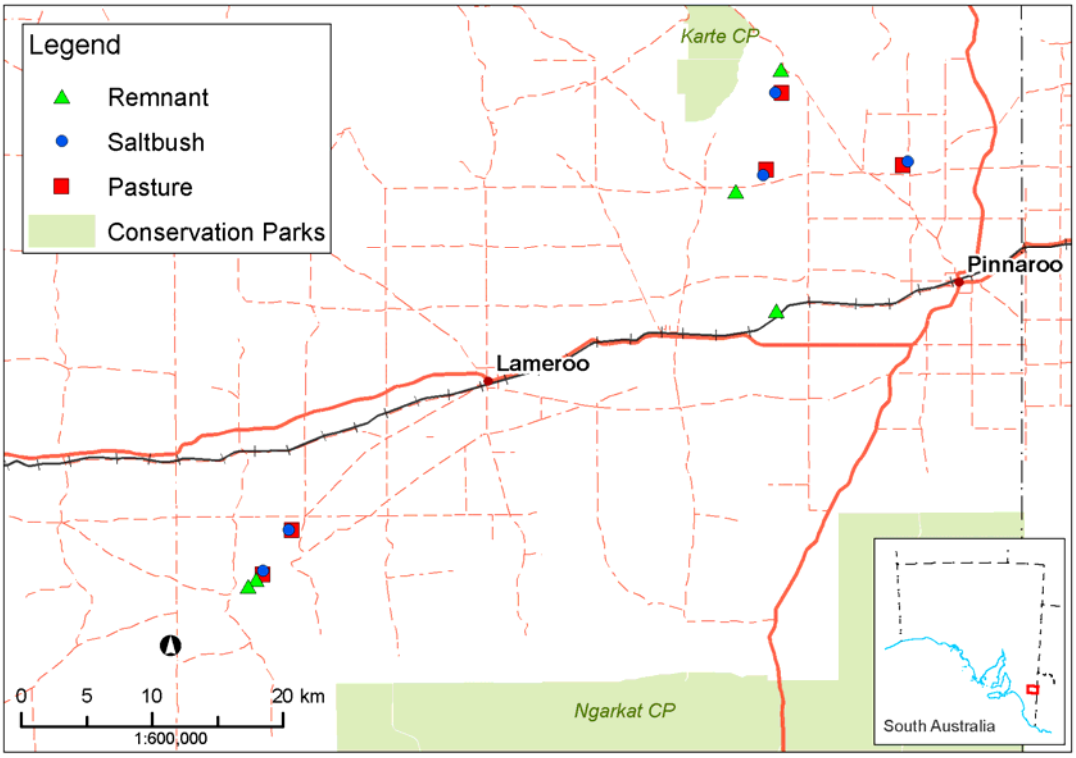


**Figure 1. Location of the study sites in the southern Murray Mallee region, South Australia. (Data source: Topo-250k (1999) from GeoScience Aust.; Parks from DEH).**

## 2.2 SAMPLING PROTOCOLS

Once the study sites had been selected, sampling of ecological indicators was conducted to investigate differences in the structure and composition of the vegetation, bird and invertebrate communities. These indicators were selected to represent aspects of biodiversity relevant to fragmented, multiple-use agricultural landscapes. Birds were chosen as a measure of landscape-scale ecological processes and to make use of spatially and temporally variable resources, while plants and invertebrates were selected as a measure of site-scale biodiversity and functional values. Sampling was conducted in two different seasons (spring and autumn), to observe changes in seasonal abundance of species and grazing management.

All sites were sampled for vegetation and birds in October 2008 (spring) and again in March 2009 (autumn), coinciding with times of low and high grazing intensity respectively. Invertebrates were sampled at only three sites in each treatment in both seasons (Table 2), however invertebrates from the autumn 2009 sampling period have not yet been identified and will not be considered further in this report.

**Table 2. Sampling regime in remnant, saltbush and pasture treatments during spring 2008 and autumn 2009. B = birds, V = vegetation, I = invertebrate sticky trap**

| | Spring 2008 | | | Autumn 2009 | | |
|---|---|---|---|---|---|---|
| **Replicate*** | **Remnant** | **Saltbush** | **Pasture** | **Remnant** | **Saltbush** | **Pasture** |
| **E1** | B,V,I | B,V,I | B,V,I | B,V,I | B,V,I | B,V,I |
| **E2** | B,V,I | B,V,I | B,V,I | B,V,I | B,V,I | B,V,I |
| **S** | B,V,I | B,V,I | B,V,I | B,V,I | B,V,I | B,V,I |
| **H** | B,V | B,V | B,V | B,V | B,V | B,V |
| **B** | B,V | B,V | B,V | B,V | B,V | B,V |

* Replicate refers to a cluster of the three different treatment types

## *2.3 VEGETATION STRUCTURE AND COMMUNITY COMPOSITION*

To assess the vegetation characteristics of our study sites, we used a modified form of the Bushland Condition Monitoring methodology devised for mallee vegetation associations of the Southern Mount Lofty Ranges (Croft et al. 2005). Due to the lack of relevance of some of the measures to highly modified farming systems, only the 'plant species diversity' and 'structural diversity' assessments from this method were conducted in this project. Native and exotic plant species were included in both species counts and cover estimates.

Briefly, a representative 30 m x 30 m quadrat was selected within each of the treatments (remnant, saltbush, pasture) at each of the replicate sites in spring 2008. The location of each of these quadrats was recorded using a GPS 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 (Appendix 1). The modified vegetation indicators selected from Croft et al. (2005) were:

**Indicator 1** – *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.

**Indicator 2** – *Structural Diversity A: Ground cover*

The percentage cover of leaf litter, exposed rock, microphytic crust, native ground cover, exotic ground cover and bare ground were estimated after Croft et al. (2005).

**Indicator 3** – *Structural Diversity B: 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.

## 2.4 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 period between 30 minutes after sunrise and 11:00 am and consisted of a 2 ha, 20 minute survey (following the ‘Birds Australia Atlas’ protocol of Barrett et al. 2003). This method involves recording bird activity in the 50 m either side of a 200 m long transect through the habitat of interest, with deviations from the central transect to identify birds. Species presence and abundance were recorded, as well as behavioural observations where possible. Birds that flew across the transect during sampling were considered in the analyses only if they were observed flying in close association with the vegetation of the transect area (i.e. within 5 m), following the methodology of Collard et al. (2008). Birds were included in the counts if they were flushed from within the transect.

## 2.5 INVERTEBRATE DIVERSITY AND COMMUNITY COMPOSITION

Flying invertebrates were sampled at three sites in each treatment (i.e. a total of nine sites) in both the spring 2008 and autumn 2009 surveys (Table 2). Sampling consisted of 5 replicate yellow sticky traps (Bugs for Bugs™) at each site, placed to represent the heterogeneity of vegetation within each of the 30 m x 30 m vegetation monitoring quadrats. These traps were suspended from inverted L-shaped wire supports with the bottom of the traps approximately 20 cm from the ground. Traps were left in place for 48 hours before being collected and stored for later identification and sorting. Invertebrates were generally identified to order, although some of the better-known taxa were identified to family, genus or species where possible. Invertebrates were grouped according to whether they were known to be beneficial to agriculture, are agricultural pests, or have unknown impacts on agriculture.

## 2.6 UNIVARIATE ANALYSES

Bird abundance and species richness data and plant species richness data (native and exotic species combined) were compared across seasons and treatments with two-way crossed analysis of variance (ANOVA) design using 'Statistix' version 8. Normality was tested using the Shapiro-Wilks test. Homogeneity of variances was tested with the Levene Test to see whether the assumption of equal variances was appropriate. After inspection of distributions, bird and plant species richness data were log (x+1) transformed to address the distributional and variance assumptions required for linear models.

## *2.7 MULTIVARIATE ANALYSES*

Analyses of the plant, bird and invertebrate data (native and exotic species combined) were conducted using the multivariate statistical package PRIMER v6 (Clark & Gorley 2006). Plant presence/absence data were analysed following generation of a resemblance matrix based on Bray-Curtis measures of similarity. Graphical analysis of the relationships between replicate samples were examined using the non-metric multi-dimensional scaling (nMDS) routine. Differences between treatments and seasons were tested using two-way Analysis of Similarity (ANOSIM) with associated pair-wise tests between treatment and season groups. Where significant differences were detected between treatments or seasons, the species most responsible for these differences were then analysed using SIMPER (Clark & Gorley 2006).

Bird community composition and abundance data were pooled across the three repeat surveys within each season and were $4^{th}$ root transformed to reduce the influence of the abundant species. Analyses were then conducted on a resemblance matrix of Bray-Curtis similarity measures (Clark & Gorley 2006). The relationship between site x treatment groups was then analysed using an nMDS plot. To look for differences between treatment groups and seasons we also ran the ANOSIM procedure with associated pair-wise tests between treatment and season groups. Once more, the species most responsible for differences between treatments or seasons were then analysed using SIMPER.

# 3. RESULTS

## 3.1 VEGETATION COMPOSITION AND STRUCTURE

Overall, 89 plant species were recorded across all sites during spring and autumn sampling combined (Appendix 2). Of these species, 35 were native, 47 were exotic and 7 were of unknown origin (Table 3). Purple Stonecrop (*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 3).

**Table 3 Cumulative native, exotic and total plant species richness recorded from five replicate sites (30 m x 30 m) in each treatment in spring 2008 and autumn 2009 surveys. Values in parentheses are the number of plant species recorded exclusively in each treatment.**

| **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** | 31 | 17 | 4 | 2 | 3 | 2 | 33 | 19 | 35 |
| **Exotic** | 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 (Spring + Autumn)*** | 58 (39) | | 38 (10) | | 35 (11) | | 89 | | |

* This row contains cumulative totals of species recorded in both Spring 2008 and Autumn 2009

** This column contains cumulative totals of species recorded across all treatments

## 3.1.1 PLANT SPECIES RICHNESS

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 (Figure 2). There were significant differences in species richness (ANOVA, $p<0.05$) between treatments across seasons and between seasons across all treatments. There was no significant interaction between main effects (Table 4).

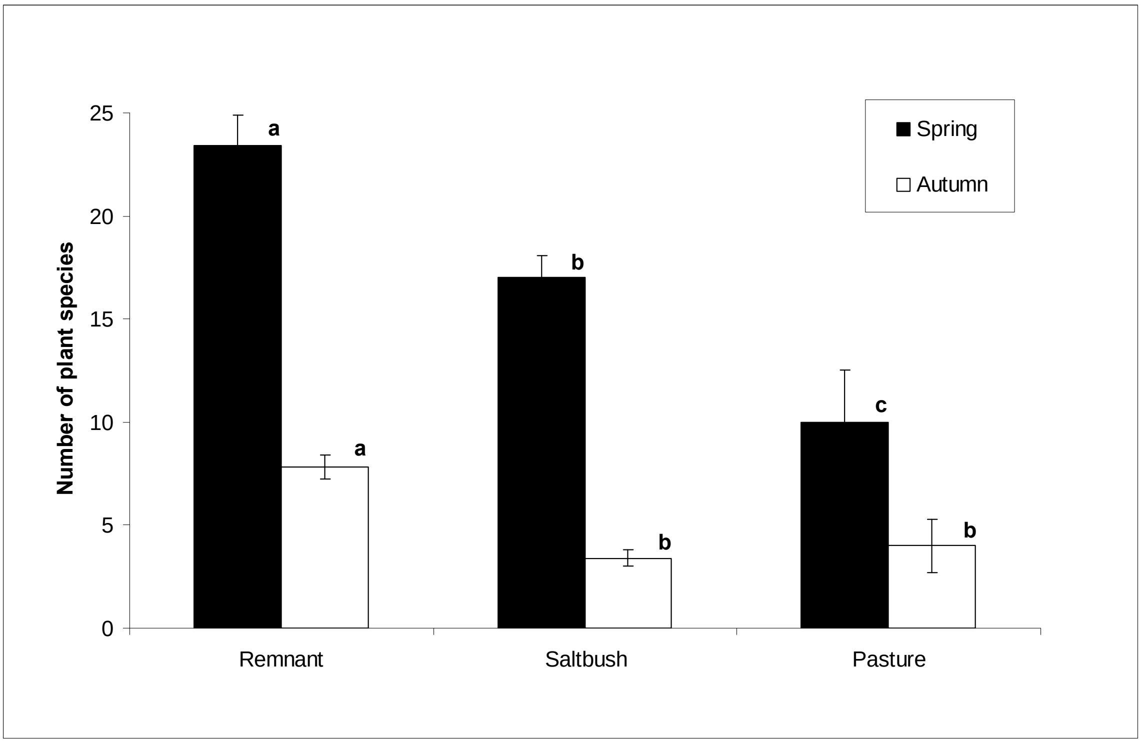


**Figure 2 Mean (± standard error) of plant species richness (native and exotic species) from five 30 m x 30 m quadrats in spring 2008 and autumn 2009. Treatments with the same letter are not significantly different. Significance tests are between treatments only and not seasons.**

**Table 4 Two way ANOVA results for plant species richness. Values are F statistics with significance indicated.**

| | Main effects | | Interaction |
|---|---|---|---|
| | **Treatment** | **Season** | **Treatment *Season** |
| d.f. | 2 | 1 | 2 |
| **Species richness** | 10.89* | 52.94* | $1.82^{ns}$ |

Species richness data log (x+1) transformed. *p<0.001, ns = not significant.

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 $p<0.05$, Figure 2).

## 3.1.2 VEGETATION STRUCTURE

*Photo point monitoring sites*

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 (Figure 3). Grazing of the saltbush sites in late summer and 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 (Figure 3).

