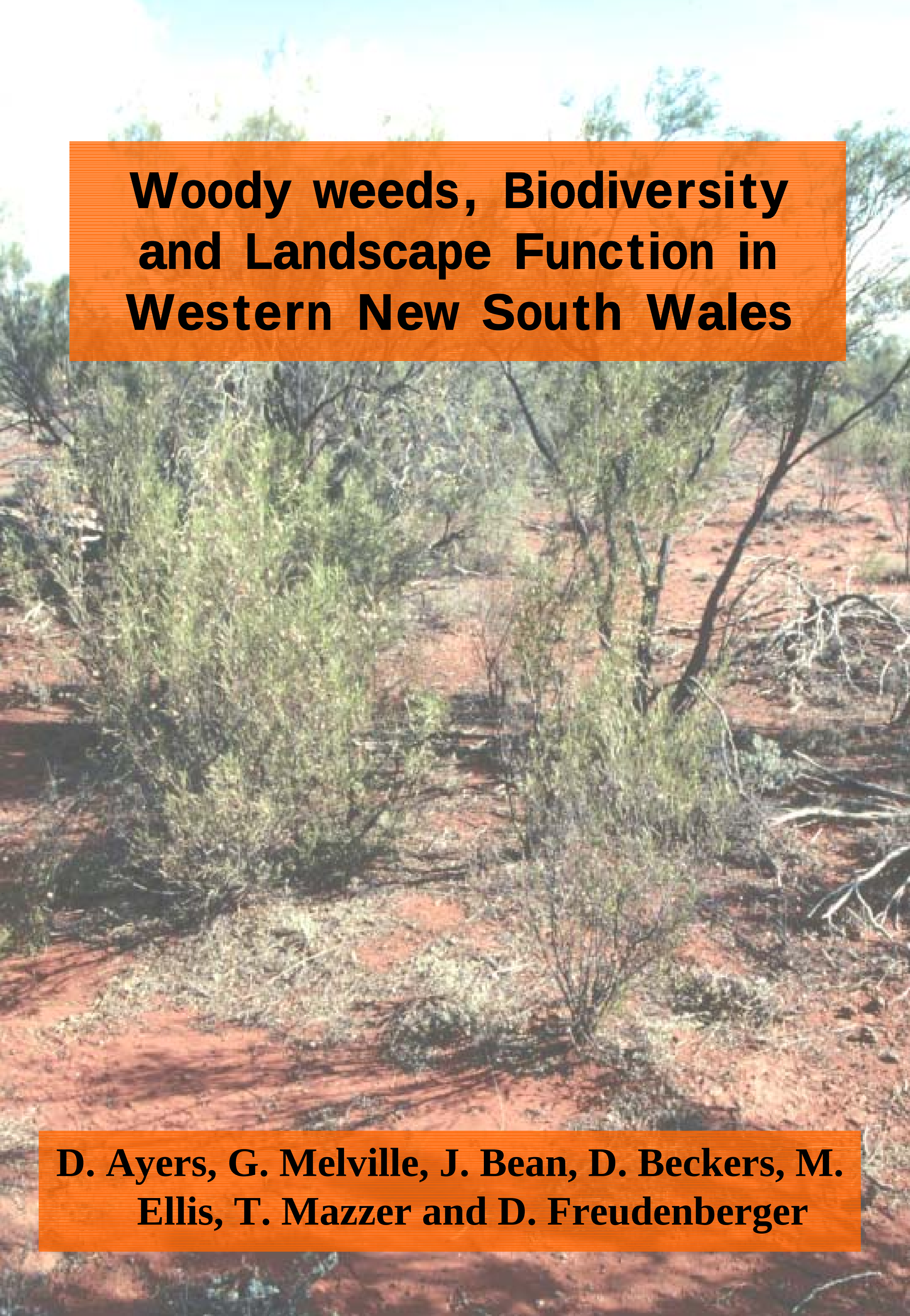

Woody weeds, Biodiversity and Landscape Function in Western New South Wales

D. Ayers, G. Melville, J. Bean, D. Beckers, M. Ellis, T. Mazzer and D. Freudenberger

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Summary

‘Woody weed’ is a general term used across the rangelands of central and eastern Australia and other continents to describe various plant species which can form dense impenetrable thickets (scrub). A feature of these species is that they are often unpalatable to stock, and frequently result in livestock management problems such as reduced carrying capacity, increased mustering time, reduced capacity to manage disease and lower lambing rates.

Unpalatable native shrubs have become increasingly abundant in many parts of western NSW. This trend was evident within two decades of European pastoral settlement. Significant research effort has been put into the impacts of shrub encroachment on the pastoral industry, determining the factors influencing shrub encroachment, and potential control measures. Impacts on biodiversity and landscape function of encroached areas have received little attention to date, causing a gap in the information required by individual land managers, regional planning committees and the Woody Weeds Task Force to develop effective management strategies for shrub-encroached landscapes. To date, general ecological principles have guided current thinking about these issues.

This study aimed to investigate the difference in biodiversity and landscape function as a response to different levels of shrub cover within three regions of the Western Division of NSW.

A literature review undertaken during this investigation confirmed that little specific information was available on the effects of woody shrub cover on biodiversity and landscape function, either in Australian or international rangeland areas. Although this is hardly surprising, given that ‘biodiversity’ and ‘landscape function’ are relatively new terms, previous investigations on related issues conducted over many decades provide information of varying detail and applicability.

Numerous species are referred to as ‘woody weeds’ within western NSW. However, the following six shrub species designated as ‘woody weeds’ in the 1992 Regulation of the *Western Lands Act* 1901 form the focus of this investigation: Turpentine *Eremophila sturtii*, Budda or False Sandalwood *Eremophila mitchellii*, Narrow-leaved Hopbush *Dodonaea viscosa* ssp. *angustissima*, Broad-leaved Hopbush *Dodonaea viscosa* ssp. *spatulata*, Punty Bush *Senna artemisiodes* ssp. *filifolia* and Silver Cassia *Senna artemisiodes* nothosubsp. *artemisiodes*.

The following three survey regions within the Western Division of NSW were investigated for the effects of woody shrub cover on biodiversity and landscape function during one-off ‘snapshot’ surveys during spring-summer of 1999/2000:

* Open Belah woodlands on sandplains north of Ivanhoe
* Rolling sandplains between Wanaaring and Louth
* Hard red country west of Cobar.

Within each region, approximately 12 study sites of similar landform, soil and vegetation type, but differing in woody shrub cover levels, were investigated simultaneously in terms of vertebrate and terrestrial invertebrate fauna, flora and landscape function over a period of 12 days.

Seasonal rainfall conditions in each region during the six months prior to investigations were generally about average in the Ivanhoe region, below average in the Wanaaring-Louth region, and above average in the Cobar region.

An enormous diversity and abundance of fauna were recorded at the 35 study sites, including 253 602 invertebrates (of which 150 119 were ants), 3 955 vertebrate fauna records and 3 479 flora records. In total, 140 vertebrate species, 30 invertebrate 'Orders', 94 ant taxa and 253 flora taxa were recorded across the three survey regions. Up to 160 flora and fauna taxa were recorded per study site within each survey period, with a trend of increasing diversity as the season progressed. Few exotic taxa were recorded on any site.

Each region contained some distinctive taxa within each broad taxonomic group, but also shared taxa with the other two regions. Species composition was most similar between the Wanaaring-Louth and Cobar regions. Between 25 and 30% of taxa recorded per region were present at a single study site.

Vertebrate faunal and floral compositions were most similar between sites in the same geographic region, rather than between sites with similar woody shrub cover. Ant compositions showed a similar, but weaker, trend.

Richness of flora and fauna taxa did not change between sites of differing woody shrub cover, across the three survey regions individually or collectively. This was also true for most broad taxonomic groups (plants, vertebrates, birds, reptiles, mammals, invertebrate 'Orders' and ants), both within and across the three regions.

Flora and fauna compositions varied between sites of different woody shrub cover levels. The results show that individual taxa, guilds and taxa associations varied in their responses to woody shrub cover or density. Response types to increasing shrub cover or density include:

- increasing abundance ("increasers")
- decreasing abundance ("decreasers")
- preference for intermediate shrub covers
- avoidance of intermediate shrub covers
- preference for one shrub cover extreme
- avoidance of one shrub cover extreme
- non-response ("generalists")

Regions differed in the proportions of taxa which responded significantly to woody shrub cover or density. In the Ivanhoe region, 5.4% of taxa responded as increasers or decreasers, and 4.1% of taxa exhibited one of the preference or avoidance responses indicated above. Comparative figures for the remaining regions are 15.4% and 3.3% respectively for the Wanaaring-Louth region; and 19.3% and 5.4% in the Cobar region. In each region, between three and six times more taxa responded as increasers than as decreasers. Only one exotic species responded significantly to shrub cover. Between 9.7% and 15.2% exhibited the generalist or non-response to shrub cover per region.

Despite diverse regional landforms, soils and vegetation types, some taxa and guilds responded similarly to woody shrub cover or density in multiple regions. However, most taxa responded differently across the regions, and this is particularly evident for several small insectivorous birds which responded as generalists in the open Belah woodlands of the Ivanhoe region, but not in the Wanaaring-Louth and Cobar regions where tree cover was considerably lower.

For many individual taxa and groups of taxa, the reasons for these responses remain difficult to interpret because detailed biological and ecological information is lacking. This is particularly true for ants and plants. For others, such as invertebrate 'Orders', the taxonomic level under consideration is too broad to allow meaningful interpretation.

Landscape function tended to be better and most variable in the Cobar region, with sites predominantly conservative in relation to both soil and water. The Ivanhoe sites were generally intermediate (and least variable) in functional status, being conservative with regard to soil, but less so in relation to water capture and retention. Landscape functionality was markedly poorer in the Wanaaring-Louth region, with sites tending to be 'leaky' with regard to both water and soil. Landform, soil type and vegetative differences, seasonal conditions and landscape degradation are thought to have influenced these results to varying degrees.

Relationships between the distribution of obstructions to overland water flow and woody shrub cover were only detected in the Ivanhoe region, where the average distance between obstructions increased with increasing shrub cover and density. However this relationship is unlikely to reflect an effect of shrub cover on landscape function.

Soil stability increased significantly with shrub cover in the Wanaaring-Louth region. No other relationships between soil surface condition and shrub cover or density were detected.

Comparison of soil surface condition data within individual study sites revealed a consistent trend between patch types. Where woody shrub patches functioned as resource sinks, soil condition was consistently better in terms of soil stability, infiltration capacity and nutrient cycling status than in adjacent run-off areas. Soil surface condition tended to be slightly better again in nearby treed and perennial grassland resource sink patches. These results highlight the importance of retaining healthy treed patches and perennial grasslands in these arid and semi-arid rangeland areas, and emphasises the consequences to landscape functionality of their degradation. Removal and replacement of these patch types with woody shrubs or run-off patches (e.g. by chaining) will result in a decline in landscape functional status. Where shrubby patches functioned as resource

source zones, they tended to be of equivalent function to source patches with a moderate vegetation cover, and were always considerably better than bare source patches.

In summary, the principal research conclusions of this investigation are:

- ‘woody weeds’ have biodiversity values, with many taxa utilising shrub-encroached areas;
- most taxa (between 75 and 90%) do not respond significantly to woody shrub cover or density; and
- shrub cover has a neutral or positive effect on landscape function in areas where the perennial ground cover has been degraded, but are not as effective as extensive dense perennial grasslands or stands of trees with associated debris.

Consequently, the following management and research directions are recommended for landscapes prone to woody shrub encroachment and proliferation:

- the biodiversity and landscape function values of shrub patches of differing densities and scales must be considered in conjunction with other landscape management issues;
- the establishment and maintenance of a mosaic of woody shrub densities within the mix of broader vegetation, soil and landform types is likely to best achieve a balance between the diversity and scale of responses to increasing shrub cover by various taxa;
- property-scale management requirements will determine the location and configuration of vegetation mosaics within each local region;
- management goals need to be established at local and regional scales, utilising site-specific information gained from on-ground inspections. On-ground monitoring relevant to these goals is crucial in assessing the success (and cost-benefit ratio) of management strategies;
- increase use of local knowledge, accumulated knowledge and existing information in determining management goals;
- landscape functional status must be maintained, with retention of resources within the local area, regardless of the management strategy being implemented;
- manage ongoing shrub encroachment, noting that resources will be required to maintain shrub densities at the desired level;
- assess the effects of woody shrub cover on biodiversity and landscape function in regions distinct from those investigated to date or, preferably, reassess the existing sites during alternative seasons following further establishment or loss of woody shrubs;
- re-interpret data from previous investigations and, where appropriate, re-visit sites. The latter may be particularly relevant for shrub control sites where some soil surface attributes have previously been recorded;
- focus further research effort on the effects of shrub treatment strategies (including multiple-technique strategies) on biodiversity and landscape function. Relevant predictions may be determined by drawing on particular results from the present investigation.

Contents

Appendix 10: Data storage and availability		A10-1

List of tables

List of illustrations

1. Introduction

1.1 The Woody Weeds and Biodiversity Project (WWBP)

1.1.1 Background

Unpalatable native shrubs have become increasingly abundant in many parts of western NSW. This was evident within two decades of European pastoral settlement, with the first report of shrub 'invasion' during the 1870s (Noble 1997). Shrub encroachment and proliferation has also affected substantial areas in the arid and semi-arid rangelands of Queensland, the Northern Territory, Western Australia and South Australia (Noble and Hodgkinson 1992). Increased densities of native shrubs are a worldwide phenomenon commonly associated with the introduction of domestic stock to semi-arid wooded grasslands (Harrington 1986).

In 1900 a Royal Commission was appointed to examine the condition of crown tenants in the western lands of New South Wales. The Royal Commission report identified seven principal causes of the widespread depression and general unprofitability of the Western Division pastoral industry (Anon. 1901, cited in Inter-Departmental Committee 1969). The 'spread of non-edible scrubs' was one of these. Each of the remaining six causes have also been implicated to varying degrees in the increased scrub levels. Three of these (low rainfall, rabbits, overstocking) were identified by the Commission as significant in ensuring that herbage fuel was unavailable for fires over large areas. To this list Noble (1997) added a fourth (sand-storms). Potential fuel was either consumed by excessive grazing pressures or prevented from reaching previous biomass levels through accelerated erosion of topsoil. In addition, deliberate measures were taken to reduce the incidence of fire from about the 1850s in western NSW, including the active suppression by European settlers of fires ignited by Aborigines and by lightning. The resulting drop in frequency and size of fires in turn encouraged regeneration by fire-sensitive species (Inter-Departmental Committee 1969, Noble 1997).

An Inter-Departmental Committee was established in 1968 to 'investigate and report on the problem of scrub and timber regrowth as it affects parts of the Western Division of New South Wales, and the Cobar-Byrock district in particular'. Their report again recognised the fundamental role of fire in regulating the population dynamics of these shrubs prior to settlement (Inter-Departmental Committee 1969). It also noted that stands of dense shrub had been noted as a feature of the Western Division since the beginning of European settlement, and that the commonly termed "woody weed invasion" was a misnomer.

Concerted scientific effort into the problem of shrub proliferation did not commence until the early 1960s. Early work focused on gaining an adequate understanding of the biology of the various shrub species and the key ecological processes involved in their proliferation (e.g. Booth *et al.* 1996a). Subsequent studies focused on determining the relative importance of the major factors involved in shrub increase (domestic stock, rabbits, fire and soil erosion) as well as their interactions (Noble 1997). The ability of native plants, particularly herbaceous species, to out-compete woody shrub seedlings for light and moisture, and the influence of grazing on this ability, was identified (Harrington 1986, 1991, Booth *et al.* 1996b). Solving the scrub problem was the next focus of scientific research. During this period of scientific research both mechanical and chemical treatments were investigated, with reasonable kill rates resulting. Biocontrol by browsing of Feral Goats and the use of fire were also studied (Woody Weeds Task Force 1992, Harland 1993). More recently, investigation of the effectiveness of biological control on woody shrubs has been undertaken by Robinson (1997). Concurrent with these investigations, an increasing understanding of soil dynamics (and more recently landscape function) in semi-arid rangeland areas has developed (e.g. Beadle and Tchan 1955, Charley and Cowling 1968, Ludwig *et al.* 1997).

Examination of the impacts of woody shrubs have focused on their effects on animal production, management costs and property values (see Woody Weeds Task Force 1990, 1992). Several studies have demonstrated a significant herbage response to overstorey reduction. Most of these relate to *Eucalyptus* communities (Walker *et al.* 1972, Tunstall *et al.* 1981, Scanlan and Burrows 1990, cited in Noble 1994), however Noble (1994) demonstrated a significant response by perennial grass species to reduction of woody shrub species in two contrasting land classes within north-western NSW. A similar response in Mulga *Acacia aneura* woodlands has also been demonstrated in south-western Queensland (Beale 1973 cited in Harrington 1986, Pressland 1976, Page 2000). Biodiversity impacts have received little attention in the research efforts to date, despite the inference that there has been a significant reduction in biodiversity with the decline in ground storey productivity and species richness based on the documented links between vegetation diversity and fauna diversity (Noble 1994). Even less research effort has been devoted to the relationships between woody shrub cover and landscape function.

A detailed compilation of the history of shrub proliferation and encroachment, as well as results of the many scientific research investigations conducted on these shrubs are summarised in Noble (1997).

1.1.2 Establishment

In mid 1998 the WEST 2000 Board of Management responded to repeated requests from landholders in western NSW for reliable information on the effects of 'woody weeds' on biodiversity. As interest in managing their land in a way that would maintain or increase biodiversity was growing, landholders were realising that very little information was available. In August the Executive Officer of WEST 2000 called a meeting of relevant organisations to discuss the purpose, objectives, methodology and management framework for the proposed project, and identified the steps required to implement the project.

Following this meeting, representatives of NSW NPWS, NSW DLWC, NSW Agriculture, CSIRO and WEST 2000 (including a landholder representative) were appointed to comprise the Woody Weeds and Biodiversity Project (WWBP) Working Group. This same group has continued to function as a Steering Committee for the duration of the project.

Even though the request had come from landholders, there was a strong awareness that the results of the project would be beneficial to a very wide range of people concerned with land management in western NSW. Ongoing development, at that time, by the Woody Weed task Force of a Code of Practice was adding immediacy to the need for such information.

1.1.3 Project objectives

The project objectives, as established by the Working Group, are:

1. Collate and analyse existing information and work in progress in order to synthesise existing information and identify information gaps.
2. Explore and determine appropriate variables (and/or indicators) for measuring biodiversity and landscape function in the woody weeds context.
3. Determine biodiversity and landscape function status at both the regional and landscape levels by:
   a) investigating change in biodiversity and landscape function as a result of different levels of shrub cover
   b) comparing the differences in biodiversity and landscape function as a result of the various shrub control practices.
4. Provide information from the project to landholders, agencies and the Woody Weed Code of Practice Committee.

Early in the project it was decided that with the funds and timeframe available for the present project, it would not be possible to attempt objective 3b.

1.1.4 Achievement of project objectives

1.1.4.1 Literature review

Objectives 1 and 2 were addressed during 1999 when these tasks were put out to tender. The literature review undertaken by Hassall and Associates concluded that there is little direct information available on the effects of woody shrub cover on biodiversity and landscape function. Recognising the recency with which these terms have entered the literature, a broader search of related issues was undertaken. From previous studies unrelated to woody shrubs this review concluded that plant cover, landscape pattern, understorey plants, birds and ants may be used as indicators of biodiversity (Hassall and Associates 1999).

As outlined by the review, an understanding of biodiversity is governed by the following general principles:

- in a given landscape, there will be few abundant species and a large number of relatively rare species;
- biodiversity will be greater with higher water and nutrient supply;
- biodiversity will be greater where there is greater environmental complexity (e.g. different heights and functional types of plants, varying slopes and ground surface textures);
- biodiversity will be greatest where there are environmental gradients (rainfall, temperature, light, soil type, run-on/run-off patches), and hence a greater diversity of niches.

The literature review concluded from general ecological principles that greater biodiversity can be expected in a landscape that contains all functional groups of vegetation arranged in a patchy or clumped distribution (large and small trees, chenopods, perennial and annual grasses and forbs). A patchy distribution of such functional vegetation types provides more edge effects and a larger number of habitats in a given landscape.

Little specific information was found about the relationships between landscape function and woody shrub cover or biodiversity (Hassall and Associates 1999). However, a general understanding of landscape function leads to the prediction that biodiversity is likely to be greatest in those patches which function well in the capture, retention and use of water, nutrients and soil. Such patches may be small, such as individual grass tussocks, or larger run-on areas. In semi-arid areas these resources are used in pulses of biological activity following irregular rainfall events. Thus it could be expected that those patches which function best have higher water and nutrient levels, are more productive and have the potential to act as rich habitats for plants, invertebrates and vertebrates. Some of the impact of woody shrub cover on biodiversity may relate to how woody shrub proliferation and encroachment affect the functioning and continued existence of these patches in the landscape. Such impacts may vary between regions differing in landform, soil, drainage, water availability and vegetation.