**Figure 3 Photo point of the same saltbush planting in Spring 2008 (left) and following grazing in Autumn 2009, showing almost complete defoliation of saltbush plants and reduction in volunteer groundcover.**

*Ground Cover*

In spring 2008, the type and relative amount of ground cover varied between treatments (Figure 4). Remnants had a higher proportion of microphytic crust and a lower proportion of introduced ground cover compared with saltbush and pasture treatments.

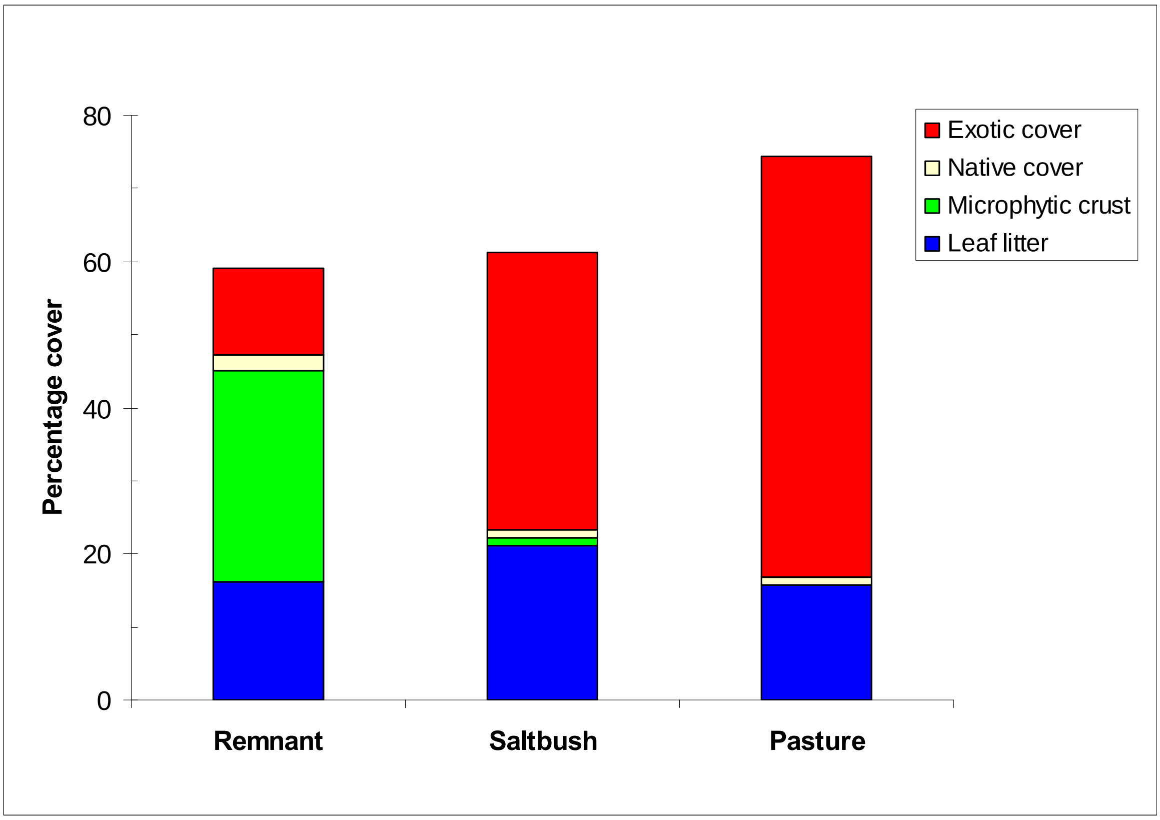


**Figure 4 Mean percentage cover of different ground cover components across land management treatments in spring 2008.**

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 (Figure 5). Microphytic crust was present only in remnant sites in autumn.

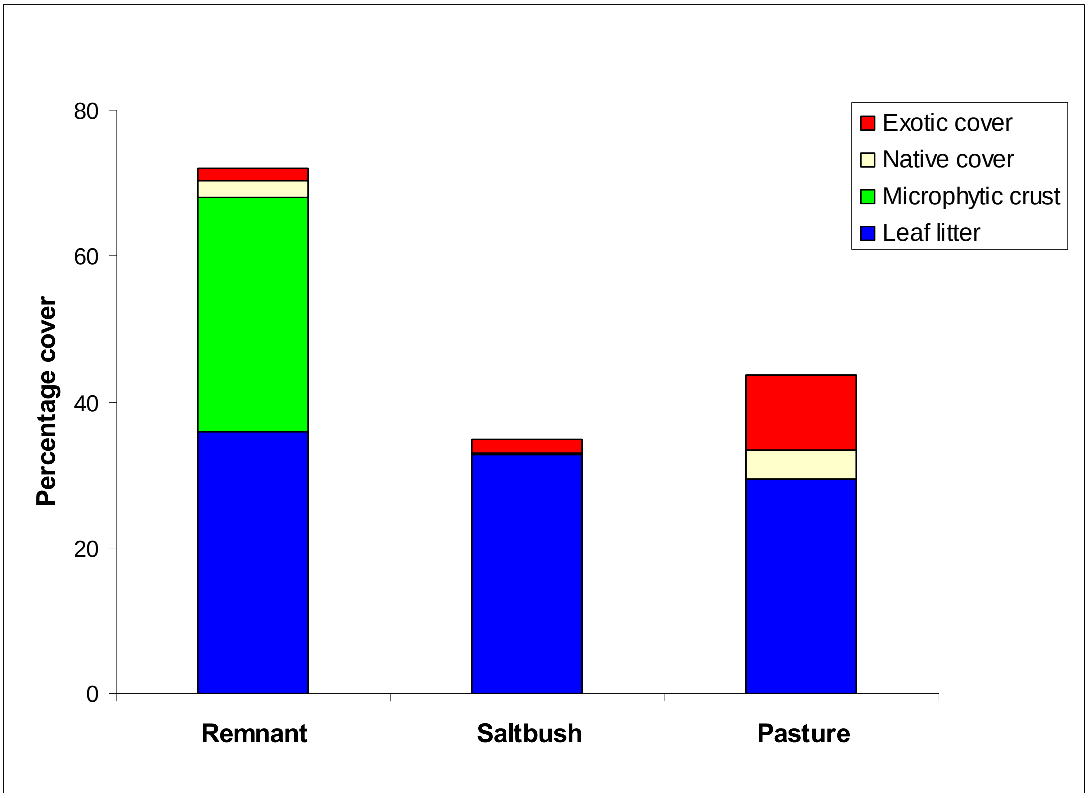


**Figure 5 Mean percentage cover of ground cover components across land management treatments from assessments in autumn 2009.**

*Number of plant life forms*

More plant life forms were present in remnant sites than saltbush or pasture in both spring 2008 and autumn 2009 (Figures 6 & 7). 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 for cover in remnants in both spring and autumn.

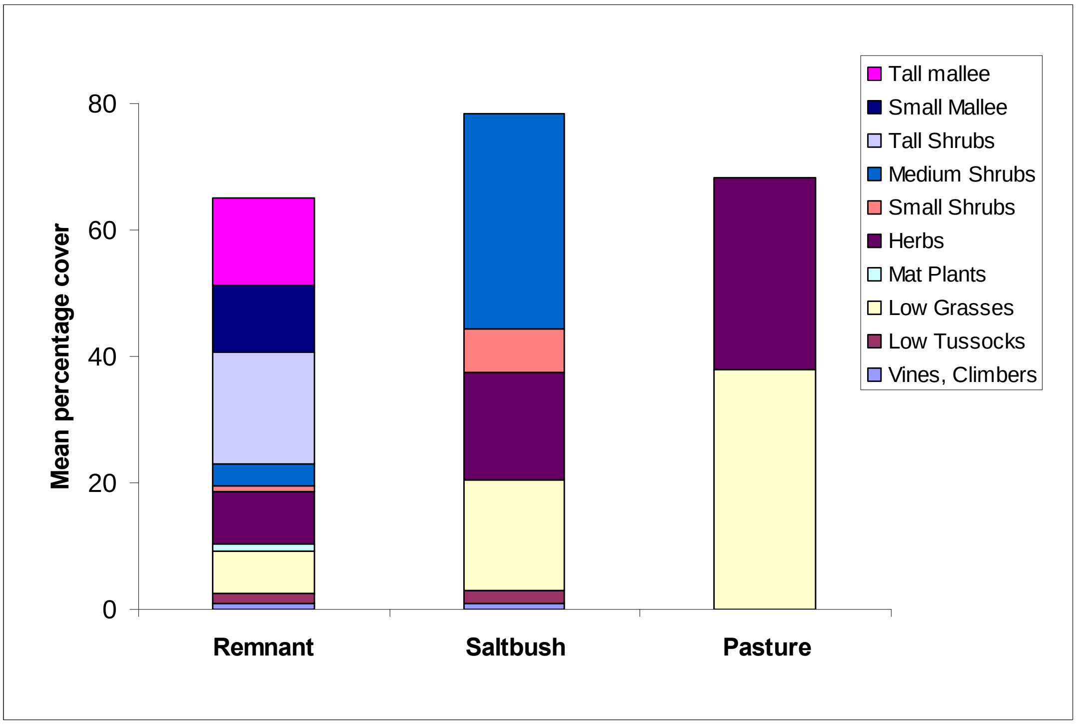


**Figure 6 Mean percentage cover of all plant life forms in spring 2008**

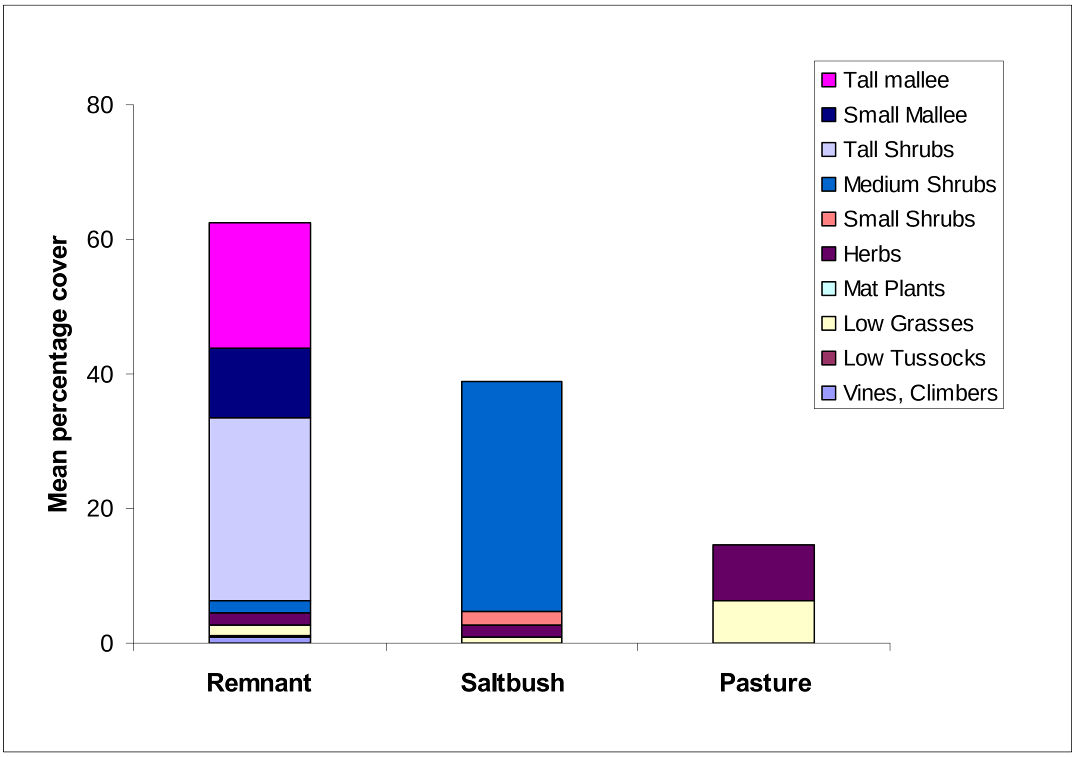


**Figure 7 Mean percentage cover of all plant life forms in autumn 2009**

### 3.1.3 VEGETATION COMMUNITY COMPOSITION

A nMDS ordination of presence/absence data separated sites in the three treatments, with the distance between points reflecting the similarity of floristic composition (Clarke and Gorley 2006). Gradients in floristic composition are evident on the ordination in spring (top to bottom) and autumn (left to right) from remnant sites through saltbush to pasture (Figure 8). Separate groupings of spring and autumn samples within the same treatment were also evident, with autumn samples displaying higher variation/separation than spring samples (Figure 8).

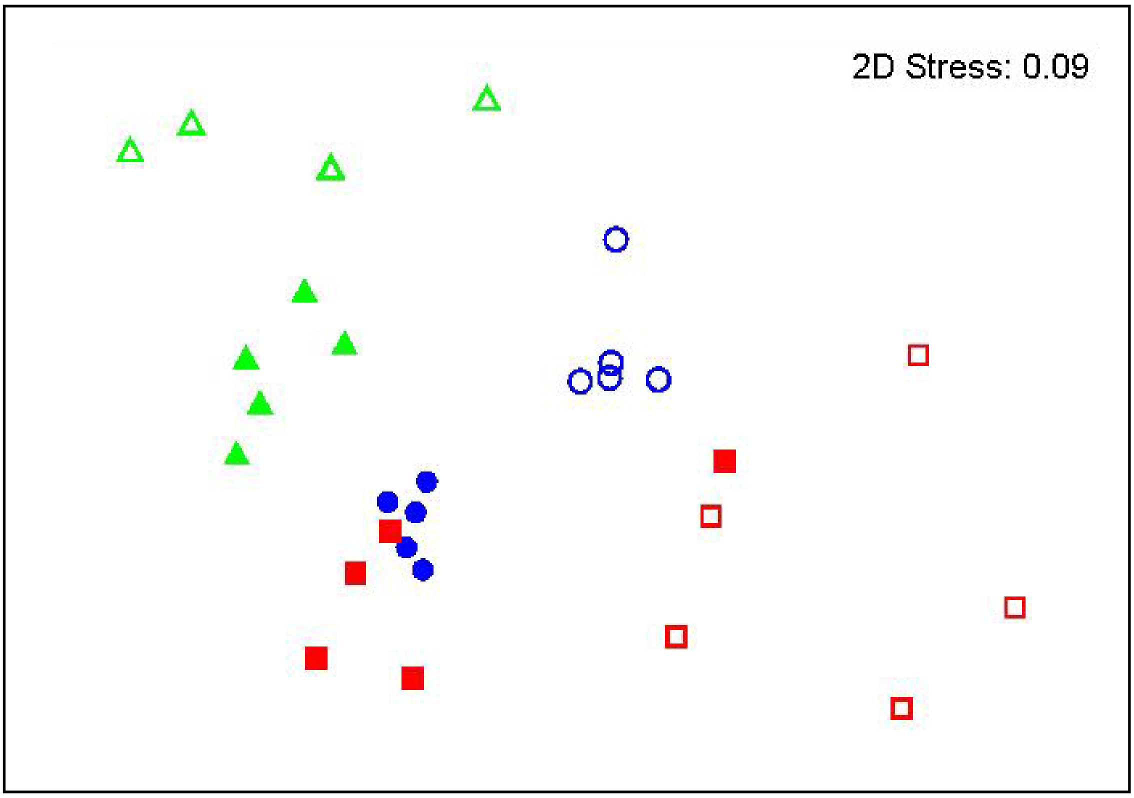


**Figure 8 Two-dimensional ordination (nMDS) of presence absence data showing Spring (shaded) and Autumn (open) samples within each treatment. ▲/ △ = remnant, ● / ○ = saltbush, ■ / □ = pasture.**

Two-way crossed Analysis of Similarity (ANOSIM) showed significant differences in plant community composition between treatments across seasons (Global R = 0.597 , P = 0.001) and between seasons across all treatments (Global R = 0.652, P = 0.001). Pairwise tests showed significant differences (P ≤ 0.001) between all treatments (Table 5).

**Table 5 Summary of Analysis of Similarity (ANOSIM) on plant presence/ absence data. Values are R statistics (from pairwise tests) with significance level indicated (Global R = 0.597, Significance level < 0.01).**

| | Remnant | Saltbush | Pasture |
|---|---|---|---|
| **Saltbush** | 0.868* | 1 | - |
| **Pasture** | 0.634* | 0.357* | 1 |

*p < 0.05

Treatments that were significantly different according to ANOSIM were tested using SIMPER. The average Bray-Curtis dissimilarities and the average abundance of species that contributed up to 30% of the dissimilarity between land management categories are listed in Table 6. In general, a combination of highly abundant species in one treatment and low abundance or absence of these species in the other treatment, contributed most to the differences between comparisons with remnants (Table 6). There was more overlap in species occurrence between saltbush and pasture treatments. A list of species contributing to 50% of the dissimilarity between treatments is provided in Appendix 3.

Not surprisingly, Oldman Saltbush was the major contributor to dissimilarity in both comparisons with saltbush treatments. The high abundance of Ridge-fruited Mallee (*Eucalyptus incrassata*) in remnant treatments contributed to a large amount of the dissimilarity in comparisons containing remnants (Table 6). In both pasture comparisons, Common Heliotrope (*Heliotropium europaeum*) contributed strongly to between-treatment dissimilarity.

**Table 6 Average dissimilarity between treatments and the average abundance of plant species that contributed up to 30% of the dissimilarity between treatments. Species are listed in decreasing order of their importance in discriminating the two sets of samples.**

| Species | Average abundance* | | Cumulative %** |
|---|---|---|---|
| ***Average dissimilarity = 84.17*** | **Remnant** | **Saltbush** | |
| Oldman Saltbush | 0 | 1 | 6.77 |
| Ridge-fruited Mallee | 0.82 | 0 | 12.08 |
| Skeleton Weed | 0 | 0.7 | 17.22 |
| Ruby Saltbush | 0.64 | 0 | 21.53 |
| Broombush | 0.64 | 0 | 25.64 |
| Narrow-leafed Red Mallee | 0.55 | 0 | 29.3 |
| Perennial Veldtgrass | 0.45 | 0.6 | 32.8 |
| ***Average dissimilarity = 87.69*** | **Remnant** | **Pasture** | **Cumulative %** |
| Ridge-fruited Mallee | 0.82 | 0 | 5.14 |
| Ruby Saltbush | 0.64 | 0 | 9.3 |
| Broombush | 0.64 | 0 | 13.28 |
| Narrow-leafed Red Mallee | 0.55 | 0 | 16.8 |
| Bridal Creeper | 0.64 | 0 | 20.23 |
| Silver Broombush | 0.45 | 0 | 23.46 |
| Common Heliotrope | 0 | 0.3 | 26.38 |
| Beaked Red Mallee | 0.45 | 0 | 29.14 |
| Wallaby Grass sp 1 | 0.36 | 0 | 31.8 |
| ***Average dissimilarity = 77.94*** | **Saltbush** | **Pasture** | **Cumulative %** |
| Oldman Saltbush | 1 | 0 | 12.92 |
| Perennial Veldtgrass | 0.6 | 0 | 20.38 |
| Skeleton Weed | 0.7 | 0.4 | 27.82 |
| Common Heliotrope | 0 | 0.3 | 34.42 |

*Average abundance represents the average presence of plant species per quadrat within each treatment.

**Cumulative % represents the cumulative influence of the variables to the overall Bray-Curtis dissimilarity.

## 3.2 BIRD DIVERSITY AND COMMUNITY COMPOSITION

A total of 57 bird species was observed during spring and autumn surveys (Appendix 4). Of these species, 52 were recorded in spring 2008 and 35 species were recorded during autumn 2009 surveys (Table 7). 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 7).

Thirty-two bird species were recorded only in remnant sites, four bird species were found only in saltbush sites and one bird species was found only in pasture sites across both seasons. Nine species were recorded in at least one site across all three treatments (Appendix 4).

**Table 7 Number of bird species (native and exotic) recorded in all remnant, 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 & Autumn)** | 50 (32) | 24 (4) | 12 (1) | 57 |

Four species listed as ‘Rare’ under Schedule 9 of the National Parks and Wildlife Act (NPWS 1972) (Elegant Parrot (*Neophema elegans*), Hooded Robin (*Melanodryas cucullata cucullata*), Restless Flycatcher (*Myiagra inquieta*) and White-winged Chough (*Corcorax melanorhamphos*)) were recorded during the survey period. Elegant Parrot was recorded in two of the saltbush sites in spring; Hooded Robin was recorded in one remnant site in spring and in one saltbush site in autumn; Restless Flycatcher was recorded in one remnant site in spring and autumn and one saltbush site in spring; White-winged Chough was recorded in only one remnant site in autumn (Appendix 4). Two introduced bird species, Common Starling (*Sturnus vulgaris*) and House Sparrow (*Passer domesticus*) were recorded infrequently across all treatments in both seasons.

Despite the coarse seasonal differences evident from Table 7, there were no statistically significant differences between seasons (across all treatments) for species richness (ANOVA, F=2.45, p>0.05). However, using combined seasonal data, there were significant differences across all treatments for bird 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 (*a priori* contrasts p<0.05, Figure 9).

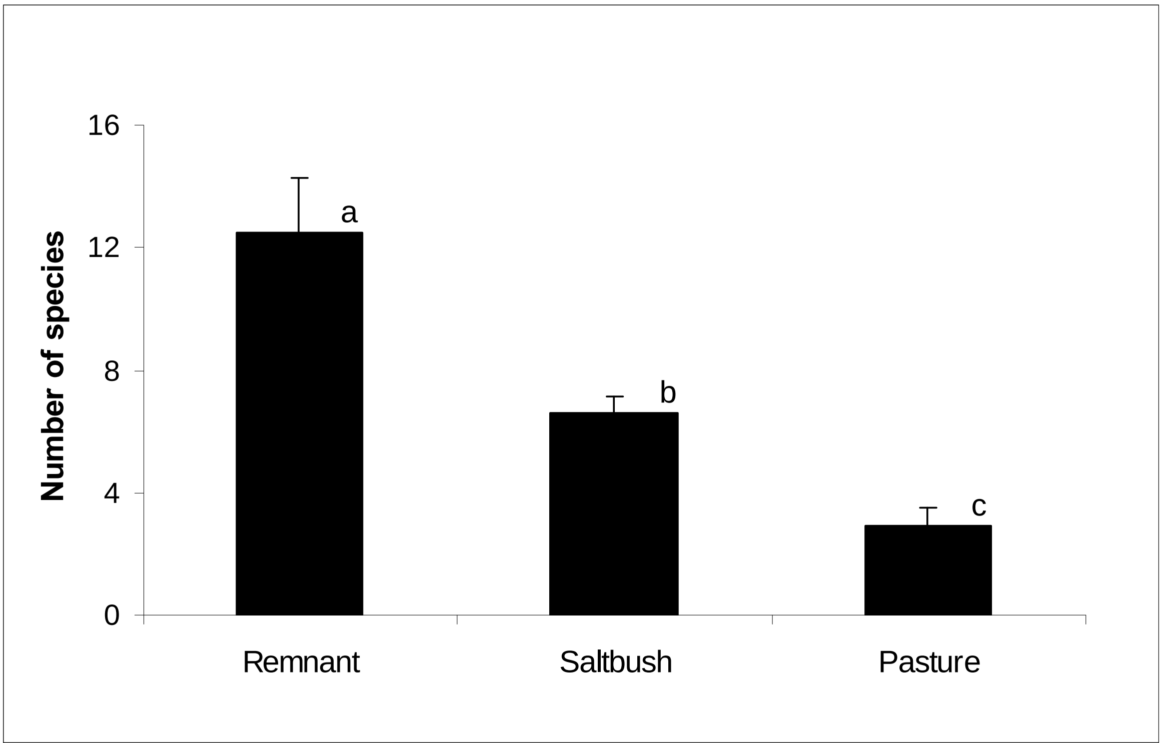


**Figure 9 Mean (± standard error) values for bird species richness (combined seasonal data) in remnant, saltbush and pasture treatments. Means sharing the same letter are not significantly different (*a priori* contrasts p>0.05).**

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 (*a priori* contrasts p>0.05, Figure 10). However, in spring, pasture sites had significantly lower total bird abundance than saltbush sites (*a priori* contrasts p<0.05). Similar trends were apparent across treatments in autumn 2009 (Figure 10).

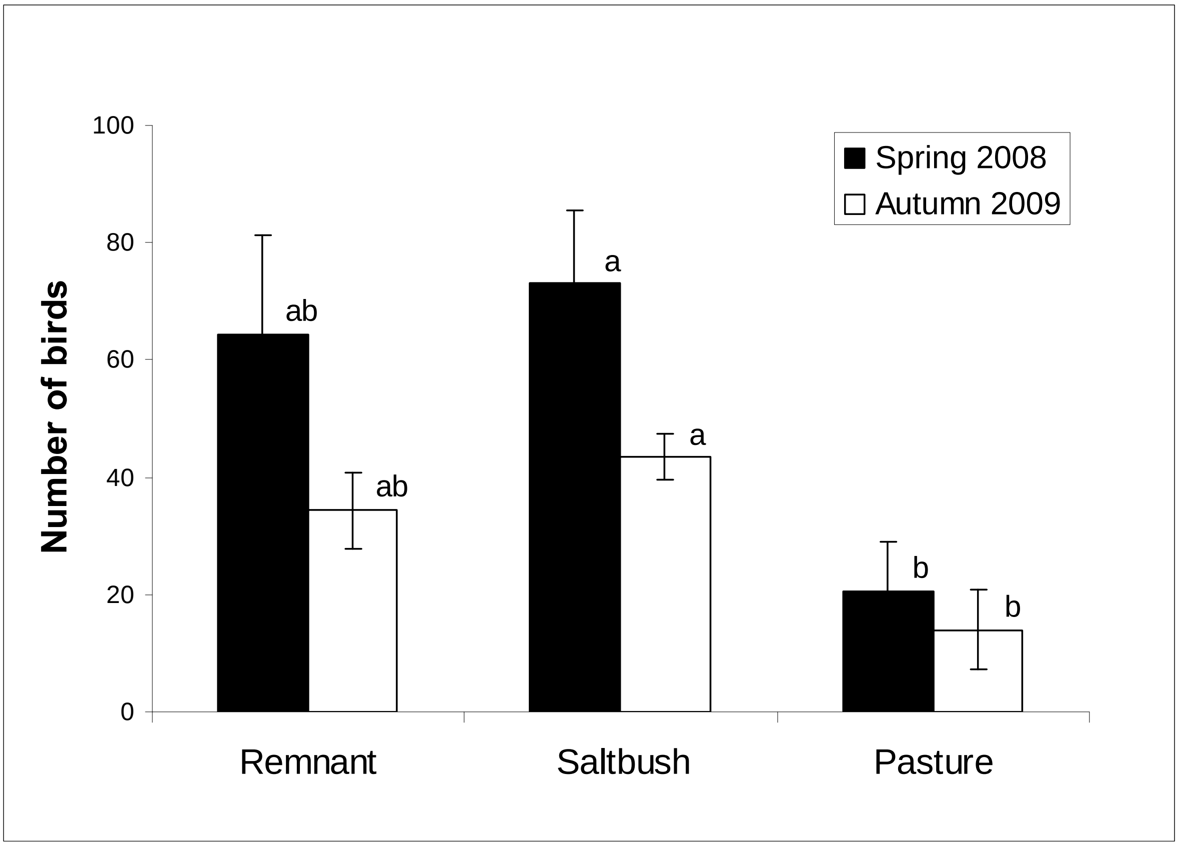


**Figure 10 Mean (± standard error) values for bird abundance in remnant, saltbush and pasture treatments in spring 2008 and autumn 2009. Means sharing the same letter are not significantly different (*a priori* contrasts p>0.05). Significance tests are between treatments only and not seasons.**

A nMDS ordination of avian abundance data showed a separation of treatments and to a lesser extent seasons within treatments (Figure 11). Outlying data points corresponded to anomalous field survey observations.