1.1.4.2 Research component of the WWBP

Objective 2 was progressed further and objective 3(a) was addressed in the survey-orientated component of the Project, the results of which are the subject of this Technical Report. The focus of the field investigations was the six shrub species designated as "woody weeds" in the 1992 Regulation of the *Western Land Act* 1901:

Turpentine *Eremophila sturtii*
Budda or False Sandalwood *Eremophila mitchellii*
Narrow-leaved Hopbush *Dodonaea viscosa* ssp. *angustissima*
Broad-leaved Hopbush *Dodonaea viscosa* ssp. *spatulata*
Punty Bush *Senna artemisiodes* ssp. *filifolia*
Silver Cassia *Senna artemisiodes* nothosubsp. *artemisiodes*

The term 'woody shrub' has been extensively used throughout this report to refer to the results of this investigation. Although tautological (shrubs are woody by definition), it was considered preferable to the alternatives: ‘woody weed’ (weeds mean different things to different people); ‘shrub’ (when used broadly this can include subshrubs which attain a much smaller height than the six species above), or ‘unpalatable native shrubs’ (too unwieldy).

For the purposes of this project the following definition of biodiversity from the National Strategy for the conservation of Australia’s biological diversity (Department of the Environment, Sport and Territories 1996), and subsequently the NSW Biodiversity Strategy (NSW NPWS 1999), has been adopted: “the variety of life forms, the different plants, animals and micro-organisms, the genes they contain and the ecosystems they form. It is usually considered at three levels: genetic diversity, species diversity and ecosystem diversity.” Of these three levels, the WWBP has predominantly focused on species diversity (mostly expressed as taxa diversity) of macrofauna and mesofauna (vertebrates and invertebrates) and vascular flora of western NSW. Some taxonomic groups could not be sampled adequately with the available resources (refer to section 2.1).

1.1.4.3 Extension component of the WWBP

Objective 4 has been addressed by a series of field days, written articles and presentations. Within each survey region a field day was held during the field surveys, and a second round of field days is to be presented, in conjunction with a representative of the Woody Weeds Task Force, at the conclusion of the project. Presentations have been made to two Regional Vegetation Committees (Brewarrina and North Lachlan-Bogan) and a series of short articles have been distributed to all Western Division landholders and many agency personnel within the bi-monthly Western Division Newsletter.

In addition to this Technical Report, a Community Report has been produced (Ayers *et al.* 2001), aimed at providing information, using more accessible language, to community members.

1.2 General survey design

Two options were available for an investigation of the effects of different levels of woody shrub cover on biodiversity and landscape function: a quick “snap shot” view of a number of sites, as similar as possible except for their cover of woody shrubs, or a long-term study investigating on-going encroachment at a variety of sites. The first option was chosen based on the limited timeframes and budget of the Project.

A survey methodology workshop was hosted by the then Wildlife and Ecology Division of CSIRO during December 1998, and attended by scientists, biometricians, Working Group members and landholders. Outcomes included the decision that investigations would be required in three regions to capture some of the variation within the Western Division in terms of topography, soil type, vegetation type and woody shrub cover. The northern, central and southern areas of the Western Division were identified initially. Within each region, a total of 12 sites was considered to be sufficient to include a wide range of shrub cover levels, as well as being logistically feasible to survey within the Project timeframes. These sites would be as similar as possible in all aspects except their level of woody shrub cover.

2. Methods

2.1 Sampling methodologies

2.1.1 Selection and stratification of survey regions and study sites

The broad survey design required the selection of three regions, each with 12 sites (section 1.3). In selecting the regions the following four criteria were applied:

- each region must have undergone encroachment by woody shrub species and exhibit a range of shrub cover levels from open (minimal encroachment) to dense (high degree of encroachment);
- woody shrub species must represent a cross-section of the six designated species, and differ between the regions;
- regions must differ in landform, vegetation and soil type, but each must include country which is fairly widespread or typical of a large area;
- the country type selected in each region must be (or potentially be) pastorally productive.

In selecting sites, the primary criteria were that the 12 sites were to be as similar as possible in every aspect, except the level of woody shrub cover. Shrub cover was to range from slightly above zero to as high as possible, preferably >40%. Each site was to be 2 ha in size (200 m x 100 m), and surrounded by a 100 m wide buffer of similar shrub cover to the enclosed site, to reduce possible effects from outside the site. To minimise differences in topography, soil type and vegetation type between sites within any one region, sites were selected within a single land unit of a particular land system. Land systems comprise a number of land units, each of which may be quite different in physical attributes, hence site selection at the land system level was in most situations not adequate. In addition, previous investigations have demonstrated that land systems are a poor predictor of faunal distribution in western NSW due to their biophysical heterogeneity (Pressey and Taffs 2001). Vegetation and landforms were demonstrated to better predict vertebrate faunal assemblages across much of western NSW (Mazzer *et al.* 1998, Smith *et al.* 1998). In addition, a detailed investigation conducted within four land systems within Sturt National Park demonstrated that although some components of biodiversity are supported predominantly on single land systems, a greater proportion of microbial, invertebrate and plant species are found on more than one land system type (Oliver *et al.* 1999). The site selection sequence for the present investigation was: region, rangeland type, land system and finally land unit.

Expert opinions were sought as to which regions within the Western Division met the criteria set for region and site selection. Candidate land systems, units and locations for on-ground inspection were identified using air photo interpretation (1:50 000 scale), in conjunction with land system descriptions and mapping, topographic and orthophoto maps. Initially, six potential survey regions were identified: around Wanaaring, north of Ivanhoe, south of Cobar, in the Lightning Ridge region, between Bourke, Cobar and Nyngan and in the south-west of the State. On closer investigation, three of these regions did not meet the above criteria, with some land units highly encroached and featuring few open areas, and others encroached to a much lower degree.

After determination of the three regions with the land units/systems to be targeted, numerous potential sites were selected for on-ground verification. Approximately 40 areas were inspected in each region, with most failing to match the selection criteria. Final selection of sites was based on logistical factors (including ease of access and travelling times between sites) and the following desirable criteria:

- similar distances to watering points
- similar fire histories
- minimum distance of 2 km between study sites so as to maintain independence
- known history of cover change and management (preferably for at least the last 50 years)
- similar soil type.

The first three criteria were given priority, although the 'distance to watering point' specification had to be modified to a minimum of approximately 1 km. Logistical constraints, such as accessibility to sites, were at times overriding determinants in site location. For these reasons, similarity of sites with respect to all the selection criteria was often considerably less than ideal. Where desirable criteria could not be met, differences between sites were recorded for analysis and later consideration (see section 2.1.3). Sites were selected despite these potentially confounding factors on the basis that these factors did not exhibit consistent trends with respect to woody shrub cover.

The original intent of the survey design was to select three replicate study sites within each of four levels of shrub cover (approximately 1 – 5%, 8 – 15%, 20 - 27%, and 30 - 45%). This plan had to be discarded due to the difficulties encountered in estimating shrub cover, and in locating sites which met other site selection criteria. Therefore the 12 sites were selected within each region to represent the range of woody shrub covers present in the chosen land unit. Even though the total range of shrub cover was fairly consistent in all three regions, the spread of sites across this range was neither even, nor consistent between regions.

2.1.2 Determination of woody shrub density and cover

On most sites, shrub density (shrubs per unit area) was determined by the "wandering quarter" method originally described by Catana (1963). This method is appropriate for species that occur in patches. It involved undertaking distance measurements between 20 shrubs in each of five replicate transects at each site (Figure 2.1). The replicates were spaced across the site to avoid encountering the same shrubs. For each transect, the distance was measured from a random starting point to the nearest shrub within a pre-determined quadrant (up to 45° either side of the transect bearing). Progressive measurements were made from each shrub to the next closest shrub within the same quadrant. At some low density sites with few shrub patches, a complete census of shrubs was undertaken. Density estimation details are described in Hall *et al.* (in press).

Shrub cover (projected foliage cover) was estimated by measuring the two diameters of each shrub canopy (considered as an ellipse), calculating the mean area covered by these ellipses and multiplying by the shrub density estimate. This was expressed as a percentage of the total area assessed (2 ha). It should be noted that although these estimators are biased with spatially aggregated populations, it is believed that the relative ordering (i.e. high/medium/low) is not affected.

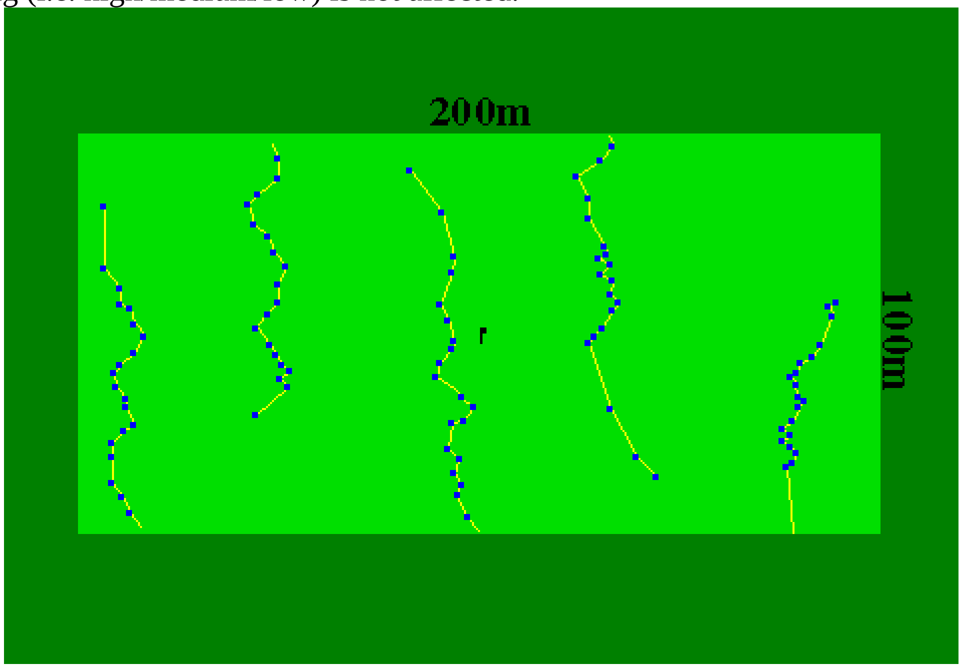


Figure 2.1 Diagrammatic representation of a study site, showing approximate location of five wandering quarter transects. Dots indicate location of measured shrubs. Buffers not to scale.

The calculation of shrub cover was checked by the following approximate method. Considering each collection of 20 distances as a randomly placed transect of fixed diameter, the percentage cover of each "transect" was determined directly. The correlation between this method and the above method was 0.9. Therefore while the above estimate of shrub cover cannot be considered definitive, it represents an improvement over the original qualitative description.

Shrub species, height and canopy or foliar density (openness), were also recorded for each shrub, as described in Appendix 1. Although this investigation focused on the six species specified in section 1.1.4.2, all plant species in the shrub structural class were measured during woody shrub cover assessment. This was defined as those trees or woody shrubs greater than 30 cm and less than 4 m tall, which included a diversity of species. The six designated species dominated this shrub class at all except those sites with lowest shrub cover in the Cobar region.

2.1.3 Assessment of potentially confounding factors

Attributes that could potentially influence the detectability or occurrence of flora or fauna taxa on the study sites were assessed and analysed in conjunction with woody shrub cover and density. These were assessed at two scales: macro (site) and micro (pitfall trap) scale. Site attributes were grouped into five broad categories:

- attributes related to the site selection criteria, including landscape scale attributes which describe broad site differences
- physical attributes
- woody shrub attributes which may be utilised by particular taxa (see section 2.1.2)
- disturbance features
- microhabitat attributes which may be of relevance to individual flora and fauna species.

These site attributes, as well as the method by which each was assessed, are summarised in Appendix 1. More descriptive comments of each site provide additional information regarding site differences within each survey region. Not all site attributes affect the occurrence of each taxonomic group or individual taxon.

Information on a second group of attributes relating specifically to pitfall traps (sections 2.1.5.1 and 2.1.5.5) was also collected. These pitfall trap attributes include microhabitat features which have previously been shown to influence capture rates in invertebrate pitfall traps (Melbourne 1999), and features which describe the location of each trap with respect to the surrounding woody shrub cover. The methods by which these pitfall trap attributes were assessed are summarised in Appendix 1.

2.1.4 Assessment of flora

Flora assessments included only vascular plants. Perennial species present as a dormant tuber or root stock were not assessed. Also, given the intent of this investigation to focus on species actively utilising and/or surviving on the chosen study sites during the survey periods, no attempt was made to assess plant species present within the soil seedbank.

2.1.4.1 Structure

Within each study site, three 50 x 20 m quadrats were sampled to assess the diversity of vegetation structure within each study site (Figure 2.2). One quadrat was consistently located in the most densely vegetated part of the site, one in the most open, and the third in an area of intermediate density. For each structural layer present (i.e. tree layer, shrub layer, chenopod layer, forb layer, grass layer) within each quadrat, the most abundant flora species were listed, their height range and the proportion of the quadrat they covered were recorded. Analyses of these latter attributes have yet to be undertaken.

2.1.4.2 Floristics and plant cover

In the centre of each of the Structure quadrats, a 20 x 20 m Floristics quadrat was pegged out (Figure 2.2). Within these smaller quadrats, every plant species present was identified or collected for later identification, and assigned a cover abundance rating based on a modified Braun-Blanquet six-point scale (Poore 1955). Analysis of the cover abundance data used the mid-points of the four highest cover categories (Table 2.1). For the two lowest cover categories, representative cover scores of 0.5 and 2.5 were assigned to represent the approximate abundance categories of 0 – 1% and 1 – 5%, respectively.

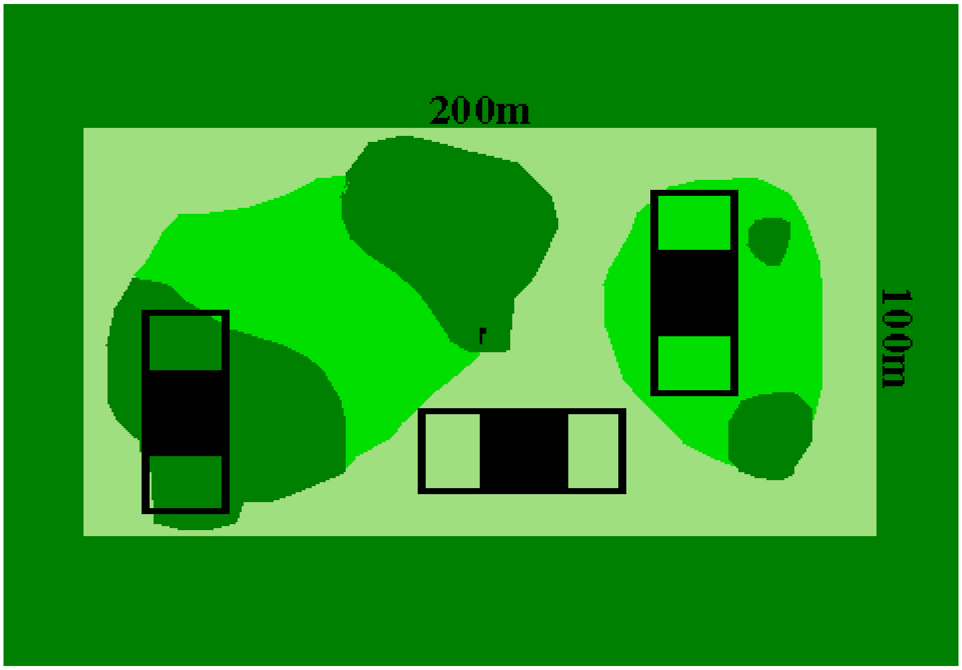


Figure 2.2 Diagrammatic representation of a study site showing sample Structure and Floristics quadrats, located in relation to dense patches (dark shading), open areas (light shading) and intermediate patches of woody shrub cover. Buffers not to scale.

Table 2.1 Modified Braun-Blanquet scale and corresponding representative (mid-point) cover scores used in data analyses.

Ordinal scale	**Braun-Blanquet cover category**	**Representative cover score**
1	<5%, few plants	0.5
2	<5%, many plants	2.5
3	6 – 25%	15
4	26 – 50%	37.5
5	51 – 75%	62.5
6	76 – 100%	87.5

Plant specimens were identified to the lowest taxonomic level possible by the Project Botanist (Jessica Szigethy-Gyula). In some instances this was only to genus level. The expression 'flora taxa' is used to collectively refer to flora species, subspecies and some genera. Identification of plant species was based primarily on Harden (1990-1994). Where necessary, confirmation was sought from the National Herbarium in Sydney and the Plant Biodiversity Centre of South Australia.

Specimens of most plant species identified during the course of this investigation were mounted in a reference collection located in the NSW NPWS Western Directorate office in Dubbo. All floristics, vegetation structure, site locality, physical and disturbance data were entered in the NSW NPWS Vegetation Survey Database and are available via the Atlas of NSW Wildlife as maintained by the NSW NPWS. Nomenclature within the flora database is maintained by the NSW NPWS based on Chapman (1991) with revision being incorporated from the literature and reflecting changes recommended by the Plant Information Network System of the Royal Botanic Gardens, Sydney (PlantNET website).

Guilds

To overcome the low counts for many plant taxa, individual results were combined for analysis as functional groups or guilds of ecologically similar taxa (Appendix 2). Two plant guilds were identified on life history strategy (drought endurer or drought avoider). 'Drought avoiders' are relatively short-lived species that die during unsuitable conditions, and persist as seed to germinate or re-invade when favourable conditions return. 'Drought endurers' are perennial species, or species with a perennial rootstock, which survive in their vegetative form during unfavourable conditions and re-commence growth under suitable conditions. In addition to the guilds specified in Appendix 2, one additional guild (the Groundcover plants) was created, which includes all groundcover and understorey taxa recorded in this investigation. It comprises all groundcover plants recorded across the three survey regions (taxa are listed as chenopods, grasses and forbs/herbs in Appendix 6).

Organization of species groups based on their palatability to stock was also attempted, but abandoned because of the difficulty in assigning palatability due to the relative nature of this classification, the influence of season, and the changing palatability of many species throughout their life (Peter Milthorpe, pers. comm.). Palatability to stock was determined for individual plant taxa that responded significantly to woody shrub cover or density using Cunningham *et al*. (1992) and Brooke and McGarva (1999). Trees, woody shrubs, mistletoes and vines were excluded from this assessment.

2.1.5 Assessment of fauna

Faunal groups targeted included vertebrates and epigaeic invertebrates that forage primarily on the ground surface. Limited resources (time, staff and budget) prevented the sampling of some invertebrate groups, including arboreal and most cryptic (soil and leaf litter inhabiting) taxa. In addition, bats and flying invertebrates were not assessed, based on the issue that such taxa may not be "using" or responding to the vegetation below. Limited resources, and the aim to not attract taxa into the site (such as by using light traps, or owl call-playback) were also factors in this decision.

Vertebrate fauna were identified by the fauna team leaders (Dani Ayers, Murray Ellis, Terry Mazzer, David Read and James Nicholls). Invertebrates were processed by the Key Centre for Biodiversity and Bioresources at Macquarie University.

2.1.5.1 Vertebrate pitfall trapping

An array of nine vertebrate pitfall traps were established on each study site (Figure 2.3), and remained open for 10 consecutive nights (equivalent to 90 trap nights per site, and 3

150 trap nights across the three regions). Each trap comprised a 60 cm length of PVC stormwater pipe (16 cm diameter) set flush with the ground surface, with two 5 m long (~25 cm high) flyscreen drift fences erected at approximately 180º to each other. Orientation of the fences from the pit was dictated by the location of nearby plants and ground debris. Each pit was shaded by a metal cap suspended between the fences.

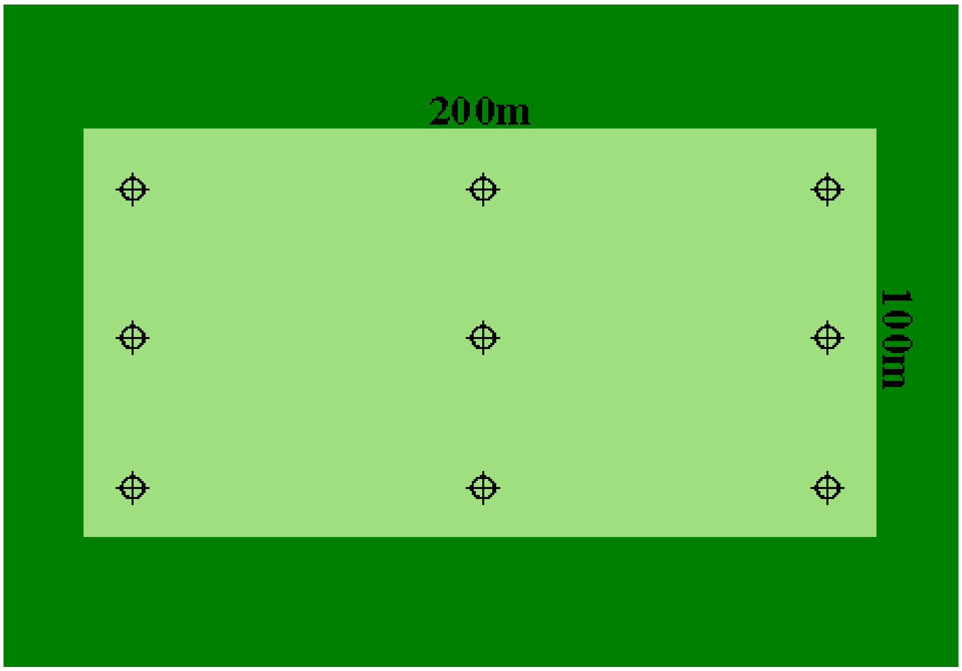


Figure 2.3 Diagrammatic representation of a study site, showing the location of the nine vertebrate pitfall traps. These locations were occasionally varied slightly if the original trap locations did not reflect the woody shrub cover for a site. Buffers not to scale.