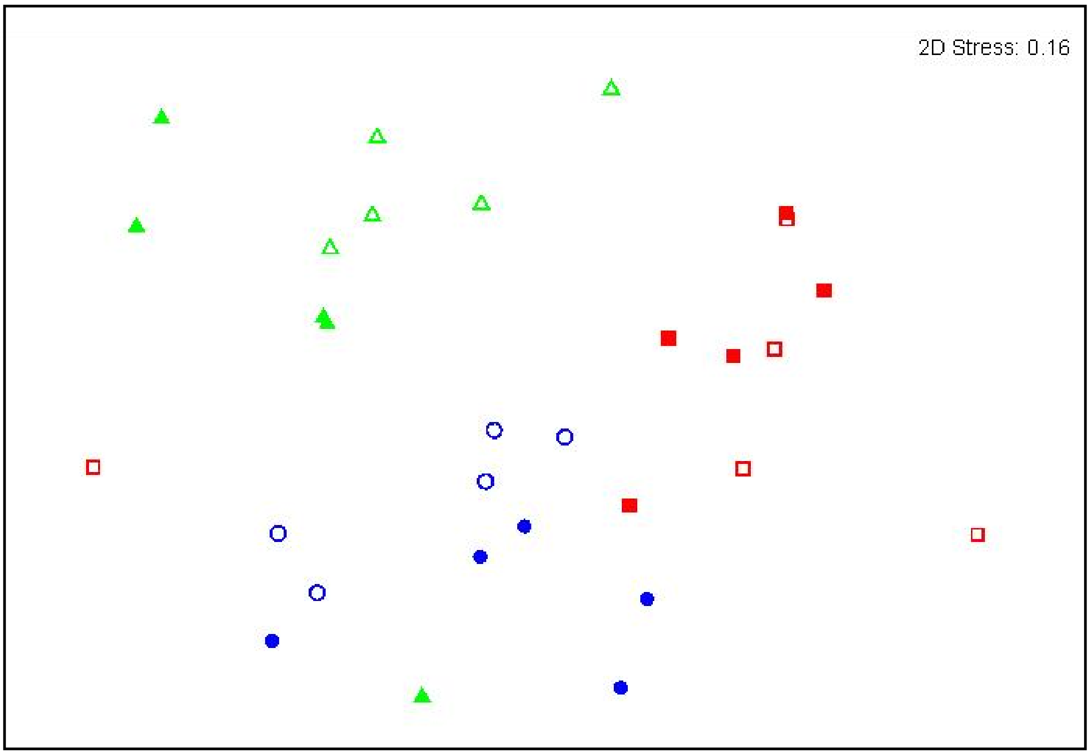


**Figure 11 Two-dimensional ordination (nMDS) of bird abundance data showing each treatment. ▲/ △ = remnant, ● / ○ = saltbush, ■ / □ = pasture. Shaded shapes are Spring 2008 surveys and unshaded shapes are Autumn 2009 surveys.**

Two-way Analysis of Similarity (ANOSIM) showed significant differences in bird community composition among treatments across seasons (Global R = 0.62, P = 0.001) and between seasons across treatments (Global R = 0.15, P = 0.036). Pairwise tests showed significant differences (P < 0.05) between all treatment groups (Table 8).

**Table 8 Summary of Analysis of Similarity (ANOSIM) on bird abundance data. Values are R statistics (from pairwise tests) with significance level indicated (Global R = 0.63, Sign level < 0.01).**

| | Remnant | Saltbush | Pasture |
|---|---|---|---|
| **Saltbush** | 0.766* | 1 | - |
| **Pasture** | 0.628* | 0.53* | 1 |

*p < 0.05

A similar suite of bird species contributed to a large proportion of the dissimilarity between sites in the different treatments (Table 9). 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 Yellow Thornbill (*Acanthiza nana*), Common Bronzewing (*Phaps chalcoptera*), Spotted Pardalote (*Pardalotus punctatus*) and Red-capped Robin (*Petroica goodenovii*), which were restricted to remnant sites (Table 9). A more complete list of species contributing to 90% of the dissimilarity between treatments is provided in Appendix 5.

**Table 9 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 the two sets of samples.**

| Species | Average abundance* | | Cumulative %** |
|---|---|---|---|
| ***Average dissimilarity = 82.23*** | **Remnant** | **Saltbush** | |
| White-fronted Chat | 0.18 | 2.2 | 10.12 |
| Yellow Thornbill | 1.1 | 0 | 15.35 |
| Yellow-rumped Thornbill | 1.11 | 1.1 | 19.66 |
| Willie Wagtail | 0.57 | 0.46 | 23.8 |
| Australian Magpie | 1.18 | 0.86 | 27.49 |
| Common Bronzewing | 0.65 | 0 | 31.09 |
| ***Average dissimilarity = 87.69*** | **Remnant** | **Pasture** | **Cumulative %** |
| Yellow-rumped Thornbill | 1.11 | 0.24 | 7.22 |
| Yellow Thornbill | 1.1 | 0 | 13.9 |
| Common Bronzewing | 0.65 | 0 | 18.95 |
| Australian Magpie | 1.18 | 1.19 | 23.52 |
| Spotted Pardalote | 0.56 | 0 | 28 |
| Red-capped Robin | 0.49 | 0 | 31.75 |
| ***Average dissimilarity = 79.14*** | **Saltbush** | **Pasture** | **Cumulative %** |
| White-fronted Chat | 2.2 | 0.27 | 18.59 |
| Yellow-rumped Thornbill | 1.1 | 0.24 | 28.61 |
| Australian Magpie | 0.86 | 1.19 | 35.73 |

*Average abundance represents the average number of birds recorded per transect within each treatment. **Cumulative % represents the cumulative influence of the variables to the overall Bray-Curtis dissimilarity.

## 3.3 INVERTEBRATE COMMUNITY COMPOSITION

Preliminary analyses of invertebrate data show that functional group abundance was similar across different treatments (Table 10). In general, taxon richness was highest in pasture sites and lowest in remnants. A more complete list of taxa is provided in Appendix 6.

**Table 10 Total number of individuals of identified invertebrate taxa in sampled treatments from spring 2008, grouped according to their impact on agriculture.**

| Functional grouping/ Order/ Species | Common name | Remnant | Saltbush | Pasture |
|---|---|---|---|---|
| **Beneficials** | | | | |
| Predatory Coleoptera | Predatory beetles | 17 | 26 | 16 |
| *M. tasmaniae* | Tasmans lacewing | | 2 | 1 |
| Aranae | Spiders | | 1 | 2 |
| Parasitoid Hymenoptera | Wasps | 220 | 138 | 193 |
| Beneficial Diptera | Beneficial flies | 1 | 1 | 2 |
| *Haplothrips sp* | Predatory thrips | 6 | 5 | 9 |
| **Number of taxa** | **-** | **4** | **6** | **6** |
| **Pests** | | | | |
| Cicadellidae | Leafhoppers | 16 | 10 | 12 |
| Other Hemiptera | Bugs | | | 5 |
| Aphididae | Aphids | 362 | 364 | 375 |
| Pest Thysanoptera | Introduced pest thrips | 34 | 11 | 28 |
| *Thrips imaginis* | Native Plague thrips | 216 | 331 | 272 |
| Psyllidae | Lerps/scales | 4 | 3 | 6 |
| **Number of taxa** | **-** | **5** | **5** | **6** |
| **Unknown impact on agriculture** | | | | |
| Coleoptera | Beetles | 9 | 2 | 5 |
| Psocoptera | Booklice | | | 1 |
| Lepidoptera | Moths | 1 | 6 | 2 |
| Acarina | Mites | 4 | 6 | 4 |
| Diptera | Flies | 1181 | 1035 | 1579 |
| Other Thysanoptera | Thrips | 5 | 3 | 7 |
| **Number of taxa** | **-** | **5** | **5** | **6** |
| **Total number of taxa** | **-** | **14** | **16** | **18** |

A nMDS ordination of invertebrate taxon abundance data showed no apparent separation of treatments (Figure 12). One-way Analysis of Similarity (ANOSIM) showed no significant differences in invertebrate community composition across treatments (Global $R$ = -0.185, $P$ = 0.782).

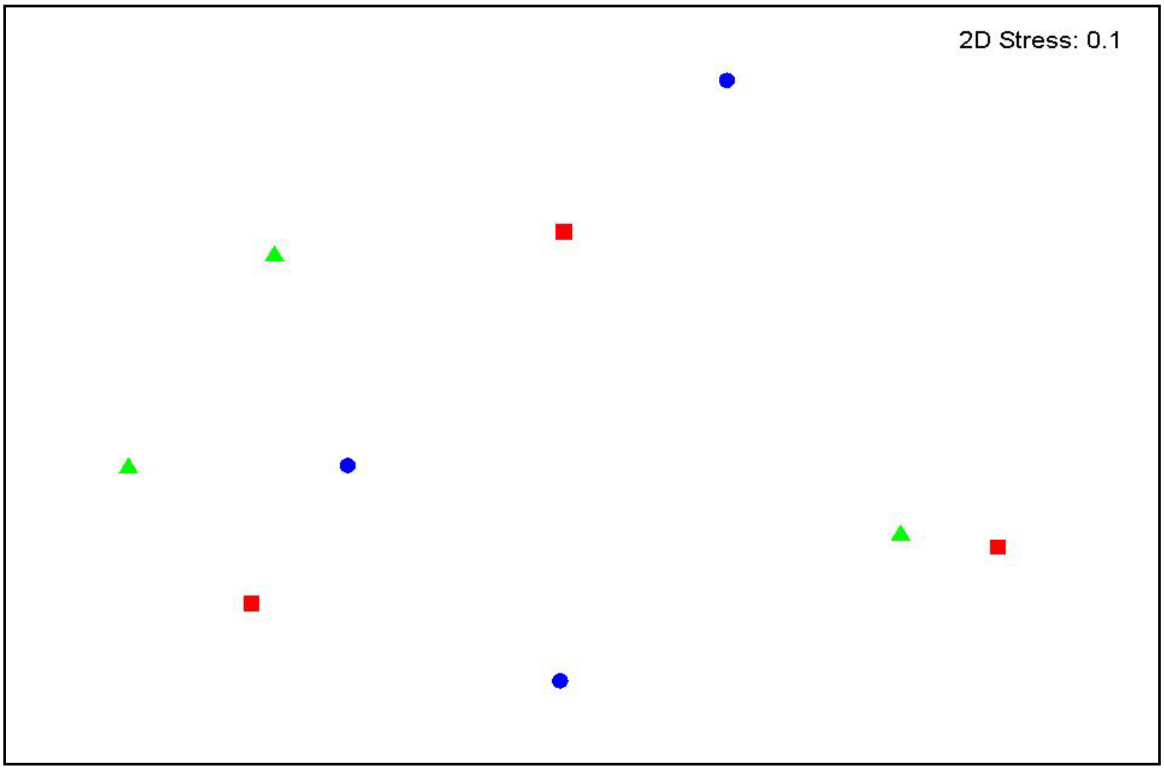


**Figure 12 Two-dimensional ordination (nMDS) of invertebrate taxon abundance data ▲ = remnant, ● = saltbush, ■ = pasture.**

# 4. DISCUSSION

## 4.1 KEY FINDINGS

Key findings from this study are:

- Vegetation structural attributes and groundcover varied between sampled land management treatments and displayed a high degree of seasonal variation
- Plant and bird species richness were higher in remnant vegetation sites than in saltbush or pasture sites in both spring 2008 and autumn 2009
- Plant species richness was higher in saltbush than pasture sites in spring but not in autumn
- Plant and bird community composition were significantly different between seasons and across all treatments
- Bird species richness was higher in saltbush than in adjacent pasture sites, but lower than in remnants
- Three threatened bird species were recorded in saltbush plantings
- A high proportion of bird species was recorded in more than one of the sampled treatments
- A mix of invertebrate taxa known to be beneficial to and pests of agriculture were recorded across saltbush, pasture and remnant sites.

## 4.2 POTENTIAL BIODIVERSITY VALUES OF SALTBUSH

In their natural state, chenopod shrublands in semi-arid areas provide habitat for a range of native fauna. For example, biological surveys of the North and South Olary Plains in South Australia, found that a number of mammal, bird and reptile groups are associated with different forms of chenopod shrubland (Forward and Robinson 1996; Playfair et al. 1997). In the North Olary Plains, Playfair et al. (1997) classified fourteen bird species that were characteristic of open chenopod shublands, including Orange Chat (*Epthianura aurifrons*), Rufous Fieldwren (*Calamanthus campestris*) and White-winged Fairy Wren (*Malurus leucopterus*). These three species were associated with low shrublands and are notable as ground-feeding specialists that forage, rest and breed at ground or low shrub level. Forward and Robinson (1996) also recorded bird species listed as vulnerable in the same region of South Australia (Blue-winged Parrot (*Neophema chrysostoma*) and Stubble Quail (*Coturnix pectoralis*)) in treeless chenopod shrublands. The apparent dependence of some native species on shrubby vegetation systems suggests that planted shrub-based plantings in agricultural areas may at least partially satisfy the habitat and resource requirements of some of these and other shrub-inhabiting species, the distributions of which extend into the study area.

Despite the fact that Oldman Saltbush (*Atriplex nummularia*) does not occur naturally in the study landscape (the extent of its natural distribution lies approximately 100 km to the north), a diverse array of native bird species was found in saltbush plantings, compared with adjacent areas of pasture. Of particular interest was the observation of nesting Orange and White-fronted Chats in only saltbush sites during the Spring 2008 survey period (Figure 12), 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.

Our results 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 plantings. However, 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. The higher structural diversity of the saltbush plantings compared with adjacent areas of pasture, is likely to be the reason for this difference.

**Figure 12 Evidence of Orange Chats (*Epthianura aurifrons*) perching and nesting in a planted saltbush sampling site in Spring 2008.**

In addition, the observations of three threatened bird species (Elegant Parrot, Hooded Robin and Restless Flycatcher) and a range of other native birds found in saltbush plantings in this study supports the notion that these ‘novel’ systems (*sensu* Hobbs et al. 2008) may also complement existing fragmented vegetation communities and thus potentially contribute to regional biodiversity conservation. Although these three threatened species are not regarded as shrubland specialists – they are typically associated with habitat types containing trees – their presence in saltbush sites (compared with adjacent pasture site where they were completely absent), suggests that the saltbush is providing resources (in the form of shelter or structure for perching/ resting etc) for these species. These bird species display features and behaviours consistent with ‘woodland generalists’ proposed by Attwood et al. (2009). Indeed, 20 of the 24 bird species recorded in saltbush sites were also recorded in one or both of the other two treatments/ land uses. This suggests that the majority of species that use the saltbush plantings also use other elements of the landscape. This is supported by the significant amount of overlap in species between different treatments evident in the SIMPER analysis.

The preliminary observations in this study suggest that planted saltbush systems have the potential to attract a range of native birds and insects. It is evident that the sampled saltbush sites may play a role in providing resources for a suite of native bird species, some of which are of conservation significance. However, without further investigation, it is uncertain whether these perennial plantings provide more than just a resting stop or stepping stone for these species as they move through the landscape, or are being used as permanent or temporary habitat for shelter, foraging or nesting. Frequent disturbance and high exposure to edge effects raises the possibility that these planted sites could be acting as ‘ecological traps’ for native biota (*sensu* Kristan 2003). Further information on the behavioural and functional characteristics of these species is needed to ascertain whether and how they are using resources provided by saltbush plantings.

## *4.3 STRUCTURAL COMPLEXITY*

From a faunal perspective, structural complexity is an important factor affecting the occurrence and abundance of different species (Fischer et al. 2004). In highly modified agricultural landscapes, different land uses create a gradient of vegetation structural complexity (Munro et al. 2007), which generally correspond to the opposing gradients of intensification and ecosystem recovery shown in Figure 13. Shrub-based systems are incorporated into this framework as an alternative woody perennial planting type.

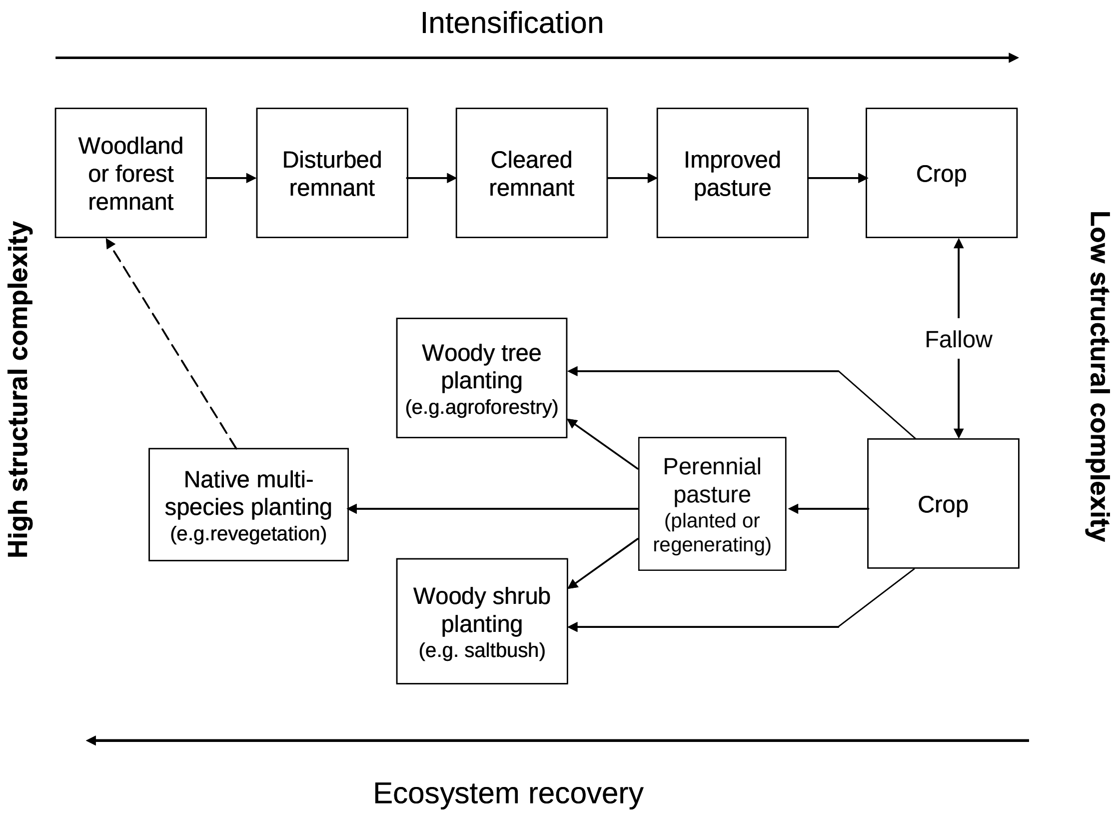


**Figure 13. Conceptual framework for incorporating shrub-based planted woody perennial vegetation into multiple use agricultural landscapes. Local-scale land management practices exist at different points along gradients of agricultural intensification (top line), ecosystem recovery (bottom line) and structural complexity (left to right). Woody shrub plantings are shown in the lowest box. The dashed line represents potential movement of native, mixed species plantings towards a natural ecosystem state.**

Native fauna may be affected by revegetation efforts in different ways, depending on the pathways and extent of ecosystem recovery shown in Figure 13. Information from the present study suggests that the higher structural complexity of saltbush plantings (compared with surrounding intensively managed pastures) and changes to vegetation structure caused by seasonal and/or management influences can have a significant effect on the sampled biodiversity indicators. Site-level attributes (e.g. native understorey plants, logs) and wider landscape context are both important determinants of species' occurrence (Lindenmayer and Hobbs 2004). Although poorly established for planted woody perennial vegetation, general principles of landscape ecology in fragmented systems (e.g. effects of patch area, connectivity and landscape context) may also be broadly applicable to planted shrub systems. As identified by Munro et al. (2007), more information is needed on these landscape factors and the habitat requirements of different species (Fischer et al. 2004) to better inform the placement of planted woody perennial systems in farming landscapes.

## 4.4 MANAGEMENT CONSIDERATIONS

Saltbush plantings are primarily established by land managers as fodder crops. When pastures are exhausted, the saltbush is often intensively grazed, resulting in sometimes drastic changes to the structure and composition of the vegetation such as the complete defoliation of the saltbush plants and the removal of most of the palatable herbaceous ground cover between saltbush rows. This intense grazing pressure is reflected in the seasonal differences in ecological indicators evident 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. The saltbush plants are able to recover from this annual heavy grazing pressure, however, the reduction in structure and groundcover may affect other plant and animal species in different ways. For example, those bird species reliant on dense shrubby vegetation may be displaced while those favouring open ground for foraging may benefit. It is possible that the timing and intensity of grazing in saltbush could be manipulated to better suit the requirements of some of these species, particularly those of conservation significance.

We have shown that saltbush plantings can enhance 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). These environmental benefits may also be enhanced by management improvements such as changes to the timing and intensity of grazing or by incorporating more than one fodder shrub species. Shrub-based forage systems are being explored as the next generation of livestock grazing systems, designed to be resilient in the face of a changing climate (Hobbs et al. 2009). Comparatively high productivity on low fertility soils also makes saltbush a potentially useful species for biosequestration in the light of the emerging carbon emissions trading industry (Hobbs 2009).

The majority of the volunteer species present in the sampled saltbush plantings were exotic in origin and a number were declared weeds in South Australia (e.g. Skeleton Weed, Salvation Jane, Horehound). These exotic species, including the saltbush plants themselves, are not native to the study landscape. They may provide some resources for native fauna, however, more consideration needs to be given to the possible consequences of saltbush sites harbouring weeds (and potentially other vertebrate and invertebrate pests) and how weed and pest management may impact on the biodiversity values at local and regional scales.

## 4.5 STUDY LIMITATIONS

This pilot study sampled only five sites in each land management treatment. There was also considerable variation in grazing management of saltbush and pasture sites and differences in time since establishment for saltbush. Despite these variations, significant differences between treatments were detected for both plant and bird communities. A larger number of replicates in each treatment and additional information from landholders would enable further investigations into the potential causes of variation in plant, bird and invertebrate communities caused by the effects of treatment, season and grazing management.

# 5. RECOMMENDATONS FOR FUTURE DIRECTIONS

This study was designed to be a small-scale investigation into the potential biodiversity value of planted saltbush systems on non-saline lands. Results presented here contribute substantially to a greater understanding of the value of planted saltbush systems for biodiversity in the study landscape. Having demonstrated that some native biota is present within planted saltbush areas, there are a number of aspects that could be explored further.

It would be valuable to examine in more detail how birds are using the resources on offer in these saltbush plantings (e.g. food, feeding substrates, nesting material). This should include consideration of the temporal availability of these resources as this will inform management recommendations.

Improved information on invertebrate communities would enable more robust conclusions to be drawn on this important component of biodiversity. This could include identification of additional invertebrates collected using sticky traps in autumn 2009, further identification of captured specimens to species or genus level for various functional groupings, and more detailed examination of selected functional groups (e.g. parasitic Hymenoptera) that may yield more information about variations in biodiversity between land uses.

Combining data on local-scale attributes (e.g. groundcover and life forms) with landscape context information (e.g. proportion and configuration of surrounding landscape elements) would provide a more informed explanation of the observed patterns in fauna communities in planted saltbush systems.

This study established an initial GIS-linked database of planted saltbush sites in the SA Murray Mallee. This database should be developed further to include information on the location and spatial extent of saltbush and other woody perennial plantings in the SA Murray Darling Basin and statewide. This will assist those working on these future farming systems to locate study sites where required, and redirect resources from site identification to more productive activities. An important component of this is further investigation and refinement of remote sensing techniques to identify and classify planted woody perennial vegetation.

Opportunities exist to further quantify the biodiversity values of saltbush plantings in the study landscape and elsewhere. This information would be useful to guide future decisions made by land managers and regional NRM planning bodies on the strategic placement and on-ground management of perennial shrubs. Given that saltbush is planted in non-saline areas for its fodder value, further investigation of the impacts of grazing management on native biodiversity in planted saltbush is warranted.

# APPENDICES

## APPENDIX 1 – SITE DETAILS FOR VEGETATION ASSESSMENTS

| $Replicate_{Site}$ | Sampling Date | | Easting | Northing | Bearing 1 | Bearing 2 |
|---|---|---|---|---|---|---|
| | *Spring 2008* | *Autumn 2009* | | | | |
| $E_{Remnant2}$ | 14-Oct | 16-Mar | 0438340 | 6075142 | 235 | 145 |
| $E_{Remnant1}$ | 14-Oct | 16-Mar | 0438538 | 6075163 | 344 | 254 |
| $E_{Saltbush2}$ | 14-Oct | 17-Mar | 0440823 | 6078928 | 350 | 260 |
| $E_{Pasture2}$ | 14-Oct | 17-Mar | 0441160 | 6078909 | 354 | 264 |
| $H_{Saltbush}$ | 16-Oct | 18-Mar | 0477029 | 6106053 | 260 | 170 |
| $E_{Saltbush1}$ | 16-Oct | 16-Mar | 0438810 | 6075754 | 64 | 334 |
| $E_{Pasture1}$ | 16-Oct | 16-Mar | 0438848 | 6075460 | 40 | 310 |
| $S_{Remnant}$ | 15-Oct | 17-Mar | 0477998 | 6113990 | 300 | 210 |
| $S_{Pasture}$ | 15-Oct | 17-Mar | 0478457 | 6112332 | 30 | 300 |
| $B_{Saltbush}$ | 15-Oct | 18-Mar | 0487727 | 6107149 | 70 | 340 |
| $S_{Saltbush}$ | 15-Oct | 17-Mar | 0478143 | 6112333 | 310 | 220 |
| $B_{Pasture}$ | 16-Oct | 18-Mar | 0487928 | 6106909 | 265 | 175 |
| $H_{Pasture}$ | 16-Oct | 18-Mar | 0477303 | 6106752 | 20 | 290 |
| $B_{Remnant}$ | 4-Nov | 17-Mar | 0478372 | 6095848 | 316 | 226 |
| $H_{Remnant}$ | 4-Nov | 18-Mar | 0475044 | 6104942 | 250 | 160 |

Bearing 1 and Bearing 2 are compass bearings (taken from the above GPS point) along 2 axes of the 30 m x 30 m quadrat used for vegetation surveys at each site.