Traps were checked each morning, and occasionally during the day whilst undertaking other activities. All captures (predominantly mammals and reptiles) were recorded as the traps were emptied. Surface insect spray was used to control ant attack. Specimens were identified, marked with a temporary marking pen stripe and released nearby. Identification confirmation was obtained on specimens forwarded to the Australian Museum for reference purposes.

Each landholder involved in the project has allowed the capped vertebrate pitfall traps to remain on their properties.

Guilds

To overcome the low counts for most individual species, guilds of ecologically similar vertebrate species were identified for analysis. Few mammals were recorded, and only one guild (the macropods) was identified. The reptile guilds were based predominantly on the main habitats occupied by species, although nocturnal and diurnal species were also separated.

2.1.5.2 Bird censuses

The 20-minute early morning bird censuses were conducted by two people on different mornings at each study site. At least one of these was timed to catch the dawn chorus, with the other censuses carried out as soon thereafter as possible. All species seen or heard on the site and in the 100m buffer were recorded. Weather conditions and time of day were also recorded.

All observations from within the study site and buffer were included in the statistical analyses, except those of birds flying above the canopy or flying across the site without landing.

Guilds

Identification of bird guilds and assignment of species to each guild was based on previous bird studies in arid and semi-arid areas of Australia. Unpublished data was provided from studies in the Mt Magnet and Gascoyne Junction areas of Western Australia by Dr Harry Recher, and in the Paroo catchment of north-western NSW by Dr Judy Smith from her doctoral studies. Studies from other regions (Recher *et al.* 1983; Recher *et al.* 1985; Ford *et al.* 1986; Holmes and Recher 1986; Recher and Davis 1997; Smith 1997; MacNally 2000, Date and Paull 2000), and information contained within the Handbook of Australian, New Zealand and Antarctic Birds series was also utilised to assign species to guilds. Most bird guilds describe a specific combination of diet, foraging substrate and foraging mode (Appendix 2). Consequently, individual species may be included in multiple guilds. Where possible, guilds were also merged into broader categories (for example, Ground-feeding granivores, Ground-feeding insectivores, Tree and shrub-feeding insectivores) for analysis.

2.1.5.3 Reptile searches

Three 30-minute diurnal reptile searches were conducted between mid-morning and early afternoon by two people on each study site. In addition, three 30-minute nocturnal searches were conducted on each site during the early evening by two people. Weather conditions and time of day were recorded for each search. Reptile searches involved the identification of active animals which were either captured, or observed (at times using binoculars). Inactive, arboreal or cryptic species were located by searching suitable habitats.

2.1.5.4 Opportunistic observations of vertebrates

Incidental observations of vertebrate animals, as well as diagnostic scats, diggings, feathers or eggshells were recorded opportunistically for each site. These observations occurred during the course of undertaking other activities. All observations were recorded with information about whether the species was on the site or in the buffer. These data were analysed with trapping and census data.

2.1.5.5 Invertebrates

Capture

An array of 10 wet pitfall traps were established on each study site (Figure 2.4), and remained open for 10 consecutive nights (100 trap nights per site, and 3 500 trap nights across the three regions). Each trap consisted of a plastic jar approximately 10cm deep and 6cm in diameter, set flush with the ground surface. A plastic plate was mounted about 10 cm above each trap to reduce evaporation of the preserving fluid and to act as a rain shield when necessary. The principal preserving fluid used was ethanol, to which was added monoethylene glycol (ratio 1:2) to reduce evaporation. However, high evaporation required the traps to be topped up with preservative after five days, particularly during the November and January surveys.

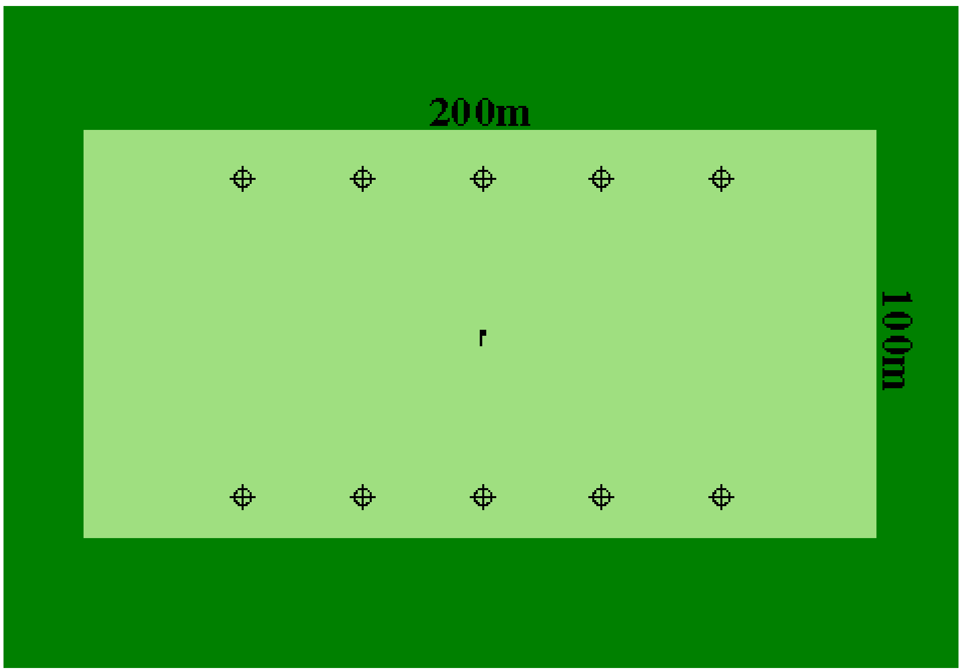


Figure 2.4 Diagrammatic representation of a study site showing the location of the 10 invertebrate pitfall traps. These locations were occasionally varied slightly if the original trap locations did not reflect the woody shrub cover for a site. Buffers not to scale.

Processing

Invertebrate specimens were sorted and identified by staff at the Key Centre for Biodiversity and Bioresources at Macquarie University. Based on initial capture estimates of approximately 30 000 specimens, all specimens were to be sorted, identified to 'Order' level, and further identified to morphospecies. Due to the enormous number of specimens actually captured, only the 150 000-odd ants were identified to the morphospecies level. Ants of the genus *Melophorus* were not separated into morphospecies. All other invertebrates were identified to 'Order' level.

'Order' level classifications include some exceptions. For example, Hymenoptera tallies include results for bees and wasps only, with the ant results listed separately within the

Family Formicidae. Results for Myriapods were provided for the two Classes Diplopoda (Millipedes) and Symphyla (Soft-bodied Myriapods), as well as several Centipede Orders. Some unidentifiable remains were attributed to the Phylum Arthropoda. Finally, all larvae were listed collectively as Larvae. The expression Invertebrate 'Orders' is used to collectively refer to these orders, families, classes and other groupings.

Classification to the morphospecies level involved identification of each specimen to genus and separation into numbered categories on the basis of morphological similarity of the specimens. Comparison of specimens required use of high magnification microscopes.

Detailed invertebrate identification is a slow process that requires specialist taxonomic input. Species level identification for every invertebrate caught, or even just the ants, was not possible within the project timeframes or budget. This is predominantly due to the enormous number of species in Australia yet to be named and described (Andersen 1991). The decision to rely on morphospecies-level identifications was three-fold: it is faster, can be undertaken by trained but non-specialist personnel, and for both these reasons is cheaper.

Genus identifications provided by Macquarie University were verified by Dr Alan Andersen, and refined to species level where possible, based on high magnification photographs supplied by Macquarie University staff. Few discrepancies were found for most genera (Appendix 4). Some specimens of each morphospecies from two similar genera (*Monomorium* and *Tetramorium*) were also pinned and identified by Dr Andersen. Species level identifications within these genera contradicted the morphospecies identifications due both to the identification of multiple species within a single morphospecies, and the identification of the same species within different morphospecies. The manner by which this can occur is discussed in section 2.3 (assumption 2). Ant data was analysed at the finest taxonomic resolution possible. The expression 'ant taxa' is used to collectively refer to ant species, morphospecies and some genera.

Guilds

The functional groupings (guilds) of Australian ants by Andersen (1997) were adopted by this investigation for analysis purposes. In this classification, some genera contain species that are assigned to different guilds. Consequently, guild analyses were restricted to those taxa for which species level (or species group) identifications were obtained, or for morphospecies of genera that were assigned by Andersen (1997) to a single guild (Appendix 2). Invertebrate 'Orders' were not grouped into guilds.

2.1.6 Assessment of landscape function

A landscape function assessment was conducted at each of the study sites according to the methods of Tongway and Hindley (1995, now also available via the website http://www.cse.csiro.au/research/SL/EFA_tools.htm). This procedure is comprised of four modules: a conceptual framework, a field methodology, a data reduction step and an interpretational framework. The following describes the field methodology and data reduction steps. The conceptual and interpretational frameworks are outlined in Tongway and Hindley (1995).

The following terms are used in the methodological descriptions below, and in the results for the three survey regions (section 5):
obstructions: "long-lived features which obstruct or divert water flow and/or collect/filter out material [organic mater, soil, seed] from run-off, e.g perennial grass plants, rocks >10 cm, tree branches in contact with the soil" (Tongway and Hindley 1995);
patch type: area with fairly consistent soil surface features, which are distinct from those of surrounding areas. Patch types which function as resource sinks (sometimes called 'fertile patches' or 'run-on' patches) are zones in a landscape where nutrients, moisture and other resources tend to accumulate (these may function as obstructions to overland flow). Patch types which function as resource sources (sometimes called 'inter-patches' or 'run-off' patches) do not capture or retain these resources very well.

Semi-arid woodlands of Australia are organised into resource source/sink systems at different scales, connected by the flow or water and nutrients (Ludwig and Tongway 1995). Landscapes in good condition efficiently capture, retain and utilise such scarce resources (i.e. they function as conservative systems). Dysfunctional landscapes lose an excessive amount of resources as outflows, and are therefore termed 'leaky' landscapes. Ludwig *et al.* (1997) discuss the consequence of these differences for landscape features and processes.

2.1.6.1 Landscape organisation assessment

A 100 m transect was located across the study site, orientated downslope where possible, and located so as to encompass the range of patch types at the site (Figure 2.5). An additional transect was employed if the first failed to adequately sample the patch types evident. A landscape record log was compiled along the transect/s, detailing location, extent and characteristic features of identified patch types, and presence/width of any obstructions. Functionality of patch types, as either resource source or sink, was determined as part of this process. In contrast to information from land system survey sources (which characterise unchanging or very slowly changing landscape factors), landscape organisation can be changed markedly by natural events (e.g. falling of trees), management practices and season, either alone or by interaction.

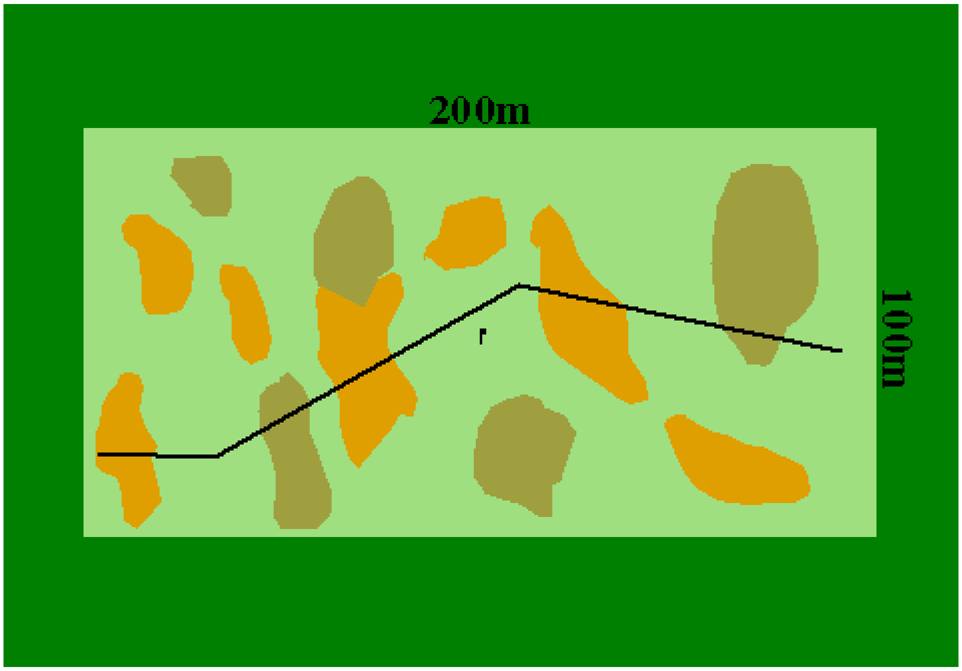


Figure 2.5 Diagrammatic representation of a study site, indicating sample location of a LFA tansect with respect to patch types. Location of the transect follows the strongest environmental gradient (e.g. downslope) on the site. Buffers not to scale.

Four measures representing landscape organisation were calculated for each site from the transect data:

- number of obstructions per 10 m
- total obstruction width (m) per 10 m
- average fetch length (m)
- obstruction index (total length of obstructions/transect length)

2.1.6.2 Soil surface condition assessment

Soil surface condition assessment was undertaken in five replicate samples of each patch type identified along the landscape organisation transect. This methodology is intended to reveal the functional status of each patch type, at the fine scale, in terms of its ability to capture and retain nutrients and water. This assessment method can be conducted as a line-based or quadrat-based method, and uses the soil surface features listed in Table 2.2, each of which has a process-based interpretation.

Table 2.2 Soil surface features considered during the soil surface condition assessment process. Objectives are as stated in Tongway and Hindley (1995).

Soil surface feature	Objective of feature
Soil cover	assesses the degree to which surface and projected plant cover resists rainsplash erosion
Perennial plant basal cover	assesses the contribution of perennial plant underground biomass (roots) to the nutrient pool (cycling)
Litter cover	assesses the availability of detached organic materials for decomposition and nutrient cycling
Cryptogam cover	assesses the contribution of cryptogamic mats to soil stability and nutrient cycling
Crust broken-ness	assesses the degree to which surface crust materials are broken or loosely attached and available for erosion
Erosion features	assesses the nature and severity of active or current loss of soil material
Deposited materials	assesses to what degree transported materials are deposited on the query zone
Soil microtopography	assesses the soil surface roughness features which retain water, organic debris and propagules
Surface nature	assesses the likely impact of mechanical stress (e.g. trampling) to yield erodible material
Slake test	tests soil stability during rain

Field records of landscape organisation and soil surface feature data were entered in the software package developed by CSIRO Division of Wildlife and Ecology that accompanies Tongway and Hindley (1995). For each patch type the package calculates the mean values (and standard errors) of three indices of soil surface condition:

- Stability: the ability of the soil to withstand erosive forces, and to reform after disturbance. This index is calculated from the scores for crust broken-ness, surface nature, slake test, erosion features, eroded materials, cryptogam cover, soil cover and litter cover;
- Infiltration: how the soil partitions rainfall into soil-water (available for plants to use), and run-off water that is lost from the local system, and may transport materials away. This index is calculated from the scores for microtopography, slake test, perennial plant basal cover, soil texture and litter cover;
- Nutrient cycling: how efficiently organic matter is cycled back into the soil. This index is calculated from the scores for cryptogam cover, microtopography, and litter cover (including where it originated and how well it has been incorporated into the soil).

These three index values were also calculated as weighted means for the entire transect by incorporating the relative proportion of each patch type within the site.

2.2 Data aggregation and analysis

2.2.1 Data aggregation

Aggregation of data collected within each site at several locations, or using several methodologies, occurred prior to site level analyses for the following flora and fauna data:

- representative plant cover abundance scores were obtained by averaging the representative cover scores over the three quadrats for each site (section 2.1.4.2);
- vertebrate species count data were combined from all four survey methodologies conducted within each site (individual analyses were also conducted within each methodology, however these are not reported here);
- invertebrate counts were summed over the 10 invertebrate pitfall traps at each site;
- taxa richness was calculated by summing the number of taxa present at each study site within and across each taxonomic group (plants, vertebrates, invertebrate 'Orders' and ants);
- total counts of individuals were also determined and used as an alternative measure of taxa abundance within and across the broad taxonomic groups;
- associations of taxa which occurred at similar study sites within each region were identified using PATN analyses similar to those conducted across the 35 study sites (section 2.2.3). These analyses were conducted separately for each broad taxonomic group;
- for each guild (sections 2.1.4 and 2.1.5) and taxa association, site-level abundance data was obtained by summing the number of individuals for all taxa within the guild or association. In the case of plants the average representative cover scores were summed over all taxa in the guild or association at each site.

2.2.2 Outline of analyses

Unless otherwise stated, analyses were performed in the statistical package Splus (SPLUS 2000, 1988-1999, MathSoft Inc.). Each of the following analyses is described in detail below.

Flora and fauna analyses

The following flora and fauna analyses were conducted across study sites within each survey region, and across the 35 sites:

- taxa composition dissimilarity analyses
- responses by individual taxa, guilds and taxa associations to site attributes

  stage 1: preliminary analysis (correlations)

  stage 2: critical assessment of preliminary results

  stage 3: more detailed regression modelling

Separate analyses were conducted for each broad taxonomic group (plants, vertebrates, invertebrate 'Orders' and ant taxa). Note that for all analyses of ant data, except guild and taxa association analyses, both the original morphospecies data and the verified species data were analysed separately. The three-stage analysis process was also undertaken collectively on all taxonomic groups to compare taxa richness across study sites within and across the three regions. Analyses conducted to date focus on the systematically assessed site attributes. Woody shrub attributes (Appendix 1) have yet to be included in analyses for relevant flora and fauna taxa.

Taxa responses to microhabitat attributes surrounding each pitfall trap were modelled for vertebrates, invertebrate ‘Orders’ and ant taxa, within each survey region. The potential impacts of rainfall events during the survey periods have yet to be analysed. This issue is of direct importance to the invertebrate pitfall trap captures as a result of flooding of traps at a subset of sites.

Reporting of results in this report is restricted to those of relevance to the stated project objectives. In considering these results the large number of analyses undertaken to date must be considered with regard to the increased prevalence of Type 1 errors (a significant result obtained where there is no actual relationship). To avoid erroneous conclusions, those who examine the preliminary results should focus initially on those correlations with *p*-values much less than 0.01.

Landscape function analyses

Landscape function analyses (correlations and linear models) focused separately on the landscape organisation data (site-level), and the soil surface condition data at both the patch and site level.

2.2.3 Taxa composition dissimilarity analyses

Associations of taxa (those taxa with similar distributions and/or abundances across the 35 study sites) were identified within each broad taxonomic group (vertebrates, invertebrate ‘Orders’, ants and flora) using PATN (Belbin 1995). For flora, cover abundance data was classified using a Bray-Curtis association measure, and displayed graphically using a sequential agglomerative hierarchical strategy (Flexible UPGMA, Beta = -0.1) which produced a dendrogram representing the relative dissimilarity between the 35 sites. This method is fully described in Belbin (1991). Similar analyses were conducted for faunal taxa, however it was necessary to use presence/absence data for both invertebrates and vertebrates. For vertebrates, this is because of the multiple census techniques used, making absolute numbers non-comparable between different taxa. Invertebrates were analysed in this way because of the extreme variability in abundance scores between taxa.

2.2.4 Preliminary flora and fauna analyses

The preliminary analyses involved conducting correlations between all the site-level predictor variables (section 2.1.3 and Appendix 3), and counts for all taxa, guilds and taxa associations, as well as taxa richness. Those taxa common to the three survey regions were also analysed in this way across all 35 sites. Pearson correlation coefficients were computed. *P*-values were calculated to determine which correlations were statistically significant. Where the significance of the association was affected by a single outlying point this was noted (see Appendix 5). This often happened when the count consisted of 11 zeros plus a non-zero count that coincided with a high or low level of shrub cover within a single region.

The site attributes were also analysed for internal relationships within each region and across all 35 sites (correlation matrices).