# APPENDIX 2 – PLANT SPECIES RECORDED IN SPRING 2008 OR AUTUMN 2009

| Species Name | Common name | Origin* | Remnant | Saltbush | Pasture |
|---|---|---|---|---|---|
| *Actinoble uliginosum* | Cotton Weed | n | x | | |
| *Aira caryophyllea* | Hair-grass | e | x | | |
| *Amsinckia intermedia* | Common Fiddleneck | e | | x | x |
| *Arctotheca calendula* | Cape Weed | e | x | x | x |
| *Asparagus asparagoides* | Bridal Creeper | e | x | | |
| *Atriplex nummularia* | Oldman Saltbush | e | x | x | |
| *Atriplex semibaccata* | Creeping Saltbush | n | | | x |
| *Atriplex stipitata* | Bitter Saltbush | n | x | | |
| *Avena barbata* | Wild Oat | e | x | x | |
| *Babingtonia behrii* | Silver Broombush | n | x | | |
| *Billardieria cymosa* | Sweet apple berry | n | x | | |
| *Brassica tournefortii* | Wild Turnip | e | x | x | x |
| *Bromus diandrus* | Great Brome | e | x | x | x |
| *Bromus madritensis* | Compact Brome | e | x | | |
| *Callitris verrucosa* | Scrub Cypress Pine | n | x | | |
| *Capsella bursa-pastoris* | Shepherd's Purse | e | | | x |
| *Carthamus lanatus* | Saffron Thistle | e | | x | x |
| *Chenopodium pumilo* | Clammy Goosefoot | n | | | x |
| *Chondrilla juncea* | Skeleton Weed | e | | x | x |
| *Citrullus lanatus* | Bitter Melon | e | | | x |
| *Climber 1* | - | n | x | | |
| *Crassula colorata* | Dense Stonecrop | n | x | x | x |
| *Crassula peduncularis* (R) | Purple Stonecrop | n | x | | |
| *Cucumis myriocarpus* | Paddy Melon | e | | | x |
| *Cynodon dactylon* | Couch | e | | | x |
| *Cyperus 1* | Flat-sedge | n | x | | |
| *Austrodanthonia Sp 1* | Wallaby Grass | n | x | | |
| *Dianella revoluta* | Black-anther Flax-lily | n | x | | |
| *Echium plantagineum* | Paterson's Curse | e | | x | x |
| *Ehrharta calycina* | Perennial Veldtgrass | e | x | x | |
| *Einadia nutans* | Climbing Saltbush | n | x | | |
| *Enchylaena tomentosa* | Ruby Saltbush | n | x | | |
| *Enneapogon nigricans* | Black-head Grass | n | | x | |
| *Eragrostis cilianensis* | Stink Grass | e | | | x |
| *Erodium cicutarium* | Common Stork's Bill | e | x | | x |
| *Eucalyptus calycogona* | Square-fruit Mallee | n | x | | |
| *Eucalyptus dumosa* | White Mallee | n | x | | |
| *Eucalyptus incrassata* | Ridge-fruited Mallee | n | x | | |
| *Eucalyptus leptophylla* | Narrow-leaf Red Mallee | n | x | | |
| *Eucalyptus socialis* | Beaked Red Mallee | n | x | | |
| *Grass 1* | - | u | x | | |
| *Heliotropium europaeum* | Common Heliotrope | e | | | x |
| *Herb 1* | - | u | x | x | x |
| *Herb 3* | - | u | x | | |
| *Herb 4* | - | u | x | | |
| *Herb 5* | - | u | x | | |
| *Herb 7* | - | u | x | | |
| *Hordeum leporinum* | Wall Barley Grass | e | x | x | x |

| Species Name | Common name | Origin* | Remnant | Saltbush | Pasture |
|---|---|---|---|---|---|
| *Limonium lobatum* | Winged Sea-lavender | e | x | | |
| *Lolium perenne* | Perennial Ryegrass | e | x | x | x |
| *Lomandra* | Mat-rush | n | x | | |
| *Lupinus albus* | White lupin | e | | | x |
| *Maireana sp.* | Bluebush sp. | n | x | | |
| *Marrubium vulgare* | Horehound | e | | x | x |
| *Medicago polymorpha* | Burr-medic | e | x | x | x |
| *Medicago sativa* | Lucerne | e | x | x | x |
| *Medicago truncatula* | Barrel Medic | e | | x | x |
| *Melaleuca lanceolata* | Dryland Tea-tree | n | x | | |
| *Melaleuca uncinata* | Broombush | n | x | | |
| *Mesembryanthemum crystallinum* | Common Iceplant | e | x | x | |
| *Moraea setifolia* | Thread Iris | e | | x | |
| *Oenothera stricta* | Common Evening Primrose | e | | x | x |
| *Onopordum acaulon* | Stemless Thistle | e | | | x |
| *Oxalis pes-caprae* | Soursob | e | | x | |
| *Podotheca angustifolia* | Sticky Long-heads | n | x | | |
| *Polycalymma stuartii* | Poached eggs | n | | x | x |
| *Polygonum aviculare* | Wireweed | e | | x | |
| *Reichardia tingitana* | False Sowthistle | e | | x | |
| *Salsola kali* | Buckbush | n | x | x | x |
| *Sclerolaena sp.* | Bindyi sp. | n | x | | |
| *Sedge 1* | | u | x | | |
| *Sonchus oleraceus* | Common Sow-thistle | e | x | x | x |
| *Spergula arvensis* | Corn Spurrey | e | x | | |
| *Austrostipa sp. 1* | Spear-grass sp. | n | x | x | |
| *Austrostipa sp. 2* | Spear-grass sp | n | x | | |
| *Austrostipa sp. 3* | Spear-grass sp | n | x | | |
| *Austrostipa sp. 4* | Spear-grass sp | n | x | | |
| *Taraxacum officinale* | Dandelion | e | x | x | x |
| *Tribulus terrestris* | Caltrop | e | | | x |
| *Trifolium arvense* | Hare's foot clover | e | | x | |
| *Trifolium glomeratum* | Cluster clover | e | | x | |
| *Trifolium hirtum* | Hairy Clover | e | | x | |
| *Trifolium tomentosum* | Woolly Clover | e | | x | x |
| *Triticum aestivum* | Wheat | e | | x | x |
| *Vicia villosa* | Woolly-pod Vetch | e | | x | |
| *Vittadinia sp.* | New Holland Daisy | n | x | | |
| *Vulpia bromoides* | Squirrel-tail Fescue | e | x | x | x |
| *Vulpia myuros* | Rat's tail fescue | e | | x | |
| *Wahlenbergia sp.* | Bluebell sp. | n | x | | |
| **Count** | **89** | **-** | **58** | **38** | **35** |

* n = native, e = exotic, u = unidentified

(R) = 'Rare' status under the SA National Parks and Wildlife Act – updated 2008

# APPENDIX 3 – PLANT COMMUNITY SIMPER RESULTS

Comparisons are between treatments and seasons, showing plant species that contribute up to 50% of the dissimilarity between groups

| **Average dissimilarity = 82.54** | **Remnant** | **Saltbush** | | | | |
|---|---|---|---|---|---|---|
| **Species** | **Av.Abund** | **Av.Abund** | **Av.Diss** | **Diss/SD** | **Contrib%** | **Cum.%** |
| *Atriplex nummularia* | 0.1 | 1 | 5.56 | 1.49 | 6.74 | 6.74 |
| *Eucalyptus incrassata* | 0.8 | 0 | 4.48 | 1.24 | 5.43 | 12.17 |
| *Chondrilla juncea* | 0 | 0.7 | 4.44 | 1.07 | 5.37 | 17.55 |
| *Enchylaena tomentosa* | 0.6 | 0 | 3.59 | 0.87 | 4.35 | 21.9 |
| *Melaleuca uncinata* | 0.6 | 0 | 3.41 | 0.9 | 4.13 | 26.03 |
| *Eucalyptus leptophylla* | 0.6 | 0 | 3.27 | 0.92 | 3.96 | 29.99 |
| *Babingtonia behrii* | 0.5 | 0 | 3.04 | 0.83 | 3.69 | 33.68 |
| *Ehrharta calycina* | 0.5 | 0.6 | 2.96 | 0.77 | 3.59 | 37.27 |
| *Asparagus asparagoides* | 0.5 | 0 | 2.57 | 0.75 | 3.11 | 40.38 |
| *Austrodanthonia sp 1* | 0.4 | 0 | 2.52 | 0.63 | 3.05 | 43.43 |
| *Eucalyptus socialis* | 0.4 | 0 | 2.27 | 0.65 | 2.76 | 46.18 |
| *Billardieria cymosa* | 0.4 | 0 | 2.2 | 0.66 | 2.66 | 48.85 |
| *Lomandra sp.* | 0.4 | 0 | 2.2 | 0.66 | 2.66 | 51.51 |

| **Average dissimilarity = 89.81** | **Remnant** | **Pasture** | | | | |
|---|---|---|---|---|---|---|
| **Species** | **Av.Abund** | **Av.Abund** | **Av.Diss** | **Diss/SD** | **Contrib%** | **Cum.%** |
| *Eucalyptus incrassata* | 0.8 | 0 | 4.67 | 1.31 | 5.2 | 5.2 |
| *Enchylaena tomentosa* | 0.6 | 0 | 3.72 | 0.91 | 4.14 | 9.34 |
| *Melaleuca uncinata* | 0.6 | 0 | 3.55 | 0.94 | 3.95 | 13.29 |
| *Eucalyptus leptophylla* | 0.6 | 0 | 3.42 | 0.97 | 3.81 | 17.1 |
| *Babingtonia behrii* | 0.5 | 0 | 3.14 | 0.85 | 3.5 | 20.6 |
| *Heliotrope europaeum* | 0 | 0.3 | 2.83 | 0.64 | 3.15 | 23.75 |
| *Asparagus asparagoides* | 0.5 | 0 | 2.74 | 0.79 | 3.05 | 26.8 |
| *Austrodanthonia sp 1* | 0.4 | 0 | 2.59 | 0.64 | 2.89 | 29.69 |
| *Ehrharta calycina* | 0.5 | 0 | 2.58 | 0.79 | 2.87 | 32.56 |
| *Eucalyptus socialis* | 0.4 | 0 | 2.36 | 0.67 | 2.63 | 35.19 |
| *Billardieria cymosa* | 0.4 | 0 | 2.29 | 0.68 | 2.55 | 37.74 |
| *Lomandra sp.* | 0.4 | 0 | 2.29 | 0.68 | 2.55 | 40.29 |
| *Chondrilla juncea* | 0 | 0.4 | 2.28 | 0.66 | 2.53 | 42.83 |
| *Eucalyptus dumosa* | 0.3 | 0 | 2.15 | 0.56 | 2.4 | 45.22 |
| *Sedge 1* | 0.3 | 0 | 1.94 | 0.57 | 2.16 | 47.38 |
| *Citrullus lanatus* | 0 | 0.2 | 1.63 | 0.47 | 1.82 | 49.2 |
| *Aira elegans/caryophyllea* | 0.5 | 0 | 1.55 | 0.95 | 1.72 | 50.93 |

| **Average dissimilarity = 73.58** | **Saltbush** | **Pasture** | | | | |
|---|---|---|---|---|---|---|
| **Species** | **Av.Abund** | **Av.Abund** | **Av.Diss** | **Diss/SD** | **Contrib%** | **Cum.%** |
| *Atriplex nummularia* | 1 | 0 | 9.51 | 1.43 | 12.92 | 12.92 |
| *Ehrharta calycina* | 0.6 | 0 | 5.49 | 0.85 | 7.46 | 20.38 |
| *Chondrilla juncea* | 0.7 | 0.4 | 5.48 | 0.77 | 7.44 | 27.82 |
| *Heliotrope europaeum* | 0 | 0.3 | 4.86 | 0.63 | 6.6 | 34.42 |
| *Citrullus lanatus* | 0 | 0.2 | 2.71 | 0.44 | 3.68 | 38.11 |
| *Taraxacum sp.* | 0.6 | 0.2 | 2.65 | 0.61 | 3.6 | 41.71 |
| *Marrubium vulgare* | 0.3 | 0.2 | 2.65 | 0.59 | 3.59 | 45.3 |
| *Medicago sativa* | 0.2 | 0.2 | 2.44 | 0.54 | 3.32 | 48.62 |
| *Cynodon dactylon* | 0 | 0.2 | 2.4 | 0.46 | 3.26 | 51.88 |

| **Average dissimilarity = 83.55** | **Autumn** | **Spring** | | | | |
|---|---|---|---|---|---|---|
| **Species** | **Av.Abund** | **Av.Abund** | **Av.Diss** | **Diss/SD** | **Contrib%** | **Cum.%** |
| *Brassica tournefortii* | 0 | 0.93 | 4.52 | 2.22 | 5.41 | 5.41 |
| *Hordeum leporinum* | 0 | 0.87 | 4.27 | 1.84 | 5.11 | 10.52 |
| *Lolium perenne* | 0 | 0.73 | 3.84 | 1.4 | 4.6 | 15.12 |
| *Arctotheca calendula* | 0 | 0.73 | 3.84 | 1.4 | 4.6 | 19.71 |
| *Crassula colorata* | 0 | 0.8 | 3.5 | 1.69 | 4.19 | 23.9 |
| *Taraxacum sp.* | 0.07 | 0.73 | 2.98 | 1.27 | 3.57 | 27.47 |
| *Medicago polymorpha* | 0 | 0.47 | 2.67 | 0.85 | 3.2 | 30.66 |
| *Bromus diandrus* | 0 | 0.53 | 2.65 | 1.02 | 3.17 | 33.83 |
| *Chondrilla juncea* | 0.4 | 0.33 | 2.28 | 0.5 | 2.73 | 36.56 |
| *Vulpia bromoides* | 0 | 0.53 | 2.08 | 1 | 2.49 | 39.05 |
| *Amsinckia intermedia* | 0 | 0.4 | 2.05 | 0.79 | 2.46 | 41.51 |
| *Heliotrope europaeum* | 0.2 | 0 | 1.94 | 0.41 | 2.33 | 43.83 |
| *Triticum aestivum* | 0 | 0.2 | 1.91 | 0.37 | 2.29 | 46.12 |
| *Trifolium tomentosum* | 0 | 0.2 | 1.38 | 0.48 | 1.66 | 47.78 |
| *Ehrharta calycina* | 0.33 | 0.4 | 1.35 | 0.67 | 1.62 | 49.4 |
| *Medicago sativa* | 0.13 | 0.2 | 1.32 | 0.59 | 1.59 | 50.98 |