Also of interest were those taxa that had a nil or very low correlation with shrub cover. For this analysis we regarded all correlation coefficients which were less than 0.1 in absolute value as “low” and taxa with such low correlations were deemed to be “generalists” with respect to woody shrub cover.

2.2.5 Critical assessment of preliminary flora and fauna results

The next stage of the analysis process, involved an assessment of the significant correlations between response variables (taxa, guilds etc.) and predictors to determine which were meaningful from a biological perspective. The normal outcome of this process is that the list of predictor variables against which each response variable is analysed is reduced to those having a significant correlation, and which are also biologically relevant. Although this process was commenced (some of the significant correlations were examined graphically, and the biological relevance of some results were assessed for some taxa), the project timeframes were insufficient for a complete critical assessment of preliminary results. Far more time would be required to critically examine in detail each of the predictor variables for each of the several hundred taxa, guilds and taxa associations. Eventually it was decided to retain the original predictor set during the next stage of the analysis.

2.2.6 Regression modelling of flora and fauna data

It has been mentioned above that discussion of results in this report is restricted to those relevant to the project objectives. Additionally, regression modelling results have been limited to those that include shrub cover or density within each model. Because of the need to retain the original predictor set for the multi-variate analyses (see section 2.2.5), most analyses included some predictors not relevant to the taxa or guild under consideration. Consequently, some models contain variables that have no obvious biological basis. Where such variables are included in models also containing shrub cover or density they have been included in the appropriate table of results (Appendix 8), however such results have not been discussed.

Linear models – site level, single region

Multi-variate analyses were conducted for the site variables as well as shrub cover and density. This stage comprised mainly step-wise regressions, where combinations of predictors were fitted in a linear model with either species count or square root of species count as the response variable. These models were of the form:

sqrt(count) ~ site variables

(the square root transformation was not used for invertebrate or vertebrate counts which were aggregated over several traps, or for flora cover scores which were averaged over three quadrats, based on the Central Limit Theorem result that summed and averaged data are normally distributed). The predictor that explained most of the variation in the count was included first in the model, followed by the predictor that explained most of the remaining variation. For many of the multi-variate models, which were based on only 12 sites, the number of predictors was limited to two in the regression models. The step-wise regressions are reported in terms of the incremental r^2 values together with *p*-values for the predictor variables.

Analyses of this type were conducted for each taxon, guild and taxa association within each survey region. In some regions predictor variables such as flowering or fruiting were omitted owing to extremely low variability (e.g. all sites were fruiting or nearly all were flowering). In addition, some variables were not recorded at all sites and these variables were analysed separately and not included in the stepwise regressions. While most of the site variables were treated as numeric, some were used as factor variables in the models (Appendix 1). Where factor variables were significant, the relationship was examined via tables of species count cross-classified by the factor.

Linear models – site level, across regions

For taxa common to the three survey regions, analyses were conducted similar to those described above (Linear models – site level, single region).

In addition, a more detailed analysis of counts was possible through combining the data across regions and fitting generalised linear models (GLMs) of the form:

count ~ region + cover + region:cover

where a log link was used for count and over-dispersion was modelled using a quasi-likelihood approach (McCullagh and Nelder 1989). For many taxa the dispersion parameter was larger than one, suggesting that a Poisson variance is not appropriate for this data. In these analyses significant correlations with shrub cover were the primary focus, with region fitted only as a design variable. Taxa showing significant associations were identified and *p*-values calculated.

Linear models - pitfall trap level, single region

A similar analysis was performed within each region for the pitfall trap microhabitat data (section 2.1.3 and Appendix 3). For both invertebrates and vertebrates these variables were related to species count using stepwise regression models of the form:

sqrt(count) ~ micro-variables

The above models were summarised in terms of r^2 values and type of correlation (positive/negative). *P*-values were also calculated for those variables in the final models.

Non-linear models - site-level, single region

Quadratic models were also fitted for individual taxa vs woody shrub cover to examine certain types of non-linear relationships. These models were fitted separately within each region and are of the form:

$$\text{sqrt(count)} \sim \text{cover} + \text{cover}^2$$

(the square root transformation was not used for the invertebrate or plant data). In order to focus on relationships that increase or decrease at intermediate levels of shrub cover, we chose models where the linear component was non-significant and the quadratic component was significant. (This does not mean that the correlation between abundance and shrub cover was not significant.) The r^2 values are reported for these models together with the *p*-values for the quadratic component.

2.2.7 Landscape function analyses

Within each survey region correlations were conducted between the number, size and separation of obstructions to overland water flow, and woody shrub cover and density. Pearson correlation coefficients were computed. *P*-values were calculated to determine which correlations were statistically significant. Similarly, correlations were conducted between each of the three weighted site soil surface condition (SSC) indices and shrub cover across the three survey regions, and within each region separately. However, the high variability in weighted index values across sites was such that all further SSC analyses were conducted via linear models fitted within each study site. These models are of the form:

$$\text{SSC Index} \sim \text{patch type},$$

where patch type designates a localised area of similar soil surface condition, and to a certain extent, vegetation (see section 2.1.6). Differences between patch types were explored via multiple comparison procedures (specifically least significant differences) in those cases where the linear model revealed a significant difference. SSC index scores are not weighted for individual patch types.

2.3 Assumptions

Eight broad assumptions were made in the course of this investigation. Each is discussed in turn:

1) observer bias is not a significant issue

In many instances the same individual undertook particular tasks at all 35 study sites, with or without assistance. This is true for the site selection, woody shrub cover assessments, flora assessments, site and pitfall trap microhabitat assessments and landscape function assessments. Invertebrate pitfall trap installation techniques were taught by one individual. Despite this consistency, individual proficiencies increased throughout the course of the investigations, and may affect between-region comparisons. This is particularly true for landscape function comparisons.

Fauna assessments were undertaken by two principal assessors, accompanied by a diversity of assistants that varied within and between regions. One principal assessor remained consistent throughout all three surveys, the second position was filled by a different (but highly experienced) person on each survey. In each region the potential for observer bias was reduced as much as possible by the constant rotation of principal assessors and assistants with respect to activity and study site throughout the survey period.

2) reliance on identification of invertebrates to morphospecies level is appropriate for this investigation

Species diversity can be overestimated or underestimated using morphospecies level identifications. Polymorphic species may be separated into several morphospecies due to morphological differences between genders, age classes, castes and individuals differing in breeding condition. In contrast, similarity between members of the same caste from different species can result in their identification as the same morphospecies. This is more common in, but not restricted to, members of the same genus.

Consequently, morphospecies identifications are not appropriate for all types of investigations. However, studies conducted to date indicate that morphospecies data can be used for three basic types of study:

- compiling species inventories,
- estimating species richness (number of species), and
- comparing species differences between sites or habitats.

These conclusions are based on the finding that for these three type of analyses, the levels of identification error made by a non-specialist are sufficiently low that similar results are obtained as if the specimens had been identified to species level (Oliver and Beattie 1995). This is particularly true for ants.

On the basis of these results, morphospecies level identifications were concluded to be appropriate for this investigation.

3) site differences have been adequately captured by the diversity of site attribute measures

A broad range of physical and site disturbance differences were recorded for each site (Appendix 1), in addition to those microhabitat features known or suspected to be of relevance to individual taxa. These attributes were tailored to this investigation, being based in part on observations made during the site selection process. Despite this, additional differences between sites relevant to some taxa were not assessed. For example, nutrient availability and other soil attributes of importance to plants were not recorded.

To date, the breadth of attributes recorded and analysed is likely to have resulted in some spurious results that may have masked some responses to woody shrub cover. Refinement of future analyses to those attributes relevant to each taxon or guild will allow clarification of these results, and may change the number of significant responses to woody shrub cover.

Differences captured as potentially confounding factors have not been assessed due to the qualitative manner in which they were recorded. Where relevant, these factors have been discussed.

4) weather and climatic conditions over the months and years preceding the surveys, as well as during the survey period, were relatively consistent between sites

Despite this broad assumption, rainfall events during the surveys are known to have affected sites differently. In the Wanaaring region this is because half the study sites were closed, and half remained open when the storm hit. In the Cobar region, pitfall trap flooding and damage to drift fences varied within and between sites. The effects of these events have yet to be analysed.

5) aggregation of taxa into guilds is appropriate for this investigation

Most guilds were based on previous studies or the known ecological attributes of each species, with bias given to studies undertaken in arid and semi-arid regions. The guild/functional group concept is widely used, particularly in ornithology.

6) taxa richness is unrelated to the number of individuals captured

This is in fact not true. Taxa accumulation curves (number of taxa captured vs number of individual vertebrate and invertebrate captured, cumulated across pitfall traps) for each survey region indicate an almost linear relationship between these variables. These results are similar to those of Willott (2001), and Moreno and Halffter (2001), where cumulative captures (taxa vs individuals) were calculated over time. Taxa richness analyses have not taken these relationships into consideration. More detailed analyses incorporating daily capture records have yet to be conducted.

7) all taxa recorded in a region have the potential to occur at all sites within that region

We assume that there are no external barriers or other factors preventing any taxa from occurring at the study sites.

8) methods employed to assess flora and fauna taxa, and landscape functional status, are not affected by woody shrub cover.

3. Survey regions and study sites

3.1 Location and descriptions

The procedure used to select survey regions and study sites is described in section 2.1.1. Location of the three regions is depicted in Figure 3.1. Availability of specific site locations is outlined in Appendix 10.

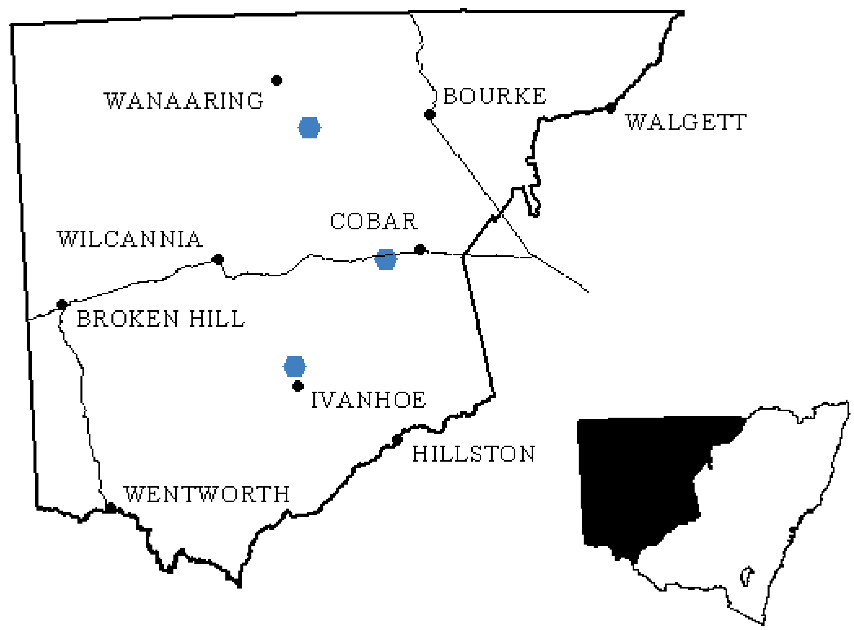


Figure 3.1 Location of the three survey regions within the Western Division of NSW. Twelve sites were located approximately 30 km north of Ivanhoe (southern location), another twelve midway between Wanaaring and Louth (northern location) and eleven approximately 50 km west of Cobar (central location).

3.1.1 Ivanhoe

The district north of Ivanhoe varies considerably from open grassy expanses to thick Belah woodland with varying densities of understorey species. Gilgais are common, and in wooded country the crytpogamic soil crust is often thick and intact over large areas. In places, large open grassy expanses separate the wooded country. Dense woody shrub patches occur in both open woodland and treeless expanses within this district. Given that much of this country is typified by open Belah woodland, a land system which included this broad vegetation type was selected for surveying (Figure 3.2).

All sites were located in the Sandplain land unit of the Wilkurra land system (Walker 1991), of the Plains landform type. This land system covers 2 885 km^2 of the Western Division, from north of Ivanhoe, south to Balranald and west to the South Australian border (Walker 1991). It forms part of the rangeland type 'Belah and Bluebush - Sandplains and Dunefields with Belah and Rosewood' as described by Scriven (1988). Soils within this land unit are loamy solonized brown soils (Walker 1991).

Study sites were located on five properties in the Ivanhoe region. No sites were burnt in the last major fires in this region during December 1984 and early 1985. Woody shrub cover on the sites varied from 1.1% to 40.3%, and density ranged from 30 to 5 230 shrubs per hectare. Other site attributes are summarised in Appendix 3.

Scattered Wilga *Geijera parviflora* and Western Rosewood *Alectryon oleifolius* trees were present within the open Belah *Casuarina pauper* woodland at most sites. Woody shrub species present on the sites included Turpentine *Eremophila sturtii*, Narrow-leaved Hopbush *Dodonaea viscosa* ssp. *angustissima*, Punty Bush *Senna artemisioides* ssp. *filifolia* and Silver Cassia *Senna artemisioides* nothosubsp. *artemisioides*. The number of species varied considerably from site to site, with some dominated by one species, and others supporting an equal proportion of two or more species. Only Turpentine was present on most sites. Blunt-leaved Cassia *Senna artemisioides* ssp. *helmsii* was also present in some areas. Emu Bush *Eremophila longifolia* and Mulga *Acacia aneura* trees occurred in low numbers.

Figure 3.2 Views from three of the 12 Ivanhoe region study sites, illustrating the variability in Belah and woody shrub cover. Note similarity of soil surfaces beneath woody shrubs to those of surrounding open patches. Low perennial vegetation was sparse on many sites, and often dominated by *Sclerolaena*. Most grasses present were not perennial.

3.1.2 Wanaaring-Louth

This district is dominated by low sandplains and dunes dotted with salt lakes of varying sizes. Patches of Gidgee *Acacia cambagei*, Western Rosewood *Alectryon oleifolius* and Belah *Casuarina pauper* are common, but much of the landscape is not wooded.

Most sites were located in the Plains land unit of the Avondale land system (Walker 1991), of the Sandplains and Dunefields landform type. This land system covers 2 811 km^2 of the Western Division, from Wanaaring to Bourke and north to the Queensland border (Walker 1991). It forms part of the 'Mulga - Sandplains and Dunefields' rangeland type (Irons and Quinlan 1988). Soils within this land unit are calcareous red earths with sandy loam topsoils (Walker 1991).

Sites were located on three properties in the Wanaaring-Louth region. No site had been burnt for a very long time, even by the most recent big fires in this region during the early 1950s. Woody shrub cover on the sites varied from 1.6% to 37.6%, and density ranged from 80 to 3 780 shrubs per hectare. Other site attributes are summarised in Appendix 3.

Sites were selected in locations with lower tree cover (Figure 3.3). Only Western Rosewood was present at most sites. Woody shrub species present on the sites included Turpentine *Eremophila sturtii*, Punty Bush *Senna artemisioides* ssp. *filifolia*, Narrow-leaved Hopbush *Dodonaea viscosa* ssp. *angustissima* and Silver Cassia *Senna artemisioides* nothosubsp. *artemisioides*. Of these, only Turpentine and Narrow-leaved Hopbush were present on most sites. Mulga *Acacia aneura* trees and Harlequin Fuschia Bush *Eremophila duttoni* were present at some sites.

Figure 3.3 Views from three of the 12 Wanaaring-Louth region study sites. Note patchiness of woody shrub cover. Small accretionary hummocks were evident beneath many shrubs (top photo). Loose sediments were also evident in many patches, such as between Woollybutt tussocks (bottom photo). Sheet erosion is evident in all photos.

3.1.3 Cobar

This district is dominated by low rolling ridges of quartzite and sandstone, with narrow to broad drainage lines. Calcrete layers lie within 1 m of the ground surface in some areas. Mulga *Acacia aneura*, Bimble Box *Eucalyptus populnea* ssp. *bimbil*, White Cypress Pine *Callitris glaucophylla*, Red Box *Eucalyptus intertexta* and Wilga *Geijera parviflora* occur throughout the region. Large open grassy expanses with scattered pine are also present. The sites varied from upper to mid slopes, with soil depth varying correspondingly (Figure 3.4). Most sites contained scattered trees. This was by far the most difficult region to find sites in similar country with a sufficiently large variation in woody shrub cover. Eleven sites were selected in this region.

All sites were located in the Lower Ridge Crests and Upper Slopes land unit of the Boulkra land system (Walker 1991), of the Rolling Downs and Lowlands landform type. This land system covers 2 228 km² of the Western Division, between Cobar and Neckarboo (Walker 1991). It forms part of the rangelands type 'Mulga – Hard Red Ridges and Flats' (Irons and Quinlan 1988). Soils within this land unit are shallow to moderately ferruginous neutral and calcareous red earths, loamy lithosols on crests, and some red-texture contrast soils (Walker 1991).

Eleven sites were located across two properties in the Cobar region. No sites were burnt during the extensive fires of either 1974 or 1984. Woody shrub cover on the sites varied from 0.5% to 41.6%, and density ranged from 40 to 5 340 shrubs per hectare. Other site attributes are summarised in Appendix 3.

Woody shrub species present in this region include Turpentine *Eremophila sturtii*, Budda *E. mitchellii*, Narrow-leaved Hopbush *Dodonaea viscosa* ssp. *angustissima* and Punty Bush *Senna artemisioides* ssp. *filifolia*. No tree species were commonly encountered, and the most common shrubs were Narrow-leaved Hopbush and Turpentine.

Figure 3.4 Views from three of the 11 Cobar region study sites. Note patchiness of woody shrub cover. The two sites with lowest shrub cover were located in dense perennial grasslands.

3.2 Survey timing and weather; seasonal conditions prior to surveys

3.2.1 Summary of seasonal conditions

Seasonal conditions prior to the surveys were estimated by comparing monthly rainfall figures for each base camp property with long-term rainfall statistics for the relevant rainfall district (Bureau of Meteorology 1986). In keeping with Bureau of Meteorology terminology, seasons are determined to be 'average' if rainfall figures were generally within the 4-7 decile range for the district. Seasons were considered to be 'below average' where rainfall was generally below decile 4, and 'above average' where generally above decile 7.

Conditions in the Ivanhoe region were predominantly average leading up to the survey, they were below average in the Wanaaring region, and above average in the Cobar region. The three surveys were conducted at a time when seasonal conditions were generally improving across much of western NSW. The varying seasonal condition assessment reflects the timing of each survey with respect to commencement of widespread rainfall in each district, as described in detail below.

3.2.2 Ivanhoe

Average annual rainfall for the Ivanhoe area is between 300 and 350 mm (30 year average, Bureau of Meteorology website) distributed fairly evenly throughout the year. However, the seasons leading up to the survey were quite unusual. Property records indicate that approximately 205 mm rainfall was recorded during 1997. Only 37.5 mm fell between December 1998 and June 1999, of which 35 mm fell in June, and none during February, March or April (Jane Stanmore, pers. comm.). This situation then reversed, with approximately 63 mm rainfall between July and September 1999 during site establishment.

Conditions were wet during the survey period of October 17 – 30th. Heavy showers interrupted activities during the first few days of the survey. Continuing light showers cleared but conditions remained overcast and temperatures were cool until the last two days of the survey, coinciding with site closure. Nocturnal reptile searches and capture rates were affected by the cool temperatures at night. Germination of new plants was promoted by the rain, but identification of the small plants was difficult.

3.2.3 Wanaaring-Louth

Average annual rainfall in this district is approximately 250 – 300 mm per year (30 year average, Bureau of Meteorology website). During the last few years this has fallen mostly as winter rain, but summer rains dominated prior to this time (Brian O'Mally, pers. comm.). Property records indicate that approximately 375 mm fell during 1998, mostly in July and September. Apart from scattered rain totalling approximately 50 mm during May 1999, very little occurred until October, when 52 mm fell as several showers.

A heavy storm of 54 mm coincided with the field survey between November 9th and 23rd 1999. Conditions during the survey were hot and dry, with warm nights. Humidity increased towards the end of the trip as the storm developed. It broke as sites were being closed, flooding the remaining traps and delaying departure by two days.

3.2.4 Cobar

Average annual rainfall for the Cobar district is approximately 350 - 400 mm, and is largely aseasonal. Property records indicate that 462.5 mm fell during 1999, with just over 60 mm in December (Sue Cox, pers. comm.), during site selection.

The field survey was conducted during late January 2000 (18th – 31st), and commenced with several very hot days as study sites were opened. The second week was interrupted by intense showers which flooded pitfall traps and disrupted drift fences. Strong winds removed rain lids from the invertebrate traps. Conditions were otherwise hot and dry during the survey, and very warm at night.

4. Flora and fauna results and discussion

4.1 Diversity and abundance of taxa

A total of 140 vertebrate species, 30 invertebrate ‘Orders’, 94 ant taxa and 253 flora taxa were recorded across the three survey regions. Of theses, 50 vertebrate species, 30 flora taxa, 20 invertebrate ‘Orders’ and 45 ant taxa were common to all three regions. A complete list of flora and fauna taxa recorded on each study site during the three survey periods is recorded in Appendix 5.

The total number of flora and fauna taxa, and the number within most broad taxonomic group (vertebrates, invertebrate ‘Orders’ and ant taxa) were lowest in the Ivanhoe region, slightly higher in the Wanaaring-Louth region, and consistently higher in the Cobar region (Table 4.1, Appendix 6.1). The high diversity in the Cobar region is particularly noticeable given that there was one fewer site in this region. The coincidence of this survey with an extensive period of sustained plant germination and growth following above average conditions, and the corresponding flush of young animals, may in part explain this high diversity.

Most ant species collected during this investigation are undescribed (Alan Andersen pers. comm.). The number of species for which this is the case is indicated by the lack of a specific name in Appendix 4.1. It is also likely that some of these species have never been collected before, although it is impossible to estimate how many (Alan Andersen pers. comm.). All ant morphospecies and species data were analysed, however this report excludes results for taxa for which there was an unresolved taxonomic discrepancy (i.e. the genera *Monomorium* and *Tetramorium*). The remaining results are referred to as ant taxa. Also excluded from the analyses were those plants recorded outside the floristics quadrats, and the bird species flying through or above the sites (as outlined in section 2.1).

Table 4.1 Total number of plant taxa, number of plant taxa occurring within the floristics quadrats, number of vertebrate species trapped or observed on the sites, number of additional vertebrate species recorded flying through or above the sites, number of invertebrate 'Orders', number of ant morphospecies, and the number of refined ant taxa for each survey region. The average number of taxa recorded per site are included in brackets for those groups which were statistically analysed. Individual site results are provided in Appendix 6.1.

Taxonomic group	Ivanhoe	Wanaaring-Louth	Cobar
Plant taxa per region	114	112	152
Plant taxa in floristics quadrats (av. per site)	108 (43)	101 (47)	135 (65)
Vertebrate species (av. per site)	84 (31)	87 (32)	100 (36)
Vertebrate species flying above/through site	7	7	8
Invertebrate ‘Orders’ (av. per site)	23 (16)	24 (18)	25 (17)
Ant morphospecies	75	81	88
Ant taxa (av. per site)	62 (23)	63 (24)	67 (29)

The abundance of the different faunal groups (measured as numbers of individual vertebrates and invertebrates) varied enormously between regions and between taxonomic groups (Appendix 6.2). Ants were by far the most abundant and variable group, particularly in the Wanaaring-Louth region where there was a 207-fold difference in the abundance between study sites. In comparison, vertebrate fauna diversity varied by roughly 2.5 times across the 35 study sites.

4.2 Similarities of taxa compositions between study sites

Assessment by PATN analysis (Belbin 1991) of most broad taxonomic groups (plants, vertebrates and ant taxa) showed the same general result: that the taxa composition at sites was most similar between sites in the same region, rather than between sites of a similar shrub cover or density from different regions. Consequently the grouping of sites (or quadrats) have been referred to by their regional name in the figures and text below. Results for the 'Order' level invertebrate data revealed no distinctive grouping by region. This result is consistent with the coarse taxonomic level being considered.

Analysis of the floristics data across three regions identified a clear distinction in taxa composition between the Ivanhoe cluster of quadrats and the clusters for the other two regions (Figure 4.1). The relatively high level of dissimilarity for the split between these two groups indicates the limited overlap in flora composition. This result reflects that there were only 13 widespread and common taxa recorded at numerous quadrats in each region. In addition, a large group of widespread but very uncommon taxa (those recorded at few quadrats across two or three regions) was also identified. The lower level of dissimilarity for the split between the Wanaaring-Louth and Cobar regions indicates closer similarity in the flora compositions of these two regions than existed between the Ivanhoe region and these two regions. This closer similarity is reflected in the presence of 19 taxa in many quadrats in both the Wanaaring-Louth and Cobar regions.

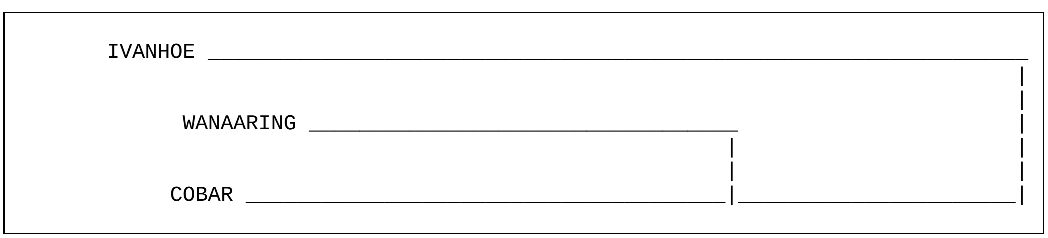


Figure 4.1 Classification of study sites using Flexible UPGMA on the basis of flora taxa cover abundance per quadrat. The principal grouping of quadrats corresponded with the regions surveyed. The forks in the tree represent the level of dissimilarity between the regions named at the end of each branch, whilst the placement of the region names represents the level of dissimilarity amongst the quadrats within each region. Dissimilarity increases from left to right.

The vertebrate fauna species composition results showed a similar pattern to the floristic data, with the Ivanhoe cluster of sites distinctly different from those of the Wanaaring-

Louth and Cobar regions (Figure 4.2). However, the relative amount of dissimilarity between the clusters compared to within the clusters was much lower for the vertebrates, meaning that a higher proportion of the vertebrate species were common to the three regions compared to the plant taxa. Approximately 20 widespread and common vertebrate species were present at many sites within each region, and another group of about 10 widespread and uncommon species was present at few sites in each region. Vertebrate species compositions of the Wanaaring-Louth and Cobar regions were most similar, with considerable overlap of species between these regions. Variation between sites within a region was much greater in the Cobar region than within the Ivanhoe or Wanaaring-Louth regions. A small number of taxa were also identified in each region that were only recorded in that region.

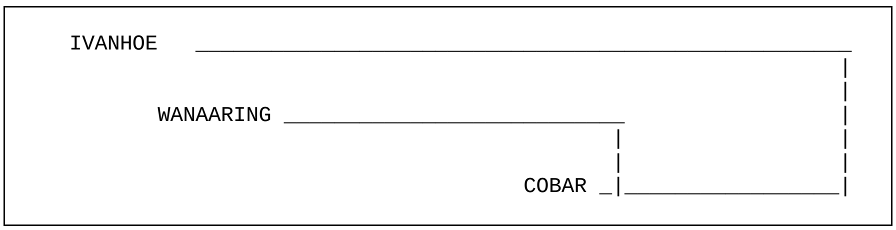


Figure 4.2 Classification of study sites using Flexible UPGMA on the basis of vertebrate fauna presence/absence per site. The principal grouping of sites corresponded with the regions surveyed. The forks in the tree represent the level of dissimilarity between the regions named at the end of each branch, whilst the placement of the region names represents the level of dissimilarity amongst the sites within each region. Dissimilarity increases from left to right.

Results of the PATN analysis for the ant taxa presence/absence data are broadly similar to those of the vertebrates and plants (Figure 4.3). The most noticeable difference is that the Wanaaring-Louth sites clustered into two groups, one of which is more similar in

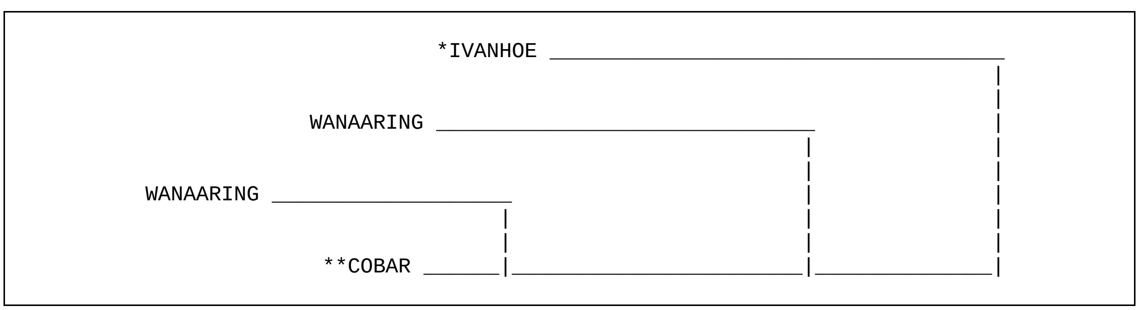


Figure 4.3: Classification of study sites using Flexible UPGMA on the basis of ant taxa presence/absence per site. The principal grouping of sites roughly corresponded with the regions surveyed, however the Ivanhoe cluster of sites (*) includes one Cobar site, and the Cobar site cluster (**) includes one of the Wanaaring-Louth sites. The forks in the tree represent the level of dissimilarity between the regions named at the end of each branch, whilst the placement of the region names represents the level of dissimilarity amongst the sites within each region cluster. Dissimilarity increases from left to right.

ant faunal composition to the Cobar sites than the remainder of the Wanaaring-Louth sites. This and other slight differences in clustering of sites are based on minor taxa composition differences.

Previous vertebrate fauna assessments in western NSW have found that for some vegetation types (e.g. Riverine woodlands, Belah woodlands, Shrublands and grasslands) faunal species composition is more similar between sites of similar vegetation type separated by hundreds of kilometres, than between dissimilar vegetation types located less than 10 km apart (Mazzer *et al.* 1998, Smith *et al.* 1998). Results of the present investigation indicate that for most taxonomic groups the major site groupings, based on taxa composition, were explained by the survey regions and not woody shrub cover or density. Each region is described by a distinctive combination of physical factors (geology, soils, landform, broad vegetation type, seasonal conditions prior to the surveys, timing of the surveys and the corresponding weather conditions during the surveys) and management histories. It is not possible to determine which of these correlated factors, if any, drive these regional flora and fauna groupings.

These results also confirm the early assumption that regional differences were sufficiently great that flora and fauna analyses be undertaken separately within each survey region.

An indication of relative similarity in taxa composition within each survey region can also be obtained from the above PATN diagrams for each broad taxonomic group. The regional taxa abundance averages (Table 4.1) and site abundance counts (Appendix 6.2) provide more detail. Faunal and floral differences are shown in Appendix 5.

4.3 Change in taxa richness with woody shrub cover

No significant relationships were detected between the richness of any of the broad taxonomic groupings (plants, vertebrates, invertebrates, ants and total taxa) and either woody shrub cover or density across the 35 study sites (Figure 4.4). Similar results were obtained when each of these broad taxa groupings was considered in more detail within each of the three survey regions. These results are contrary to the expectation, based on ecological principles, of increased richness in sites of greater vegetation structural complexity (i.e. in areas of intermediate woody shrub cover where other structural elements of the vegetation are also well represented).

Total taxa richness did not respond significantly to woody shrub cover within any of the three survey regions (Figure 4.4). However, in the Ivanhoe region, vertebrate richness and abundance were correlated with shrub cover. Woody shrub density was the site attribute which most influenced the richness of vertebrates present in this region ($r^2 = 0.36$, $p = 0.040$). Similarly, vertebrates were the only group for which the total number of individuals showed any relationship to woody shrub cover ($r=-0.64$, $p = 0.020$) or density.

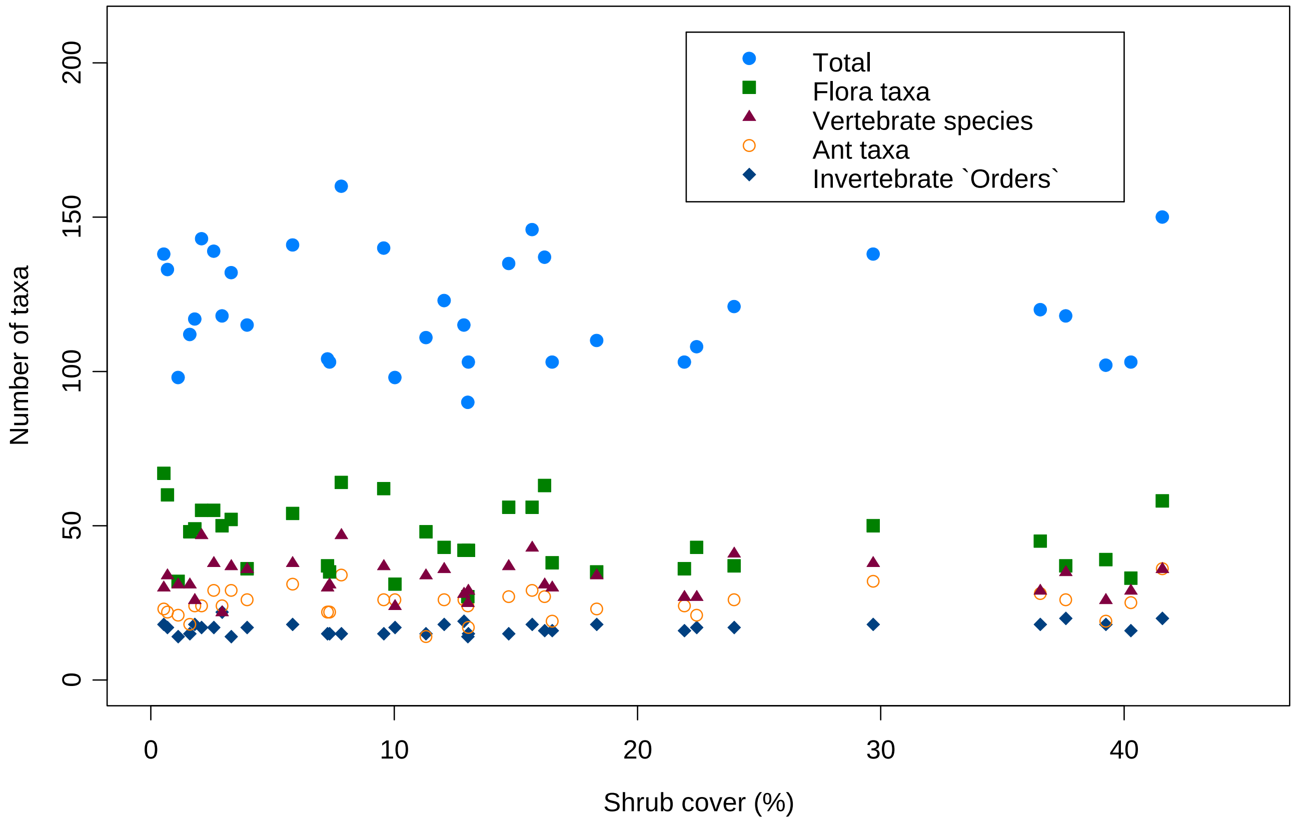


Figure 4.4 Richness of species and other taxa at the 35 study sites. Ant taxa do not include *Monomorium* or *Tetramorium* morphospecies.

Both of these relationships indicated that fewer vertebrates were present in areas of greater shrub cover (Figure 4.5). However, no significant correlations between species richness or abundance and shrub cover or density were detected for birds, mammals or reptiles within this region. Similar results were obtained for the other two regions, and across the three regions collectively. An interesting observation is that most (79.2%) of these correlation results for vertebrate class richness and abundance were non-significant negative trends. In the Ivanhoe region at least, these trends are sufficiently strong that collectively they produce the significant result seen in Figure 4.5.

In the Wanaaring-Louth region, total plant cover was significantly greater in sites with higher shrub cover ($r = 0.67$, $p = 0.017$). Neither the richness nor abundance of any other broad taxonomic group showed any consistent relationship between sites of different woody shrub cover or density in this region.

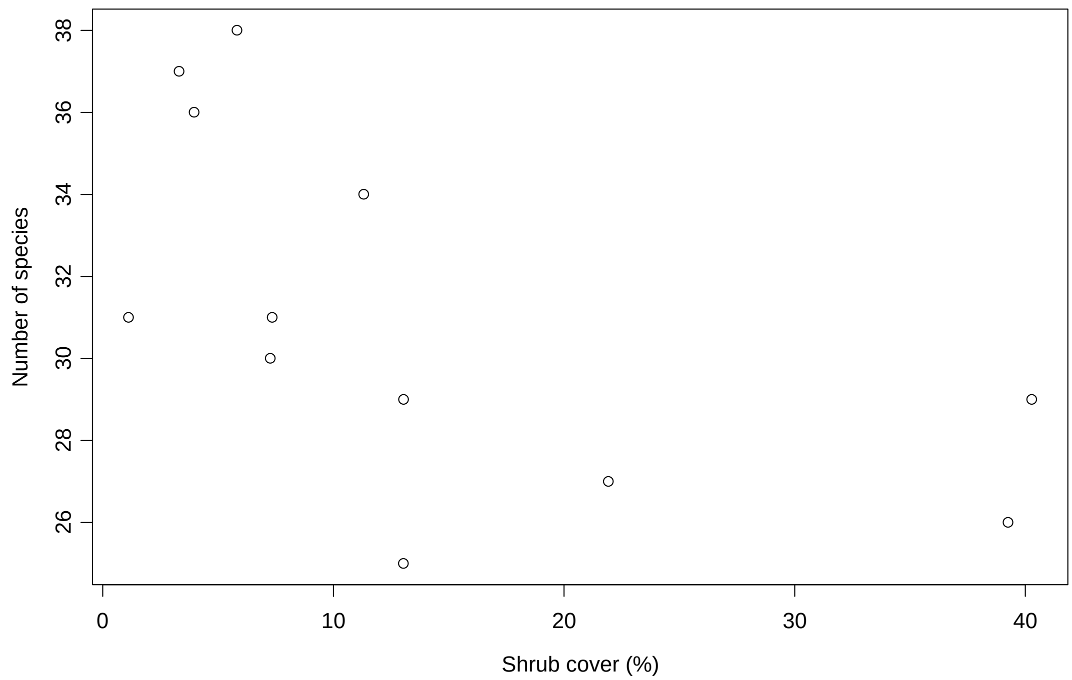


Figure 4.5 Vertebrate richness (and abundance) decreased with woody shrub cover in the Ivanhoe region. When birds, mammals and reptiles were analysed separately, no significant results were obtained.

Increasing woody shrub cover was the best predictor for total number of ant taxa across the 11 study sites of the Cobar region (p = 0.008, Figure 4.6), with increasing soil texture (=increasing infiltration rate, $p < 0.001$) the second variable in the linear model ($r^2 = 0.95$). None of the remaining taxonomic groups varied significantly in richness or abundance with woody shrub cover.

In conclusion, except for a small number of isolated (single-region) exceptions, shrub cover does not significantly affect taxa richness for most broad taxonomic groups.

4.4 Responses of individual taxa and guilds to woody shrub cover

Relationships between individual species, guilds and taxa associations and increasing woody shrub cover were analysed to identify any significant responses. These more detailed investigations of the data were conducted for each region separately, and then pooled across the three regions. Note, however, that analysis of guilds and taxa associations was limited to the detection of an increase or decrease in abundance with shrub cover or density.

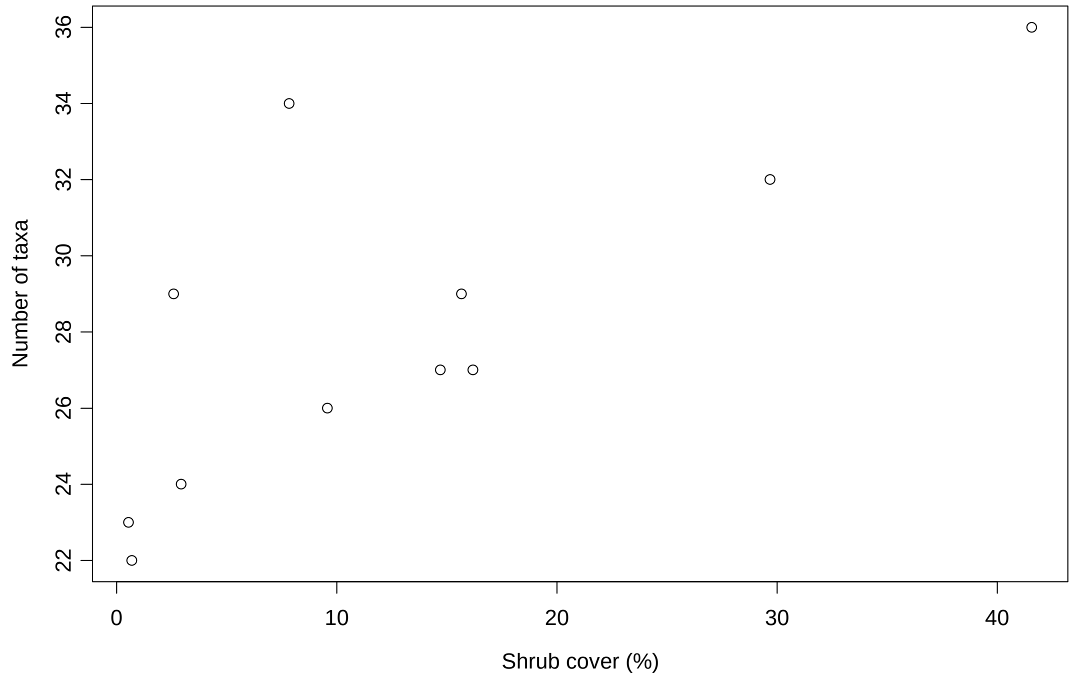


Figure 4.6 Ant richness increased with woody shrub cover in the Cobar region (r = 0.63, $p = 0.008$).