# APPENDIX 4 – BIRD SPECIES RECORDED IN SPRING 2008 AND AUTUMN 2009

| Common name | Species Name | Remnant | | | | Saltbush | | | | Pasture | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Spring | | Autumn | | Spring | | Autumn | | Spring | | Autumn | |
| | | Total no. of indiv. | No. of sites (n=5) | Total no. of indiv. | No. of sites (n=5) | Total no. of indiv. | No. of sites (n=5) | Total no. of indiv. | No. of sites (n=5) | Total no. of indiv. | No. of sites (n=5) | Total no. of indiv. | No. of sites (n=5) |
| Australian Kestrel | *Falco cenchroides* | | | | | 1 | 1 | | | | | | |
| Australian Magpie | *Gymnorhina tibicen* | 20 | 3 | 21 | 5 | 19 | 3 | 11 | 3 | 37 | 5 | 10 | 3 |
| Australasian Pipit | *Anthus australis* | | | | | 8 | 2 | 18 | 3 | 3 | 2 | 9 | 3 |
| Australian Raven | *Corvus coronoides* | 7 | 2 | 2 | 1 | | | 2 | 1 | 31 | 2 | | |
| Blue Bonnet | *Northiella haematogaster* | 7 | 1 | 2 | 1 | 7 | 2 | | | | | | |
| Brown Falcon | *Falco berigora* | 1 | 1 | | | | | | | | | | |
| Brown Goshawk | *Accipiter fasciatus* | 2 | 2 | | | | | | | | | | |
| Brown Songlark | *Cinclorhamphus cruralis* | | | | | | | | | 6 | 3 | 8 | 2 |
| Brown Thornbill | *Acanthiza pusilla* | 5 | 2 | 2 | 1 | | | 10 | 2 | | | | |
| Brown Treecreeper | *Climacteris pucumnus* | 1 | 1 | | | | | | | | | | |
| Brown-headed Honeyeater | *Melithreptus brevirostris* | 13 | 2 | 8 | 1 | | | | | | | | |
| Chestnut-rumped Thornbill | *Acanthiza uropygialis* | 6 | 1 | 3 | 1 | | | | | | | | |
| Collared Sparrowhawk | *Accipiter cirrhocephalus* | 1 | 1 | | | | | | | | | | |
| Common Bronzewing | *Phaps chalcoptera* | | | 15 | 5 | | | | | | | | |
| Common Starling (I) | *Sturnus vulgaris* | 3 | 1 | 2 | 1 | 8 | 2 | 2 | 2 | 6 | 1 | | |
| Crested Pigeon | *Ocyphaps lophotes* | 4 | 2 | 9 | 3 | 4 | 2 | 6 | 1 | 2 | 1 | | |
| Dusky Woodswallow | *Artamus cyanopterus* | 1 | 1 | | | | | | | | | | |
| Elegant Parrot (R) | *Neophema elegans* | | | | | 2 | 2 | | | | | | |
| Galah | *Cacatua roseicapilla* | 10 | 1 | 16 | 1 | 2 | 1 | 4 | 1 | 4 | 1 | | |
| Golden Whistler | *Pachycephala pectoralis* | 2 | 1 | | | | | | | | | | |
| Grey Shrike-thrush | *Colluricincla harmonica* | 4 | 2 | 2 | 2 | | | | | | | | |
| Hooded Robin (R) | *Melanodryas cucullata* | 2 | 1 | | | | | 1 | 1 | | | | |
| House Sparrow (I) | *Passer domesticus* | 6 | 1 | | | 4 | 1 | | | | | | |
| Little Raven | *Corvus mellori* | 4 | 3 | 3 | 2 | | | 3 | 2 | 3 | 1 | | |
| Magpie-lark | *Grallina cyanoleuca* | | | | | | | 2 | 1 | | | | |
| Masked Woodswallow | *Artamus personatus* | 25 | 1 | | | | | | | | | | |
| Orange Chat | *Epthianura aurifrons* | | | | | 101 | 4 | | | 6 | 1 | | |
| Peaceful Dove | *Geopelia striata* | 6 | 2 | 2 | 1 | | | | | | | | |
| Rainbow Bee-eater | *Merops ornatus* | 6 | 2 | | | | | | | | | | |
| Red Wattlebird | *Anthochaera carunculata* | 18 | 3 | | | | | | | | | | |

| Common name | Species Name | Remnant | | | | Saltbush | | | | Pasture | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Spring | | Autumn | | Spring | | Autumn | | Spring | | Autumn | |
| | | Total no. of indiv. | No. of sites (n=5) | Total no. of indiv. | No. of sites (n=5) | Total no. of indiv. | No. of sites (n=5) | Total no. of indiv. | No. of sites (n=5) | Total no. of indiv. | No. of sites (n=5) | Total no. of indiv. | No. of sites (n=5) |
| Red-backed Kingfisher | *Todiramphus pyrrhopygia* | 1 | 1 | | | | | | | | | | |
| Red-capped Robin | *Petroica goodenovii* | 7 | 2 | 3 | 2 | | | | | | | | |
| Red-rumped Parrot | *Psephotus haematonotus* | 4 | 1 | 2 | 1 | 10 | 1 | | | | | | |
| Restless Flycatcher (R) | *Myiagra inquieta* | 3 | 1 | 2 | 1 | | | 2 | 1 | | | | |
| Rufous Whistler | *Pachycephala rufiventris* | 5 | 2 | 1 | 1 | | | | | | | | |
| Silvereye | *Zosterops lateralis* | 1 | 1 | | | | | | | | | | |
| Singing Honeyeater | *Lichenostomus virescens* | | | | | 4 | 2 | | | | | | |
| Spiny-cheeked Honeyeater | *Acanthagenys rufogularis* | 2 | 1 | 1 | 1 | | | | | | | | |
| Splendid Fairy-wren | *Malurus cyaneus* | 5 | 1 | 3 | 1 | | | | | | | | |
| Spotted Pardalote | *Pardalotus punctatus* | 10 | 2 | 6 | 2 | | | | | | | | |
| Striated Pardalote | *Pardalotus striatus* | 1 | 1 | 2 | 2 | | | | | | | | |
| Superb Fairy-wren | *Malurus cyaneus* | 11 | 2 | | | | | | | | | | |
| Varied Sitella | *Daphoenositta chrysoptera* | 5 | 1 | | | | | | | | | | |
| Variegated Fairy-wren | *Malurus lamberti* | 4 | 1 | | | 11 | 1 | 17 | 1 | | | | |
| Weebill | *Smicrornis brevirostris* | | | 10 | 3 | | | | | | | | |
| Welcome Swallow | *Hirundo neoxena* | 6 | 1 | 2 | 1 | 1 | 1 | | | | | | |
| White-browed Babbler | *Pomatostomus superciliosus* | | | 2 | 1 | 4 | 1 | | | | | | |
| White-browed Woodswallow | *Artamus superciliosus* | 18 | 1 | | | | | | | | | | |
| White-eared Honeyeater | *Lichenostomus leucotis* | | | 4 | 3 | | | | | | | | |
| White-fronted Chat | *Epthianura albifrons* | 10 | 1 | | | 151 | 5 | 104 | 5 | 4 | 1 | 3 | 1 |
| White-fronted Honeyeater | *Phylidonyris albifrons* | 2 | 2 | | | | | | | | | | |
| White-winged Chough (R) | *Corcorax melanorhamphos* | | | 6 | 1 | | | | | | | | |
| White-winged Triller | *Lalage tricolour* | 1 | 1 | | | | | | | | | | |
| Willie Wagtail | *Rhipidura leucophrys* | 7 | 4 | 2 | 1 | | | 8 | 4 | | | 5 | 1 |
| Yellow Thornbill | *Acanthiza nana* | 34 | 4 | 15 | 3 | | | | | | | | |
| Yellow-plumed Honeyeater | *Lichenostomus penicillatus* | 5 | 1 | | | | | | | | | | |
| Yellow-rumped Thornbill | *Acanthiza chrysorrhoa* | 25 | 4 | 24 | 3 | 28 | 3 | 27 | 4 | | | 35 | 1 |
| **Number of species** | | **45** | | **29** | | **17** | | **15** | | **10** | | **6** | |

Total no. of individuals = no. of individual birds of each species recorded at 5 sites, sampled on 3 occasions each - individual birds may have been sampled more than once at the same site.
No. of sites = the number of sites of each treatment (n = 5) where species were recorded.
(R) = 'Rare' status under the SA National Parks and Wildlife Act – updated 2008. (I) = Introduced bird species
* c = carnivore, o = omnivore, i = insectivore, n = nectarivore, f = frugivore, g = granivore
** g = ground, a = aerial, f = foliage, b = bark

# APPENDIX 5 – BIRD COMMUNITY SIMPER RESULTS

Comparisons are between treatments and seasons, showing bird species that contribute up to 90% of the dissimilarity between groups

| Average dissimilarity = 84.17 | Remnant | Saltbush | | |
|---|---|---|---|---|
| **Species** | **Av.Abund** | **Av.Abund** | **Contrib%** | **Cum.%** |
| White-fronted Chat | 0.18 | 2.2 | 10.19 | 10.19 |
| Yellow Thornbill | 1.1 | 0 | 5.27 | 15.46 |
| Yellow-rumped Thornbill | 1.11 | 1.1 | 4.34 | 19.79 |
| Willie Wagtail | 0.57 | 0.46 | 4.17 | 23.97 |
| Australian Magpie | 1.18 | 0.86 | 3.71 | 27.68 |
| Common Bronzewing | 0.65 | 0 | 3.6 | 31.28 |
| Orange Chat | 0 | 0.86 | 3.6 | 34.88 |
| Australasian Pipit | 0 | 0.7 | 3.43 | 38.31 |
| Crested Pigeon | 0.62 | 0.39 | 3.18 | 41.49 |
| Spotted Pardalote | 0.56 | 0 | 3.14 | 44.62 |
| Brown Thornbill | 0.37 | 0.29 | 2.97 | 47.59 |
| Little Raven | 0.54 | 0.22 | 2.85 | 50.44 |
| Red-capped Robin | 0.49 | 0 | 2.65 | 53.1 |
| Common Starling | 0.25 | 0.48 | 2.48 | 55.58 |
| Australian Raven | 0.38 | 0.12 | 2.23 | 57.81 |
| Galah | 0.38 | 0.26 | 2.19 | 60 |
| Brown-headed Honeyeater | 0.47 | 0 | 2.17 | 62.18 |
| Red Wattlebird | 0.44 | 0 | 2.04 | 64.21 |
| Variegated Fairy-wren | 0.14 | 0.39 | 2 | 66.22 |
| Grey Shrike-thrush | 0.44 | 0 | 1.89 | 68.1 |
| Weebill | 0.39 | 0 | 1.87 | 69.97 |
| Blue Bonnet | 0.28 | 0.27 | 1.68 | 71.66 |
| Peaceful Dove | 0.37 | 0 | 1.64 | 73.3 |
| Red-rumped Parrot | 0.26 | 0.18 | 1.55 | 74.84 |
| Rufous Whistler | 0.35 | 0 | 1.53 | 76.37 |
| White-eared Honeyeater | 0.32 | 0 | 1.52 | 77.89 |
| Superb Fairy-wren | 0.31 | 0 | 1.45 | 79.35 |
| Restless Flycatcher | 0.25 | 0.12 | 1.28 | 80.63 |
| Chestnut-rumped Thornbill | 0.29 | 0 | 1.28 | 81.91 |
| Splendid Fairy-wren | 0.28 | 0 | 1.25 | 83.16 |
| Striated Pardalote | 0.3 | 0 | 1.22 | 84.38 |
| Welcome Swallow | 0.28 | 0.1 | 1.21 | 85.58 |
| White-browed Babbler | 0.12 | 0.14 | 1.11 | 86.7 |
| Spiny-cheeked Honeyeater | 0.22 | 0 | 0.93 | 87.63 |
| White-fronted Honeyeater | 0.2 | 0 | 0.93 | 88.56 |
| Rainbow Bee-eater | 0.26 | 0 | 0.9 | 89.46 |
| Singing Honeyeater | 0 | 0.23 | 0.89 | 90.36 |