This study found five types of responses by taxa to increasing woody shrub cover, however, most taxa, guilds and taxa associations did not respond significantly to woody shrub cover (Table 4.2). This may be due in part to the large number of taxa recorded at very few sites. Of those taxa analysed (see Table 4.1), 83 (approximately 30%) were recorded at only one site in the Ivanhoe region, compared with 70 (25.5%) in the Wanaaring-Louth region and 87 (26.6%) across the Cobar sites (see Appendix 5 for details). In the Ivanhoe region, this effect was compounded by the capture or observation of fewer vertebrate and invertebrate taxa than elsewhere (section 4.1.1). Fauna activity in this region may have been suppressed due to the cold temperatures that persisted until the last two days of the survey period, in conjunction with the wet conditions early on in the survey process. Nocturnal reptile searches produced particularly poor results throughout this survey. Although flora diversity was comparable in this region to the Wanaaring-Louth region, identification was made difficult on the Ivanhoe sites due to the survey timing (earlier in the season), coupled with the recent germination of many species and their presence on sites as young seedlings. Ease of identification increased during the survey period due to growth and development of these young plants (Jessica Szigethy-Gyula, pers. comm.). Detection of a significant response by taxa to shrub cover was also made difficult by the small number of sites within each region, particularly for those taxa that exhibited a large variability in abundance.

Table 4.2 Principal response types with respect to increasing woody shrub cover, and the proportion of taxa which responded in each region (%). Figures for 'no change' and preference or avoidance of intermediate shrub covers include taxa present in both categories.

Response type	Ivanhoe	Wanaaring-Louth	Cobar
Significant decrease	0.7	5.2	4.3
Significant increase	4.7	10.2	15
Preference for intermediate level of shrub cover	1.5	1.1	3.8
Avoidance of intermediate level of shrub cover	2.6	2.2	1.6
No change	15.2	11.9	9.7

Linear model results for each survey region and for taxa common to the three regions are presented in Appendix 8 (8.1 – 8.4 inclusive). Results are restricted to those taxa and guilds for which woody shrub cover or density featured as a significant variable in the two-variable models. Similarly, pitfall trap microhabitat linear model results which include shrub-related attributes (e.g. trap location with respect to shrub cover, distance to the closest shrub) are presented separately for each survey region in Appendix 8.5. Results of the Generalised Linear Models for taxa common to the three regions, for which the impact of region has been removed, are presented in Appendix 8.6. Predictor variables not relevant to particular taxa or guilds may be included in some model results (see section 2.2.6 for an explanation), however such results have not been discussed below. Discussion of model results has been limited to shrub cover, shrub density and those variables of relevance to the particular taxon or guild.

4.4.1 Decreaser taxa, guilds and taxa associations

Those taxa, guilds and taxa associations which significantly decreased in abundance with increasing woody shrub cover or density are listed separately for each region, and collectively for species common to the three regions (Table 4.3). Detailed statistical results for individual taxa are shown in Appendix 5, and in Appendix 7.1 for guilds and taxa associations. Relatively few taxa responded negatively to increasing woody shrub cover or density in comparison with the number of increaser taxa (Table 4.4). This is true for all broad taxonomic groups (flora, vertebrates, invertebrate 'Orders' and ants) in all regions, except for flora in the Wanaaring-Louth region. In contrast, considerably more guilds and taxa associations were found to respond as decreasers than as increasers for each region.

Discussion of decreaser taxa and guilds is focused on "repeat decreasers" which declined in abundance with increasing woody shrub cover or density in more than one region. A small number of other taxa and guilds for which particular site differences or other attributes are relevant are also discussed.

Drought Avoider plants

This guild of annual grass and forb species declined significantly in abundance with increasing woody shrub cover and density in both the Wanaaring-Louth and Cobar regions. Several individual plant species in this guild also showed this decreasing response in the

Table 4.3 Taxa, guilds and taxa associations for which a significant negative response to woody shrub cover or density was recorded in each region, or across the three regions collectively (taxa common to all three regions only). Appendix 8.6 lists taxa common to the three regions for which a significant response to woody shrub cover was obtained when the 'region' effect was removed. * indicates taxa/guilds or associations for which shrub cover or density was the best predictor in the corresponding linear model (Appendices 8.1 – 8.4).

Ivanhoe	Wanaaring-Louth	Cobar	Three-regions
Plants	**Plants**	**Plants**	**Plants**
Atriplex stipitata	* *Aristida contorta*	*Salsola kali* var. *kali*	* *Sida fibulifera*
	Aristida jerichoensis var. *jerichoensis*	*Digitaria brownii*	
	* *Dactyloctenium radulans*	*Enneapogon avenaceus*	
	* *Bulbine alata*	*Enteropogon acicularis*	
	* *Goodenia cycloptera*	* *Boerhavia dominii*	
	* *Harmsiodoxa blennodioides*	*Carthamus lanatus*	
	Pimelea trichostachya	*Salvia verbenaca*	
	Portulaca intraterranea	* *Sida fibulifera*	
	* Drought Avoiders plant guild	* Groundcover plant guild	
	* Groundcover plant guild	Drought Avoiders plant guild	
		* Drought Endurers plant guild	
		Cobar Plant Association B	
Vertebrates	**Vertebrates**	**Vertebrates**	**Vertebrates**
Trachydosaurus rugosus	*Aphelocephala leucopsis*	*Northiella haematogaster*	*Cacatua leadbeateri*
Ground-feeding Granivorous Birds	*Merops ornatus*	*Diplodactylus steindachneri*	*Northiella haematogaster*
* Non-passerine Granivorous Birds	*Diplodactylus steindachneri*	*Trachydosaurus rugosus*	*Ocyphaps lophotes*
Ground Pursuers bird guild	Ground-feeding Granivorous Birds	Ground-feeding Granivorous Birds	*Trachydosaurus rugosus*
Omnivorous and Herbivorous Birds	Passerine Granivorous Birds		*Macropus rufus*
	* Ground Pursuers bird guild		Ground-feeding Granivorous Birds
	Ground Gleaners bird guild		* Non-passerine Granivorous Birds
	Macropods		Ground Pursuers
			* Ground Gleaners
			Macropods
Invertebrates	**Invertebrates**	**Invertebrates**	**Invertebrates**
none	*Anochetus armstrongi*	Acarina	none
	*Iridomyrmex*0008	*Melophorus* genus	
	Pheidole sp. A	*Rhytidoponera*0001	
		* Hot Climate Specialists ant guild	

Wanaaring-Louth region, including Button Grass *Dactyloctenium radulans*, Hairy-pod Cress *Harmsiodoxa blennodioides*, Spiked Rice-flower *Pimelea trichostachya* and Large Pigweed *Portulaca intraterranea*. Increasing woody shrub cover explained more of the decline in abundance of Button Grass, than any other site attribute ($r^2 = 0.513$, $p = 0.009$).

Palatability of decreaser plants

In the Wanaaring-Louth region, a mixture of highly palatable species (Button Grass *Dactyloctenium radulans*, Large Pigweed *Portulaca intraterranea* and Hairy-pod Cress *Harmsiodoxa blennodioides*), palatable species (Serrated Goodenia *Goodenia cycloptera* and Native Leek *Bulbine alata*) and largely unpalatable species (Kerosene Grass *Aristida contorta*, No. 9 Wiregrass *Aristida jerichoensis* var. *jerichoensis*, and Spiked Rice-flower *Pimelea trichostachya*) were found to be less abundant in shrubbier sites (Table 4.3).

A similar pattern was observed in the Cobar region, with a mixture of highly palatable species (such as Cotton Panic Grass *Digitaria brownii*, Common Bottlewashers *Enneapogon avenaceus*), palatable species (including Tar Vine *Boerhavia dominii* and Pin Sida *Sida fibulifera*), less palatable species (including Curly Windmill Grass *Enteropogon acicularis* and Buckbush *Salsola kali* var. *kali*), and largely inedible species such as Wild Sage *Salvia verbenaca* and Saffron Thistle C*arthamus lanatus*, found to be less abundant in shrubbier sites (Table 4.3). Increasing woody shrub cover better explained the abundance of Tar Vine, Wild Sage and Pin Sida than any other site attribute in this region (see Appendix 8.3 for linear model results).

Only Bitter Saltbush *Atriplex stipitata*, a generally unpalatable chenopod, decreased in abundance with woody shrub cover in the Ivanhoe region.

In conclusion, there was no consistent trend in the palatability to stock of individual decreaser understorey and groundcover taxa in any of the survey regions.

Trees

An important point to remember when considering significant results for tree species is that many of the trees are likely to be considerably older than the woody shrubs, and therefore any relationship is unlikely to be a response by the trees to the shrub cover. Western Rosewood *Alectryon oleifolius*, for example, decreased with increasing woody shrub cover and density across the three regions collectively, after the region effect was removed ($r = -0.172$, $p = 0.014$, for shrub cover). All of the Rosewoods on the study sites were gnarled old plants which are likely to have been growing there considerably longer than the woody shrubs. No other tree species responded as decreasers in any region, however several increased with woody shrub cover (Table 4.4).

Western Rosewood suckers readily from the roots (Cunningham *et al*. 1992), explaining the clumped nature of their distribution. That no young plants were observed is of concern. It is, however, consistent with the observations by Auld (1995) that recruitment of several tree and shrub species, including Western Rosewood, appears to be suppressed by current management practices.

Ground-feeding birds and groundcover plants

The Ground-feeding Granivorous Birds guild (actually a grouping of guilds) includes several parrots, pigeons, finches, quails, button-quails and the Emu. As a group, this guild consistently responded negatively to increasing woody shrub cover in all three survey regions, even though very few individual species showed this response and none of the seven species in this guild common to all three regions responded in this way (Table 4.3). Despite the consistency of this result, other site attributes influenced the abundance of this guild to a greater extent than shrub cover in all survey regions. In the Cobar region, one guild member, the Blue Bonnet *Northiella haematogaster*, did respond negatively to increasing woody shrub cover (r = -0.566, p = 0.024). These parrots largely do not inhabit shrubby areas, even though they are known to feed in seeding or flowering shrubs and roost in dense shrubs. For the most part they feed on the ground amongst dry chenopods or grasses, and roost in open woodland areas (Higgins 1999). In contrast, other guild members (such as Emus *Dromaius novaehollandiae* and Mulga Parrots *Psephotus varius*) showed the opposite response in the Cobar region, increasing with woody shrub cover and/or density.

Within particular regions individual guilds within this broader group of granivorous birds also declined significantly in abundance with increasing woody shrub cover. The Non-passerine members of this guild responded negatively in the Ivanhoe region (r^2 = 0.408, p = 0.025) and across the three regions collectively (r^2 = 0.245, p = 0.003). The relationship with woody shrub cover was the most important variable in explaining the variability of this guild in both analyses (Appendices 6.1 and 6.4). In the Wanaaring-Louth region the Granivorous Passerines (r^2 = 0.38, p = 0.033), and one small species in particular, the Southern Whiteface *Aphelocephala leucopsis* (r = -0.65, p = 0.022), became less abundant as woody shrub cover increased across the study sites (Figure 4.7).

In the Wanaaring-Louth and Cobar regions these results may reflect the observed decline in overall cover of grass, forb and chenopod species (the Groundcover plant guild) with increasing woody shrub density (r^2 = 0.422 p = 0.022; r^2 = 0.386, p = 0.041, respectively). This response was not detected in the Ivanhoe region, possibly due to the lower overall cover of understorey plants in the open Belah woodland compared with the two regions with lower tree cover. The intact soil crust across the Ivanhoe sites (see section 5.1.1) and average seasonal conditions in the Ivanhoe region (see section 3.2.2) indicate that this lack of response is unlikely to reflect a low moisture availability or excessive grazing impact.

Some of the ground-feeding insectivorous bird guilds responded similarly to the granivores. The Ground Pursuers bird guild became less abundant as woody shrub cover increased in the Ivanhoe (r^2 = 0.359, p = 0.039) and Wanaaring-Louth regions (r^2 = 0.462, p = 0.015), and across the three regions collectively (r^2 = 0.209, p = 0.006). Ground Gleaners also responded negatively to increasing woody shrub cover in the Wanaaring-Louth region (r^2 =

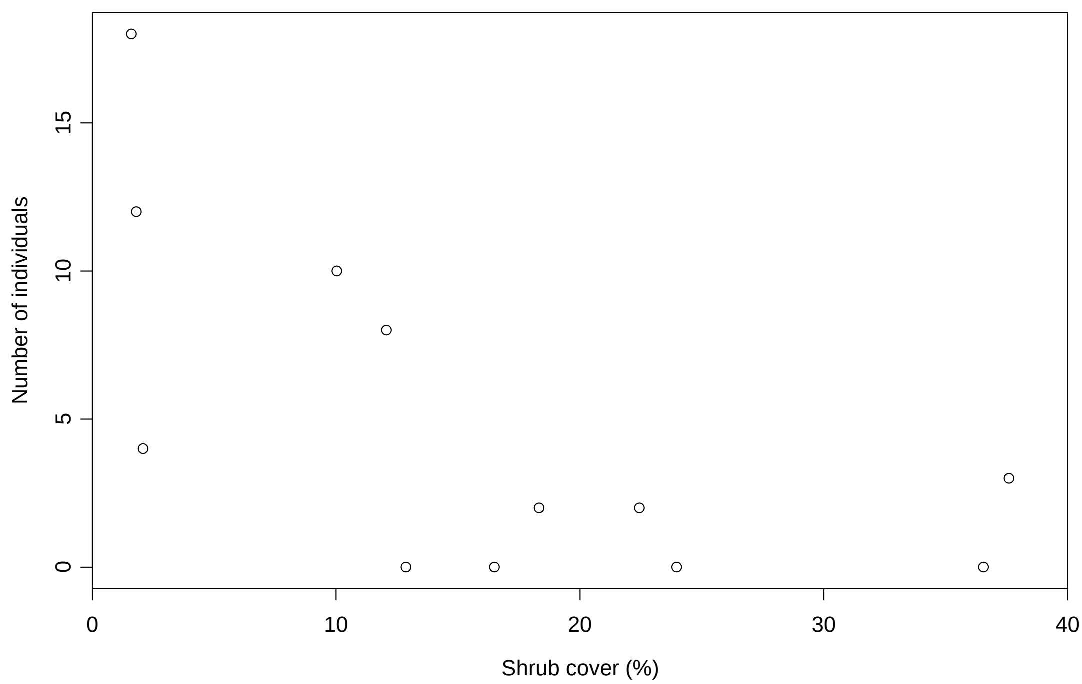


Figure 4.7 The Southern Whiteface decreased markedly in abundance as woody shrub cover increased in the Wanaaring-Louth region.

0.437, p = 0.019) and across the three regions collectively (r^2 = 0.119, p = 0.042). Once again, this is despite a strong positive response by an individual guild member, the Splendid Wren (r = 0.727, p = 0.007).

Steindachner's Gecko

The terrestrial Steindachner's Gecko *Diplodactylus steindachneri* was found to be less abundant in shrubby sites within the Wanaaring-Louth (r = -0.602, p= 0.038) and Cobar (r = -0.52, p = 0.017) regions. In the Cobar region, the linear model for this species (r^2 = 0.813) includes decreasing leaf litter cover (p = 0.001) and decreasing fire intensity (p = 0.011). No significant relationship was found between Steindachner's Gecko and woody shrub cover or density in the Ivanhoe region. However, increasing shrub density (p = 0.001) was the second predictor in the linear model (r^2 = 0.875) in this region. In addition, increasing distance to the closest woody shrub was the only pitfall trap microhabitat attribute which significantly influenced abundance of this gecko species in this region (r^2 = 0.075, p = 0.004).

Shingle-back Lizards

This familiar lizard species decreased with increasing woody shrub cover (r = -0.462, p = 0.024) and with the number of small logs (r = -0.559, p = 0.007) in the Cobar region. This latter site attribute was the second predictor in the most explanatory model for this species (model $r^2 = 0.877$, $p < 0.001$). In the Ivanhoe region the relationship with woody shrub cover was also negative, however the principal factor affecting its abundance was the presence of bark accumulations on the ground ($r^2 = 0.917$, $p < 0.001$). Most of this bark was from the Belah trees present on each site. The presence of tree cracks was the other variable in the linear models for this species in both regions. More refined analyses removing this and other irrelevant site attributes have yet to be conducted (see section 2.2.6).

Kangaroos

The three most common kangaroo species in western NSW (*Macropus fuliginosus*, *M. giganteus* and *M. rufus*) were found in low number in each survey region. The Red Kangaroo *M. rufus* declined in abundance with shrub cover when considered across the three survey regions collectively ($r = -0.345$, $p = 0.024$). When the region effect was removed, all three species were found to decline across the three regions collectively (Appendix 8.6). The Macropod guild declined across the three regions with increasing woody shrub cover ($r^2 = 0.202$, $p = 0.007$), however shrub cover was not included as one of the key variables in the multivariate model for this guild. In the Cobar region *M. fuliginosus* showed a negligible response to woody shrub cover ($r = 0.0004$).

Highly shrub encroached areas are often thought to harbour large numbers of kangaroos. Although this pattern was not supported by the results, kangaroos are highly mobile and this study was not designed to investigate this issue. Systematic surveys of habitat use by kangaroos on Yathong Nature Reserve indicated that most kangaroos were distributed in areas with either no or sparse occurrence of shrubs (McCullough and McCullough 2000). It was also noted that kangaroos are susceptible to tripping and tend to avoid shrubby areas. Significant differences in the use of habitats of different shrub density were detected between species, and between sexes (McCullough and McCullough 2000). In contrast, Hill (1981) found that Eastern Grey Kangaroos preferred areas with above average 'lateral cover' which obscures horizontal vision, such as shrubs and tree trunks. Many incidental observations also attest to the use of shrubby stands as refuge belts by kangaroos and other large vertebrates when threatened.

***Pheidole* sp. A**

This ant species decreased with increasing woody shrub cover in the Wanaaring-Louth region ($r = -0.629$, $p = 0.034$). A small negative response to increasing woody shrub cover was also detected across the three regions when the region effect was removed ($r = -0.18$, $p < 0.001$). However, in the Ivanhoe and Cobar regions it was very poorly correlated with woody shrub cover. Most *Pheidole* species are general predators and scavengers with very broad diets. When foraging, they are capable of gather large numbers of seed very rapidly (Shattuck 1999).

Hot Climate Specialists ant guild

Only one ant guild decreased in abundance with increased woody shrub cover and density across any of the survey regions. This was the Hot Climate Specialists in the Cobar region, and decreasing woody shrub cover (p = 0.001) remained the best predictor for this guild even when all site attributes were considered (r^2 = 0.821). Decreasing nutrient cycling status (a landscape function index, see section 2.1.6) was the second variable in the linear model (p = 0.041) for this guild of ants.

All species of the genus *Melophorus*, most *Meranoplus* species and some *Monomorium.* species comprise this ant guild. It consists of arid-adapted taxa with morphological, behavioural or physiological specialisations that reduce their interaction with highly aggressive ant groups, such as the "meat ants" in the genus *Iridomyrmex* (Andersen 1997). For example, *Meranoplus* species tuck their legs in under a shield-like plate, retract their antennae into grooves on the sides of their head and lie motionless when under attack. Together with their very thick exoskeleton, this protects them well from other ants (Andersen 1991).

Melophorus specimens were not separated into morphospecies (see section 2.1.5.5), and were therefore analysed at the genus level. Given that this endemic genus is extremely large and particularly diverse in arid Australia, it is not surprising that specimens were captured at all 35 study sites. Although less abundant in areas of higher woody shrub cover in the Cobar region (r = -0.654, p = 0.025), shrub cover did not feature in the linear model for this genus. All *Melophorus* species are strictly diurnal foragers, and in arid areas are the only ants active during the hottest part of the day (Andersen 1991). They move extremely rapidly when hot, and are very timid (Shattuck 1999). These omnivorous ants are ground-nesters.

Given the response of members of this guild to ants of the genus *Iridomyrmex*, the decreaser result for this guild in the Cobar region may reflect the trend of increasing abundance of four *Iridomyrmex* species with increasing woody shrub cover in the Cobar region (see section 4.4.2, Increaser ant genera). This inference is supported by the observation that no *Iridomyrmex* morphospecies responded as increasers in the other two regions, nor did the Hot Climate Specialists guild respond as a decreaser guild in either of these regions.

4.4.2 Increaser taxa, guilds and taxa associations

Those taxa, guilds and taxa associations which significantly increased in abundance with increasing woody shrub cover or density are listed separately for each region, and collectively for species common to the three regions (Table 4.4). Detailed statistical results for individual taxa are shown in Appendix 5, and in Appendix 7.2 for guilds and taxa associations. As mentioned in section 4.4.1, comparatively more taxa, and comparatively fewer guilds, increased in abundance with increasing woody shrub cover in each of the three survey regions.

Discussion of increaser taxa and guilds is focused on "repeat increasers" which declined in abundance with increasing woody shrub cover or density in more than one region. A small number of other taxa and guilds for which particular site differences or other attributes are relevant are also discussed.

Palatability of increaser plants

In the Wanaaring-Louth region a mixture of highly palatable species (Mulga Mitchell Grass *Thyridolepis mitchelliana*), moderately palatable species including Variable Daisy *Brachyscome ciliaris* and Rough Speargrass *Austrostipa scabra* subsp. *scabra* (when young) and largely unpalatable species (Doubah *Marsdenia australis*) were found to be more abundant in shrubbier sites (Table 4.4).

A similar pattern was observed in the Cobar region, with a mixture of highly palatable species (Mulga Mitchell Grass), palatable species (Arabian Grass *Schismus barbatus*, Cane Panic *Panicum subxerophilum* and the goosefoot species *Chenopodium desertorum* ssp. *microphyllum*), species of unknown palatability (Downy Mother-of-Misery *Cuphonotus andraeanus* and Red-berried Stick-plant *Spartothamnella puberula*) and palatable but toxic species such as the spurge *Phyllanthus lacunellus*, were found to be more abundant in shrubbier sites (Table 4.4). Increasing woody shrub density better explained the abundance of Cane Panic, Arabian Grass and the goosefoot species than any other site attribute in this region (see Appendix 8.3 for linear model results).

Pale Twinleaf *Zygophyllum glaucum*, a somewhat palatable species, was the only individual increaser flora species in the Ivanhoe region (except for trees and shrubs). It was present at only the site with highest woody shrub cover (Appendix 5).

In conclusion, there was no consistent trend in the palatability to stock of individual increaser understorey and groundcover taxa in any of the survey regions.

Pine trees

A relatively large number of plant species were found to respond significantly to woody shrub cover in the Cobar region. However, many of the results are based on a fairly minimal occurrence of the species, and are marked as such in Appendix 5. One such species, White Cypress Pine *Callitris glaucophylla*, was positively correlated with woody shrub cover and density, as well as the number of small logs present on the sites. This result is perhaps difficult to understand unless you realise that the two shrubbiest sites occurred relatively close (>150 m) to a large belt of Cypress Pine trees, and that one or two individual trees occurred on each of these sites. In addition, some of these trees had been cleared from at least one of the more open sites, and no trees occurred on the remaining sites.

Table 4.4 Taxa for which a significant positive response to woody shrub cover or density was recorded in each region or across the three regions collectively. Appendix 8.6 lists taxa common to the three regions for which a significant response to woody shrub cover was obtained when the 'region' effect was removed. * indicates taxa/guilds or associations for which shrub cover or density was the best predictor in the corresponding linear model (Appendices 8.1 – 8.4).

Ivanhoe	Wanaaring-Louth	Cobar	Three-regions
Plants	**Plants**	**Plants**	**Plants**
* *Myoporum platycarpum*	* *Austrostipa scabra* subsp. *scabra*	*Acacia aneura*	* *Eremophila sturtii*
* *Pittosporum phylliraeoides*	*Brachyscome ciliaris*	*Callitris glaucophylla*	* *Senna artemisioides* ssp. *filifolia*
* *Senna artemisioides* ssp. *filifolia*	* *Marsdenia australis*	*Eucalyptus intertexta*	
Senna artemisioides ssp. *helmsii*	* *Senna a.* nothosubsp. *artemisioides*	*Eremophila bowmanii* ssp. *bowmanii*	
* *Zygophyllum glaucum*	* *Thyridolepis mitchelliana*	*Eremophila mitchellii*	
		Senna artemisioides ssp. *filifolia*	
		* *Chenopodium desertorum* ssp. *microphyllum*	
		* *Panicum subxerophilum*	
		* *Schismus barbatus*	
		Thyridolepis mitchelliana	
		Amyema quandang	
		Amyema miraculosum ssp. *boormanii*	
		Brassica sp.	
		Cuphonotus andraeanus	
		Parsonsia eucalyptophylla	
		Phyllanthus lacunellus	
		Spartothamnella puberula	
		Swainsona affinis	
Vertebrates	**Vertebrates**	**Vertebrates**	**Vertebrates**
Chlamydera maculata	* *Acanthagenys rufogularis*	* *Acanthiza apicalis*	*Acanthagenys rufogularis*
* *Smicrornis brevirostris*	* *Corvus bennetti*	* *Acanthiza nana*	*Acanthiza uropygialis*
* *Varanus gouldii*	* *Malurus splendens*	*Colluricincla harmonica*	* *Smicrornis brevirostris*
Neobatrachus sudelli	* *Petroica goodenovii*	*Coracina novaehollandiae*	
	* *Ctenophorus nuchalis*	*Dromaius novaehollandiae*	
	Ctenotus schomburgkii	*Melithreptus brevirostris*	
	* *Egernia inornata*	* *Merops ornatus*	
	* Scavenging Birds	*Pardalotus striatus*	
	Burrowing Reptiles	*Psephotus varius*	
	Terrestrial Skinks	* *Smicrornis brevirostris*	
		Turnix varia	
		Lerista muelleri	
		Ramphotyphlops bituberculatus	

Ivanhoe	Wanaaring-Louth	Cobar	Three-regions
Vertebrates (cont'd)	**Vertebrates (cont'd)**	**Vertebrates (cont'd)**	**Vertebrates (cont'd)**
		Capra hircus	
		Felis catus	
		Sminthopsis murina	
		* Tree and Shrub Canopy-feeding Insectivorous Birds (bark)	
		Burrowing Reptiles	
Invertebrates	**Invertebrates**	**Invertebrates**	**Invertebrates**
Neuroptera	Araneae	Blattodea	Lepidoptera
Scolopendrida	Collembola	* Scorpionida	*Camponotus ephippium*
Meranoplus sp. K	* Diplopoda	*Brachyponera lutea*	*Iridomyrmex*0004
* *Stigmacros* sp. C	Hymenoptera	*Camponotus ephippium*	*Iridomyrmex*0010
	Orthoptera	*Camponotus nigiceps*	* *Pheidole* sp. B
	* Scolopendrida	*Camponotus* sp. D	*Pheidole* sp. H
	* Thysanoptera	* *Iridomyrmex*0004	
	Camponotus sp. A	*Iridomyrmex*0010	
	Camponotus sp. nr. *aurocinctus*	* *Iridomyrmex*0013	
	* *Crematogaster* sp. A	*Iridomyrmex*0014	
	* *Meranoplus* sp. B	*Meranoplus* sp. D	
	* *Meranoplus* sp. D	*Pheidole* sp. B	
	Pheidole sp. H	*Pheidole* sp. C	
	* *Polyrhachis* sp. A	* *Pheidole* sp. H	
	* *Solenopsis* sp. A	*Stigmacros* sp. C	
	* *Stigmacros pilosella*	Subordinate Camponotini ant guild	
	* Subordinate Camponotini ant guild	Cryptic Species ant guild	
	Cold Climate Specialists ant guild	Cobar Ant Association A	

Spiny-cheeked Honeyeater

The common honeyeater *Acanthagenys rufogularis* was observed at 26 of the 35 study sites, and responded as an increaser to woody shrub cover (and density) in both the Ivanhoe region (r = 0.795, p = 0.002) and across the three regions collectively (r = 0.444, p = 0.027). Although an increaser response may be anticipated by honeyeater species to woody shrub cover where nectar-producing species occur, none of the surveys occurred whilst any of the shrub species were in flower. Its increaser response to woody shrub cover therefore highlights other interactions with shrubby habitats (e.g. use of shrubs as feeding substrates and/or shelter), and reflects its common occurrence in scrubby areas and woodlands across much of dry inland Australia (Blakers *et al.* 1984).

Small insectivorous birds

Splendid Wrens *Malurus splendens* were frequently observed flying in small groups from shrub to shrub in the Wanaaring-Louth region sites. These birds mostly feed amongst foliage and on the ground, and often retreat to the cover of shrubs when disturbed. Increasing woody shrub cover (p = 0.001) and decreasing rabbit disturbance together accounted for more of the variability in occurrence of this species (r^2 = 0.785) than any other combination of site attributes.

Woody shrub density was the best predictor for two species of thornbills, the Inland Thornbill *Acanthiza apicalis* and the Yellow Thornbill *A. nana* when all the site attributes were analysed for the Cobar region. In both cases increasing grazing severity was the second variable in the linear model (r^2 = 0.706 and r^2 = 0.873, respectively). Increasing woody shrub cover (p = 0.001) was the best predictor for occurrence of a similar species, the Weebill *Smicrornis brevirostris*, with a decline in the number of small logs (p = 0.036) also included in the linear model for this species (r^2 = 0.803). Although recorded at only two sites in the Ivanhoe region, an increaser response to woody shrub density (p = 0.008) was also exhibited there by the Weebill (r^2 = 0.417). The presence of shedding bark on trees (p = 0.029) was the second variable in the linear model for this species.

An even greater number of individual Yellow-rumped Thornbills *A. chrysorrhoa* were recorded in the Cobar region (50 spread across 7 sites), however there was no significant response between abundance of this species and either woody shrub cover or density. This result reflects the greater tendency for Yellow-rumped Thornbills to venture into open areas far more frequently than many other thornbill species known from western NSW. It often feeds on the ground as it moves around, a tendency that also holds true for open woodland areas (Slater 1974).

Tree and shrub canopy-feeding insectivorous birds (bark)

The guild of insectivorous birds which forage amongst the bark of shrubs and trees significantly increased in abundance with increasing woody shrub cover and density in the Cobar region (r^2 = 0.611, p = 0.004). Species in this guild include the Grey Shrike-thrush *Collurincla harmonica*, Varied Sitella *Daphoensitta chrysoptera*, Buff-rumped Thornbill *Acanthiza reguloides*, Black-faced Cuckoo-shrike *Coracina novaehollandiae* and treecreepers *Climacteris* spp. Across the three regions collectively, the linear model which best explains the variation in this guild (r^2 = 0.520) includes the presence of shedding bark on trees (p = 0.030) and increasing woody shrub cover (p = 0.028). Region contributed significantly to this model. A positive relationship with shrub cover by Black-faced Cuckoo-shrikes, Grey Shrike-thrushes and White-browed Treecreepers has previously been observed in the Upper Lachlan region (Seddon *et al.* 2001).

Burrowing Reptiles

The guild of Burrowing Reptiles increased in abundance with increasing woody shrub density (and cover) in the Wanaaring-Louth (r = 0.42, p = 0.023) and Cobar (r = 0.479, p =

0.018) regions. The presence of shed bark accumulations best predicts the occurrence and abundance of burrowing reptiles in the Cobar survey region ($p < 0.001$), with the number of small logs ($p = 0.002$) the second variable in the linear model ($r^2 = 0.941$). These results may reflect the use by many of these reptile species of ground debris accumulations as shelter or foraging habitats.

In the Wanaaring-Louth region, soil comparisons on the study sites revealed minimal differences, however some sites were located on softer sandy soils (low sand dunes within the plains), and others on harder sandy soils (both low dunes and flatter plains). These differences did not directly correspond with differences in the woody shrub cover, however they may have influenced the response of this reptile guild, predominantly due to the presence of Broad-banded Sand Swimmers *Eremiascincus richardsonii*, Desert Skinks *Egernia inornata* and blind snakes *Ramphotyphlops bituberculatus* at some of the Wanaaring-Louth sites. Both Sand Swimmers and Desert Skinks were recorded in sites with harder sandy and sandy loam soils, as well as the loose sandy sites. The pitfall trapping linear model results for the Desert Skink indicated that increased shrub density explained more of the capture variation than any of the attributes measured immediately around the pitfall traps ($r^2 = 0.077$, $p = 0.004$).

Pheidole sp. H

All *Pheidole* species trapped in this investigation are undescribed (Appendix 4). *Pheidole* sp. H increased considerably in abundance with woody shrub cover and density in the Wanaaring-Louth and Cobar regions (Figure 4.8 illustrates the strength of this relationship in the Wanaaring-Louth region), and across the three regions collectively ($r = 0.653$, $p < 0.001$). Two other *Pheidole* species exhibited an increaser response in the Cobar region (*Pheidole* sp. B and *Pheidole* sp. C). All of these relationships, except for that of *Pheidole* sp. C, are based on good representation across the study sites and are highly significant results. When the regional influence was removed from the three-region analysis, all three *Pheidole* species increased significantly with shrub cover (sp. B: $r = 0.362$; sp. C: $r = 0.326$; sp. H: $r = 0.653$, $p < 0.001$).

Increaser ant genera

For many ant genera trapped in this investigation, multiple species were collected. However, few congeners responded similarly to increasing woody shrub cover. *Camponotus* is one such genus of ants, the details for which are discussed below (see Subordinate Camponotini ant guild).

Within the genus *Iridomyrmex*, four morphospecies increased significantly with woody shrub cover, and one decreased. *Iridomyrmex*0004 and *Iridomyrmex*0010 increased in the

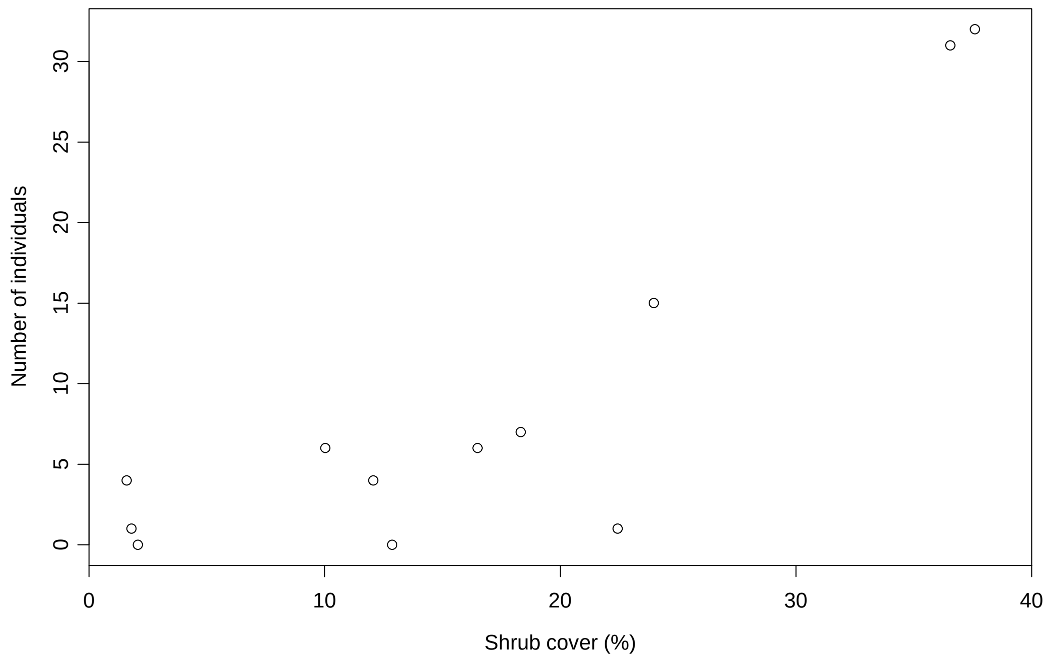


Figure 4.8 *Pheidole* sp. H increased markedly in abundance as woody shrub cover increased in the Wanaaring-Louth region (r = 0.86, p = 0.001). Information on this taxon is included in section 4.4.1.

Cobar region and across the three regions collectively (as well as when the regional effect was removed), and *Iridomyrmex*0013 and 0014 responded as increasers in the Cobar region (Appendix 5; Appendix 8.6). *Iridomyrmex*0009 also increased with shrub cover across the three regions collectively when the regional effect was removed (while four other *Iridomyrmex* species decreased when analysed in this way, Appendix 8.6). Ants of the genus *Iridomyrmex* tend to interact strongly with many plants: many tend aphids and coccids, and collect nectar when available; some associate closely with caterpillars; and many collect seeds with elaiosomes (food bodies) attached (Shattuck1999). The increaser response to woody shrub cover by multiple morphospecies in the Cobar region may reflect some of these associations.

Five significant relationships between abundance of particular *Meranoplus* species and woody shrub cover and/or density were recorded, three of which were based on occurrence at a limited number of sites within each region (Appendix 5). In the Wanaaring-Louth region, *Meranoplus* sp. D was present at more sites, but also in very low numbers. The increaser relationship was far stronger with woody shrub density than cover for this species.

Of the three increaser relationships by *Stigmacros* species, two were based on limited data (Appendix 5). In the Cobar region, *Stigmacros* sp. C appeared to indicate a preference for sites of greater woody shrub cover, however when all site attributes were considered only the abundance of small logs was included in the linear model for this species (r^2 = 0.868, p

< 0.001). These responses to increasing shrub cover may reflect the niche filled by *Stigmacros* species as general predators that forage on the ground, amongst leaf litter and within trees and shrubs (Shattuck 1999). *Stigmacros* species are included in the Cold Climate Specialists guild, which increased in abundance with increasing woody shrub density in the Wanaaring-Louth region. ($r^2 = 0.421$, $p = 0.022$). Common features of this guild are that their distributions are centred on the cool-temperature zone, and they occur in habitats where the more aggressive ant genera (such as *Iridomyrmex* and *Dolichoderus*) are absent (Andersen 1997). Although most species in this guild are absent from the central arid zone, it is common for them to be well-represented in southern semi-arid areas (A. Andersen, pers. comm.). This is particularly true for *Notoncus* species. Also included in this guild are some *Monomorium* species. Given that very few *Monomorium* species were included in the guild analyses, the results for this guild are dominated by the *Stigmacros* species results.

Subordinate Camponotini ant guild

The Subordinate Camponotini guild significantly increased in abundance with increasing woody shrub cover in both the Cobar ($r^2 = 0.47$, $p = 0.02$) and Wanaaring-Louth ($r^2 = 0.612$, $p = 0.003$) regions. Members of this guild co-occur with, but are behaviourally submissive to more aggressive genera such as *Iridomyrmex* and *Dolichoderus*. They are generally large in body size and often forage nocturnally. Included in this guild are all species of the genera *Camponotus, Polyrhachis, Opisthopsis* and *Calomyrmex* (Andersen 1997).

Species of the genus *Polyrhachis* are most commonly seen foraging on vegetation at night during warm weather (Andersen 1991). The only *Polyrhachis* species recorded in this investigation (sp. A) was also very responsive to increasing woody shrub cover in the Wanaaring-Louth region ($r = 0.616$, $p = 0.014$). Woody shrub cover was the only significant variable in the linear model for this species in the Wanaaring-Louth region ($r^2 = 0.473$, $p = 0.014$).

Calomyrmex is another genus of the semi-arid and arid zone. These diurnal ants are common on non-sandy soils. They do not attack living invertebrates, but collect nectar and other plant secretions, and honeydew from bugs (Shattuck 1999). Species of *Opisthopsis* are often seen running swiftly on trunks of trees and shrubs during even during the hottest part of the day (Greenslade 1979). They nest in the soil or in branches of trees or large shrubs (Shattuck 1999). No individual *Calomyrmex* or *Opisthopsis* species increased in abundance with increasing woody shrub cover in either region.

Two *Camponotus* species in the Wanaaring-Louth region, and three in the Cobar region, increased significantly in abundance with increasing woody shrub cover and/or density (Appendix 5). One of these, *Camponotus ephippium*, increased in the Cobar region and across the three regions collectively. Species of *Camponotus* are extremely abundant and diverse in arid areas and are commonly seen on vegetation. These predominantly groundnesting ants vary enormously in their foraging times. Inconspicuous whilst inactive, they can be found in large numbers whilst foraging (Shattuck 1999).

Cryptic Species ant guild

The Cryptic Species ant guild responded as an increaser in the Cobar region. Species included in the Cryptic Species guild are members of the *Hypoponera* and *Solenopsis* genera, some *Cerapachys* species and *Brachyponera lutea.* Members of this guild forage predominantly within soil and litter, and have relatively little interaction with ants which forage on the soil surface (Andersen 1997). They are often very small, being no more than 1.5-2 mm long, have tiny eyes, and are rarely seen except under timber or rocks where they nest. *Brachyponera lutea* also increased in abundance with increasing woody shrub cover in this region ($r = 0.736$, $p = 0.01$).

4.4.3 Decreasing increasers

Decreasing increasers is the term given taxa for which woody shrub cover and density collectively explained more variation than any other combination of site attributes (Appendix 8.1 – 8.4). For example, the linear model for Tar Vine *Boerhavia dominii* in the Cobar region ($r^2 = 0.851$) is based on presence of this species at 10 of the 11 study sites, and comprises a decreasing relationship with woody shrub density ($p < 0.001$) and an increasing relationship with woody shrub cover ($p = 0.026$). These results indicate that Tar Vine, a preferentially grazed forb which responds readily to summer rain (Brooke and McGarva 1998), may be more abundant in this region where fewer larger-canopied woody shrubs are present than where a larger number of smaller shrubs occur.