| Average dissimilarity = 87.69 | Remnant | Pasture | | |
|---|---|---|---|---|
| **Species** | **Av.Abund** | **Av.Abund** | **Contrib%** | **Cum.%** |
| Yellow-rumped Thornbill | 1.11 | 0.24 | 7.22 | 7.22 |
| Yellow Thornbill | 1.1 | 0 | 6.68 | 13.9 |
| Common Bronzewing | 0.65 | 0 | 5.05 | 18.95 |
| Australian Magpie | 1.18 | 1.19 | 4.57 | 23.52 |
| Spotted Pardalote | 0.56 | 0 | 4.48 | 28 |
| Australasian Pipit | 0 | 0.6 | 3.94 | 31.95 |

| | | | | |
|---|---|---|---|---|
| Red-capped Robin | 0.49 | 0 | 3.75 | 35.7 |
| Brown Songlark | 0 | 0.63 | 3.73 | 39.43 |
| Willie Wagtail | 0.57 | 0.15 | 3.69 | 43.12 |
| Crested Pigeon | 0.62 | 0.12 | 3.67 | 46.79 |
| Little Raven | 0.54 | 0.13 | 3.07 | 49.86 |
| Australian Raven | 0.38 | 0.35 | 2.86 | 52.73 |
| Brown-headed Honeyeater | 0.47 | 0 | 2.73 | 55.46 |
| Red Wattlebird | 0.44 | 0 | 2.54 | 58 |
| Weebill | 0.39 | 0 | 2.38 | 60.38 |
| Grey Shrike-thrush | 0.44 | 0 | 2.37 | 62.75 |
| Brown Thornbill | 0.37 | 0 | 2.31 | 65.06 |
| Peaceful Dove | 0.37 | 0 | 2.03 | 67.09 |
| Galah | 0.38 | 0.14 | 2 | 69.09 |
| White-eared Honeyeater | 0.32 | 0 | 1.94 | 71.03 |
| Rufous Whistler | 0.35 | 0 | 1.88 | 72.9 |
| Superb Fairy-wren | 0.31 | 0 | 1.83 | 74.73 |
| White-fronted Chat | 0.18 | 0.27 | 1.8 | 76.54 |
| Common Starling | 0.25 | 0.16 | 1.59 | 78.13 |
| Chestnut-rumped Thornbill | 0.29 | 0 | 1.58 | 79.71 |
| Splendid Fairy-wren | 0.28 | 0 | 1.55 | 81.26 |
| Striated Pardalote | 0.3 | 0 | 1.51 | 82.77 |
| White-fronted Honeyeater | 0.2 | 0 | 1.17 | 83.94 |
| Spiny-cheeked Honeyeater | 0.22 | 0 | 1.14 | 85.08 |
| Blue Bonnet | 0.28 | 0 | 1.09 | 86.17 |
| Welcome Swallow | 0.28 | 0 | 1.08 | 87.25 |
| Rainbow Bee-eater | 0.26 | 0 | 1.06 | 88.31 |
| White-winged Chough | 0.16 | 0 | 1.06 | 89.37 |
| Red-rumped Parrot | 0.26 | 0 | 1.03 | 90.4 |

| **Average dissimilarity = 77.94** | **Saltbush** | **Pasture** | | |
|---|---|---|---|---|
| **Species** | **Av.Abund** | **Av.Abund** | **Contrib%** | **Cum.%** |
| White-fronted Chat | 2.2 | 0.27 | 19.11 | 19.11 |
| Yellow-rumped Thornbill | 1.1 | 0.24 | 10.21 | 29.32 |
| Australian Magpie | 0.86 | 1.19 | 7.34 | 36.66 |
| Orange Chat | 0.86 | 0.16 | 7.09 | 43.75 |
| Australasian Pipit | 0.7 | 0.6 | 6.87 | 50.62 |
| Brown Songlark | 0 | 0.63 | 5.57 | 56.19 |
| Common Starling | 0.48 | 0.16 | 4.76 | 60.95 |
| Willie Wagtail | 0.46 | 0.15 | 4.62 | 65.57 |
| Australian Raven | 0.12 | 0.35 | 3.75 | 69.31 |
| Crested Pigeon | 0.39 | 0.12 | 3.46 | 72.77 |
| Variegated Fairy-wren | 0.39 | 0 | 3.34 | 76.12 |
| Little Raven | 0.22 | 0.13 | 3.3 | 79.42 |
| Brown Thornbill | 0.29 | 0 | 3.29 | 82.71 |
| Galah | 0.26 | 0.14 | 2.94 | 85.65 |
| Blue Bonnet | 0.27 | 0 | 1.91 | 87.56 |
| Red-rumped Parrot | 0.18 | 0 | 1.89 | 89.44 |
| Singing Honeyeater | 0.23 | 0 | 1.73 | 91.17 |

| **Average dissimilarity = 66.22** | **Spring** | **Autumn** | | |
|---|---|---|---|---|
| **Species** | **Av.Abund** | **Av.Abund** | **Contrib%** | **Cum.%** |
| Australian Magpie | 1.15 | 1 | 8.67 | 8.67 |
| Australasian Pipit | 0.33 | 0.53 | 7.09 | 15.76 |
| Yellow-rumped Thornbill | 0.75 | 0.89 | 6.83 | 22.59 |
| Orange Chat | 0.68 | 0 | 5.7 | 28.29 |
| Willie Wagtail | 0.3 | 0.49 | 5.6 | 33.89 |

| | | | | |
|---|---|---|---|---|
| Australian Raven | 0.4 | 0.16 | 5.01 | 38.9 |
| Brown Songlark | 0.23 | 0.18 | 4.86 | 43.76 |
| Common Starling | 0.38 | 0.21 | 3.77 | 47.53 |
| Little Raven | 0.3 | 0.29 | 3.67 | 51.2 |
| Crested Pigeon | 0.39 | 0.37 | 3.46 | 54.65 |
| White-fronted Chat | 0.98 | 0.79 | 3.22 | 57.88 |
| Galah | 0.29 | 0.23 | 2.91 | 60.79 |
| Brown Thornbill | 0.17 | 0.27 | 2.52 | 63.3 |
| Common Bronzewing | 0 | 0.43 | 2.13 | 65.43 |
| Variegated Fairy-wren | 0.22 | 0.14 | 1.81 | 67.24 |
| Blue Bonnet | 0.29 | 0.08 | 1.77 | 69.01 |
| Red Wattlebird | 0.29 | 0 | 1.61 | 70.62 |
| Red-rumped Parrot | 0.21 | 0.08 | 1.59 | 72.21 |
| Yellow Thornbill | 0.45 | 0.29 | 1.48 | 73.69 |
| Spotted Pardalote | 0.2 | 0.17 | 1.19 | 74.88 |
| Brown-headed Honeyeater | 0.2 | 0.11 | 1.18 | 76.06 |
| Weebill | 0 | 0.26 | 1.16 | 77.22 |
| Superb Fairy-wren | 0.2 | 0 | 1.14 | 78.36 |
| Restless Flycatcher | 0.09 | 0.16 | 1.09 | 79.45 |
| Singing Honeyeater | 0.15 | 0 | 1.07 | 80.52 |
| Red-capped Robin | 0.18 | 0.15 | 1.06 | 81.58 |
| Welcome Swallow | 0.17 | 0.08 | 1.03 | 82.61 |
| White-browed Babbler | 0.09 | 0.08 | 1.01 | 83.63 |
| House Sparrow | 0.2 | 0 | 0.99 | 84.62 |
| White-eared Honeyeater | 0 | 0.21 | 0.94 | 85.56 |
| Peaceful Dove | 0.17 | 0.08 | 0.93 | 86.49 |
| Rufous Whistler | 0.17 | 0.07 | 0.91 | 87.4 |
| Elegant Parrot | 0.13 | 0 | 0.89 | 88.29 |
| Grey Shrike-thrush | 0.16 | 0.13 | 0.87 | 89.16 |
| Chestnut-rumped Thornbill | 0.1 | 0.09 | 0.75 | 89.91 |
| Hooded Robin | 0.08 | 0.07 | 0.74 | 90.65 |

# APPENDIX 6 – INVERTEBRATE SPECIES LIST

| Beneficial | | Pest | | Unknown impact on agriculture | |
|---|---|---|---|---|---|
| **Species list** | **Common names (if known)** | **Species list** | **Common names (if known)** | **Species list** | **Common names (if known)** |
| **Predatory Hemiptera** | **Predatory bugs** | **Cicadellidae** | **Leafhoppers** | **Coleoptera** | **Beetles** |
| Nabidae | Damsel bug | Opsiini | | Corylophidae | |
| Reduviidae | | **Other Hemiptera** | **Bugs** | Curculionidae | |
| Anthocoridae | Pirate bug | Fulgoroidea | Planthopper | Cucujoidea 01 | |
| Geocoridae | | *Nysius vinitor* | Rutherglen bug | Tenebrionid - Alleculinae 01 | |
| **Predatory Coleoptera** | **Predatory beetles** | Pentatomidae | Shield bug/Stink bug | Elateridae 01 | |
| Staphylinidae sp. 01 | | *Corydromus variegata* | Mirid | Anthrenini 01 (Cucujoidea 01) | |
| *Coccinella transversalis* | Transverse ladybeetle | Bryocorinae | Mirid | Bostrichidae | |
| *C. undecimpunctata* | ladybeetle | **Aleyrodidae** | **Whiteflies** | Lathridiidae | |
| *Harmonia conformis* | ladybeetle | **Aphididae** | **Aphids** | **Psocoptera** | **Booklice** |
| *H. variegata* | ladybeetle | (3 species) | | **Lepidoptera** | **Moths** |
| *Diomus notescens* | | **Pest Thysanoptera** | **Introduced pest thrips** | **Acarina** | **Mites** |
| Anthicidae | | *Frankliniella occidentalis* | Western flower thrips | (Most mites found were parasitic on flies) | |
| Lathridiidae 01 | | *Frankliniella schultzei* | Tomato thrips | **Diptera** | **Flies** |
| ***Micromus tasmaniae*** | **Tasmans lacewing** | *Thrips tabaci* | Onion thrips | Chloropidae 01 | |
| **Chrysopidae** | **Green lacewing** | ***Thrips imaginis*** | **Native Plague thrips** | Phoridae 01 | |
| **Aranae** | **Spiders** | **Psyllidae** | **Lerps/scales** | Sciaridae 01 | |
| **Parasitoid Hymenoptera** | **Wasps** | Psyllidae 01 | | Acalyptrate 02 | |
| Aphelinidae 01 | | Psyllidae 02 | | Acalyptrate 03 | |
| Bethylidae 01 | | Psyllidae 03 | | Acalyptrate 04 | |
| Bethylidae 02-Chrysididae | | Psyllidae 04 | | Acalyptrate 05 | |
| Braconidae Aphidiinae 01 | (aphid parasite) | Psyllidae 05 | | Acalyptrate 06 | |
| Braconidae 02 | | | | Acalyptrate 07 patterned wings | |
| Chalcidoidea ns01 | | | | Muscoidea:Caliphoridae 01 | |
| Encyrtidae 01 | | | | Caliphoridae 02 | |
| | | | | | |
| Eulophidae12: Ceranisus | (thrips parasite) | | | Cecidomyiidae | |
| Eulphidae 01-red ocelli | | | | Tachinidae 01 | |
| Eulophidae 02 | | | | Tachinidae 02 | |
| Eulophidae: Hemiptasenus | (leafminer parasite) | | | Agromyzidae | |
| Ichneumonidae 01 | | | | Bombyliiidae 02 | |
| Mymaridae 01 | | | | Bombyliidae 03 | |
| Mymaridae 03 | | | | Empididae 01 | |
| Mymaridae 04 | | | | Tachinidae 01 | |
| Mymaridae 05-long body | | | | Tachinidae 04 | |
| Mymaromatid 01 | | | | Dolichopodidae 02 | |
| Platygastroidea 01 (MS7 claire) | | | | Psycodidae | |
| Proctotrupoidea diapriidae01 | | | | Syrphid 02 | |

| Beneficial | | Pest | | Unknown impact on agriculture | |
|---|---|---|---|---|---|
| **Species list** | **Common names (if known)** | **Species list** | **Common names (if known)** | **Species list** | **Common names (if known)** |
| Scelionidae: Telenomus | (rutherglen bug egg parasite) | | | Muscidae ms 01 | |
| Scelionidae 02 | | | | **Other Thysanoptera** | **Thrips** |
| Scelionidae (big telenomus)03 | | | | *C. manicatus* | |
| Signaphoridae 01(HYPER P) | | | | Pseudanaphothri ps | |
| Trichgramatidae 01 | (egg parasites) | | | Flower thrips | |
| Trichgramatidae 02 | (egg parasites) | | | *Heliothrips haemorrhoidalis* | Glasshouse thrips |
| Trichgramatidae 03 (red eyes) | (egg parasites) | | | Spotted thrips | |
| Trichgramatidae 05 | (egg parasites) | | | Other thrips | |
| Trichgramatidae 07(black eyes) | (egg parasites) | | | | |
| Big pterostigma | | | | | |
| Medium pterostigma | | | | | |
| Bethylidae 03 | | | | | |
| Eulophidae 04 | | | | | |
| Eulophidae 03 | | | | | |
| Aphelinidae 03 | | | | | |
| Encyrtidae 02 | | | | | |
| Mymaridae new 1 | | | | | |
| Eucoilidae ms 1 | | | | | |
| **Beneficial Diptera** | **Beneficial flies** | | | | |
| Diptera:Syrphidae-common lge | Hoverfly | | | | |
| Therevidae | | | | | |
| Dolichopodidae 01 | | | | | |
| ***Haplothrips sp*** | **Predatory thrips** | | | | |
| *Haplothrips victoriensis* | | | | | |
| *Haplothrips robustus* | | | | | |

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