All other models of this nature comprised a positive relationship with woody shrub density, and a negative relationship with woody shrub cover, and apply to species present at one site, e.g. Butterbush *Pittosporum phylliraeoides* in the Ivanhoe region, or at most two sites (Little Crow *Corvus bennetti* in the Wanaaring-Louth region). Confidence in the apparent preference by these taxa for areas with a greater number of narrow or small shrubs, is reduced by the observation that each is present in very low numbers and at very few sites.

4.4.4 Non-linear responses to woody shrub cover

Individual taxa were analysed to determine whether they exhibited a simple non-linear response to woody shrub cover. Guilds and taxa associations were not analysed in this way, nor was the relationship of taxa abundance to shrub density.

Those taxa more abundant at intermediate woody shrub cover levels, and less abundant at one or both cover extremes are listed in Table 4.5, with corresponding quadratic model results. Some of these taxa appear to exhibit a preference for intermediate levels of woody shrub cover (Figure 4.9). A small number of species in this group exhibited a very low correlation with woody shrub cover and are considered generalists (section 4.4.6).

However, the nature of the relationship between abundance and woody shrub cover for other taxa in this group is more appropriately described as an avoidance of one of other of the extremes of woody shrub cover (Figure 4.10). Most taxa in this latter group were present in low abundance, hence it is possible that some of these taxa may be increaser or decreaser taxa which were simply recorded in low number. It is also possible that intermediate cover levels provide the combined benefits of less shrubby areas and denser patches. For example, for animals there may be a greater diversity of foods in a sheltered environment. For plants, shrubs may offer protection, but reduce overcrowding.

Table 4.5 Quadratic model results for taxa which were most abundant at sites with intermediate woody shrub covers, as well as those which were least abundant at one of the extreme cover levels. * indicates generalist taxa.

Taxa	**r^2**	***p***
Ivanhoe		
Dicaeum hirundinaceum	0.519	0.033
*Lichenostomus virescens**	0.552	0.009
Sminthopsis murina	0.624	0.007
Diptera	0.41	0.04
Wanaaring-Louth		
*Dissocarpus paradoxus**	0.656	0.003
Colluricincla harmonica	0.385	0.047
*Rhynchoedura ornata**	0.501	0.015
Cobar		
Calotis lappulacea	0.603	0.013
Chamaesyce drummondii	0.716	0.013
Glossogyne tannensis	0.447	0.047
Vittadinia cuneata var. *cuneata*	0.553	0.031
Wahlenbergia luteola	0.456	0.042
Acanthiza chrysorrhoa	0.561	0.023
Aphelocephala leucopsis	0.465	0.034
Lichenostomus virescens	0.55	0.014
Oreoica gutturalis	0.767	0.001
Petroica goodenovii	0.642	0.016
Ctenophorus nuchalis	0.828	<0.001
*Iridomyrmex*0008*	0.486	0.026

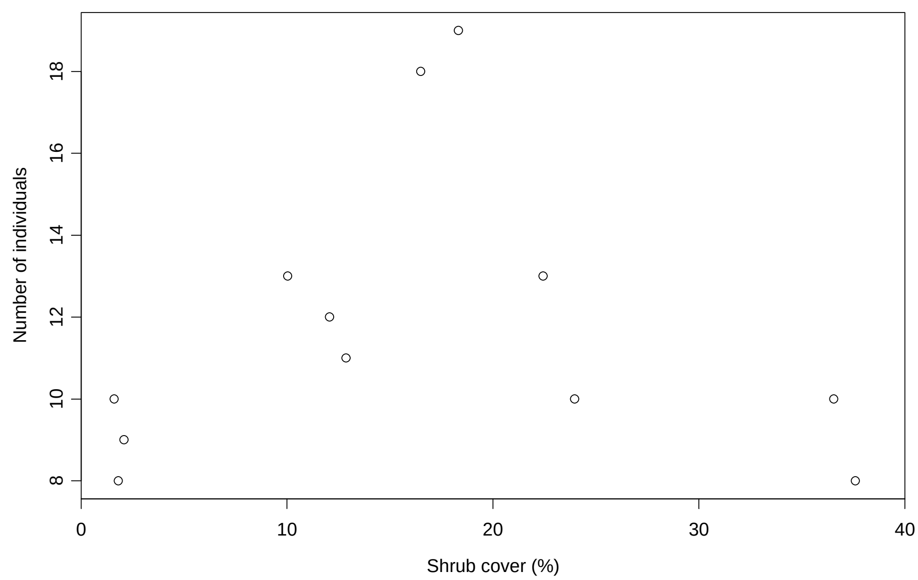


Figure 4.9 Beaked Gecko *Rhynchoedura ornata*. Example of a mid-cover favouring species which was found in greatest abundance at intermediate shrub covers in the Wanaaring-Louth region. Several species which exhibited this response were present in moderate to high abundance.

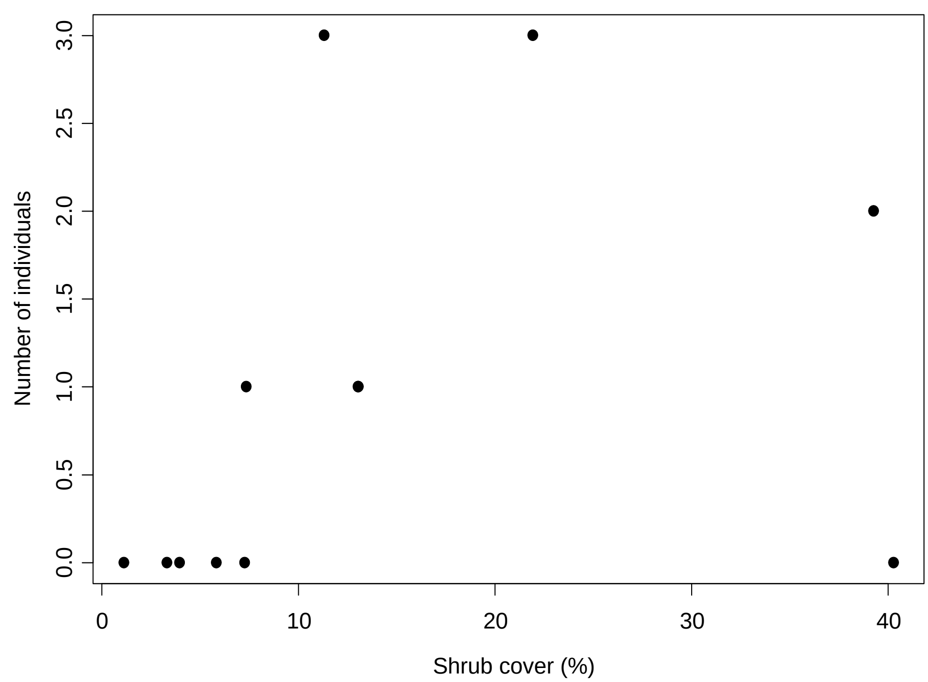


Figure 4.10 Common Dunnart *Sminthopsis murina*. Example of a low-cover avoider which was found in greatest abundance in the Ivanhoe region at intermediate and high woody shrub cover levels. Note low abundance scores.

Those taxa less abundant at intermediate woody shrub cover levels and more abundant at one or both cover extremes are listed in Table 4.6, with corresponding quadratic model results. Some of these taxa appear to avoid sites of intermediate shrub cover (Figure 4.11). Two of these species exhibited a very low correlation with woody shrub cover and are also considered generalists (section 4.4.6). However, for other species in this group the nature of the relationship between abundance and woody shrub cover is more appropriately described as a preference for one of other of the extremes of woody shrub cover, such as Hemipterans in the Ivanhoe region (Figure 4.12). Most extreme-cover specialists were present in low abundance. Thus it is possible that some of these taxa may be increaser or decreaser taxa which were simply recorded in low number.

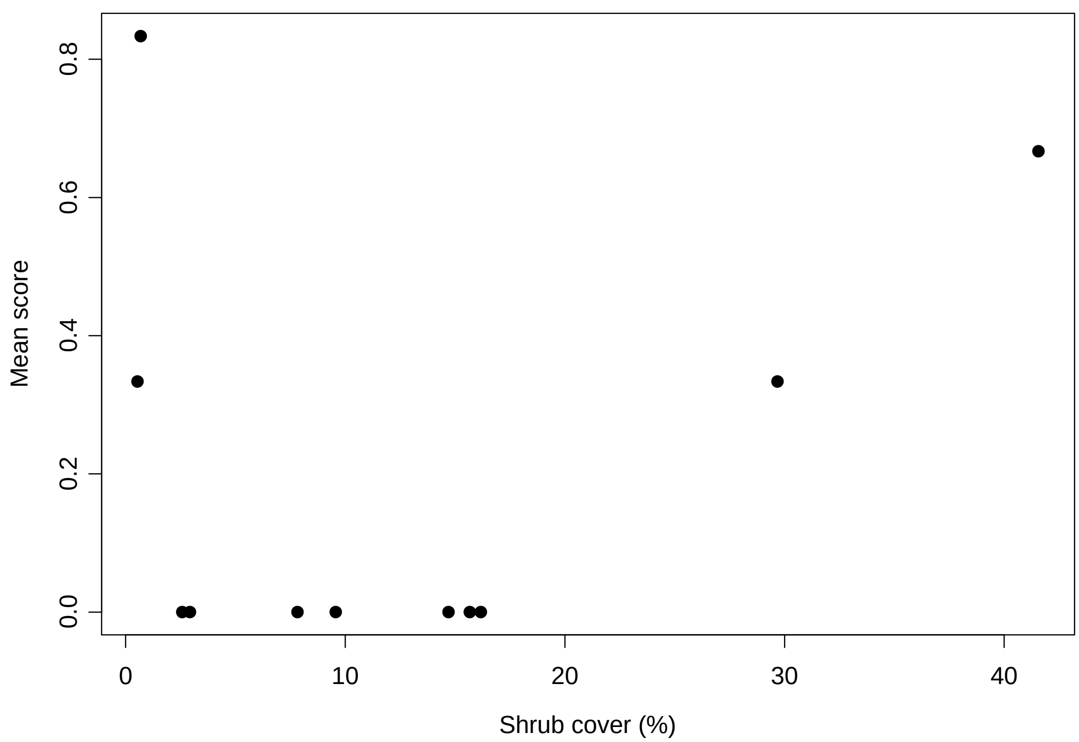


Figure 4.11 Spiny Potato-bush *Solanum ferocissimum*. Example of a mid-cover avoider that was found in greatest abundance in the Cobar region at extreme woody shrub cover levels. Note low cover abundance scores. Most mid-cover avoiders were present in low abundance.

Table 4.6 Quadratic model results for taxa which were least abundant at sites with intermediate woody shrub covers, as well as those which were most abundant at one of the extreme cover levels. * indicates generalist taxa.

Taxa	**r^2**	***p***
Ivanhoe		
*Chenopodium cristatum**	0.74	0.001
Calotis hispidula	0.568	0.012
Barnardius barnardi	0.55	0.013
Gymnorhina tibicen	0.513	0.022
Plectorhyncha lanceolata	0.467	0.026
Diplodactylus steindachneri	0.582	0.016
Hemiptera	0.406	0.045
Wanaaring-Louth		
Abutilon otocarpum	0.741	0.001
Alternanthera species A	0.427	0.032
Chamaesyce drummondii	0.538	0.012
Oxalis corniculata	0.649	0.003
Flora richness	0.481	0.048
Isoptera	0.409	0.041
Scorpionida	0.479	0.02
Cobar		
Solanum ferocissimum	0.562	0.019
*Pomatostomus ruficeps**	0.414	0.045
Orthoptera	0.525	0.028
Psocoptera	0.585	0.012
Scolopendrida*	0.713	0.002

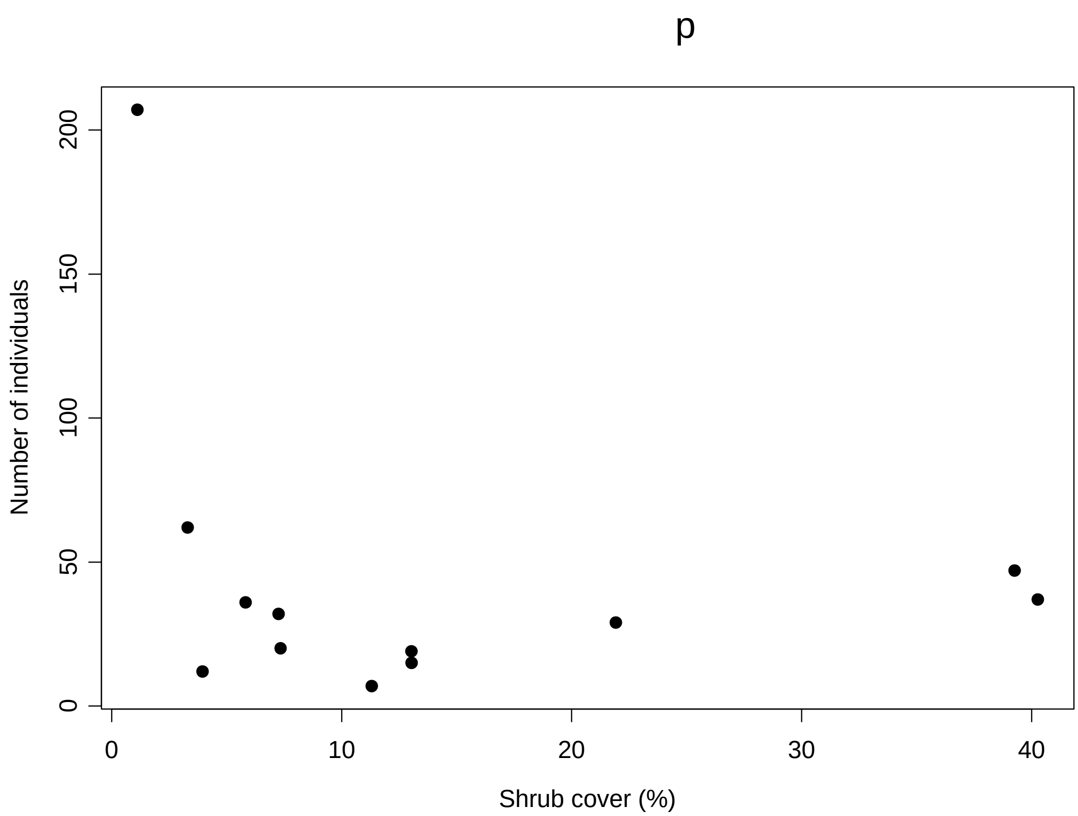


Figure 4.12 Hemipterans (bugs) are an example of a low cover specialist which was found in greatest abundance at very low woody shrub cover levels in the Ivanhoe region. Note that this response is based on the high abundance of bugs at two study sites of low woody shrub cover (particularly the lowest cover site).

4.4.5 Generalists

Taxa which exhibit a very low correlation with woody shrub cover ($-0.1 < r < 0.1$) have been termed generalists. They presumably include taxa with broad habitat requirements that can utilise a range of woody shrub covers, as well as taxa for which the presence of woody shrubs is irrelevant. For the latter species, other habitat features drive their distribution and abundance, and the presence of shrubs is of minimal significance.

All generalist taxa are indicated in Appendix 5. Individual taxa were not assessed for a non-response to woody shrub density. Guilds and taxa associations were not assessed for non-response to either woody shrub cover or density.

The most consistent generalist species was the Beaked Gecko *Rhynchoedura ornata*. More than 280 individual observations of this species were made across all 35 study sites, and a non-response result was obtained in all three survey regions, as well as across the three regions collectively. In the Wanaaring-Louth region, this generalist response was determined to be a preference for intermediate woody shrub covers when analysed in more detail (Figure 4.9). These results reflect the common occurrence of this fragile-looking terrestrial gecko in a wide diversity of arid and semi-arid habitats, either open or very scrubby (Cogger 1996). Woody shrub cover may influence occurrence of this species by the provision of shelter from aerial predators, and through microhabitat modification. Pitfall trap microhabitat analyses indicated that in the Cobar region more of these geckoes were caught in pits within clumps of woody shrubs than in open areas between clumps ($p < 0.001$), with a negative association with leaf litter near the pitfall trap ($p = 0.02$) the second predictor in the linear model (model $r^2 = 0.169$). Decreasing leaf litter was the only pitfall trap microhabitat attribute which significantly influenced abundance of this gecko species in the Ivanhoe region ($r^2 = 0.143$, $p < 0.001$).

Other consistent generalist taxa include:

- Echidna *Tachyglossus aculeatus*: generalists at Ivanhoe, Wanaaring-Louth and three-regions (not significant (n.s.) at Cobar)
- Owlet Nightjar *Aegotheles cristatus*: generalists at Ivanhoe and Wanaaring-Louth regions; (n.s. at Cobar and three-regions)
- White-winged Chough *Corcorax melanorhamphos*: generalists at Ivanhoe, Cobar and three-regions; (n.s. at Wanaaring-Louth)
- Crested Bellbird *Oreoica gutturalis*: generalists at Ivanhoe and Wanaaring-Louth regions; (n.s. at Cobar and three-regions)
- Singing Honeyeater *Lichenostomus virescens*: generalists at Ivanhoe, Wanaaring-Louth and three-regions; (n.s. at Cobar)
- Ants (Formicidae): generalists at Ivanhoe, Wanaaring-Louth and three-regions; (n.s. at Cobar)
- *Iridomyrmex*0001: generalists at Ivanhoe, Wanaaring-Louth and three-regions; (n.s. at Cobar)
- *Pheidole* sp. A: generalists at Ivanhoe and Cobar; (decreaser at Wanaaring-Louth and three-regions)
- *Pheidole* sp. F: generalists at Ivanhoe, Wanaaring-Louth and three-regions; (n.s. at Cobar)
- Shy Nightshade *Solanum cleistogamum*: generalists at Wanaaring-Louth and Cobar regions; (not present at Ivanhoe; not analysed across the three regions).

Several taxa were identified as generalists in one survey region and across the three regions collectively (Tables 4.7 and 4.8). All of these taxa exhibited non-significant relationships with woody shrub cover in the remaining two survey regions, except for the following taxa:

- Acarina (mites and ticks) which responded collectively as decreasers in the Cobar region;
- Hymenoptera (bees and wasps), which responded as an increaser in the Wanaaring-Louth region;
- Inland Thornbills *Acanthiza apicalis* which were increasers in the Cobar region; and
- *Iridomyrmex*0008 which were decreasers in the Wanaaring-Louth region.

Within each survey region additional taxa were identified as generalists solely or predominantly within that region (the term 'predominantly' denotes that generalist responses within other regions were based on a presence at one site only). These are also listed in Table 4.8, according to whether they were more or less common across the relevant region.

Table 4.7 Generalist taxa. Within each survey region, taxa that are generalists in that one region as well as across the three regions collectively, are listed. (Q) indicates taxa for which a significant quadratic model indicates preference or avoidance of intermediate shrub cover levels.

Ivanhoe	Wanaaring-Louth	Cobar
Austrostipa nitida	*Ptilotus atriplicifolius* var. *atriplicifolius*	*Rhodanthe floribunda*
Rhyncharrhena linearis	*Acanthiza apicalis*	*Paspalidium constrictum*
Pachycephala rufiventris	*Acanthiza chrysorrhoa*	Diptera
Araneae	*Meranoplus* sp. C	Hymenoptera
Coleoptera	*Pheidole* sp. G	*Iridomyrmex*0005
*Iridomyrmex*0003		*Iridomyrmex*0008 (Q)
Meranoplus sp. A		*Iridomyrmex*0009
*Rhytidoponera*0003		*Meranoplus* sp. E

These results indicate that generalist taxa comprise a mix ranging from highly mobile species and widely ranging taxa (predominantly birds) to sedentary taxa (plants).

4.4.6 Pitfall trap model results

Microhabitat attributes surrounding each pitfall trap appear to have influenced captures of both invertebrate and vertebrate taxa in each survey region. Results for those taxa that exhibited a significant response to woody shrub-related attributes in the vicinity of the traps are summarised in Appendix 8.5. These attributes include distance to the closest woody shrub, trap location in relation to shrub patches, and to shrub canopy, as well as woody shrub cover and density (measured for the study site and applied to all traps in that site, then analysed across all sites in a region).

The following taxa exhibited a similar response to shrub attributes in more than one survey region:

- the ant species *Anochetus armstrongi* decreased in abundance with increasing woody shrub cover (analysed at the pit level) in the Wanaaring-Louth region ($r^2 = 0.086$, $p = 0.001$), reflecting the decreaser response by this species at the site level (Table 4.3). These ants were also more abundant in traps located further from the closest shrub in the Cobar region ($r^2 = 0.081$, $p = 0.003$);
- the ant *Camponotus ephippium* was more abundant in traps within woody shrub patches in the Ivanhoe region ($r^2 = 0.08$, $p < 0.002$), and more abundant in traps located closer to the closest shrub in the Cobar region ($r^2 = 0.094$, $p = 0.001$);

Table 4.8 Generalist taxa. Within each survey region, taxa that are generalists predominantly in that one region, are listed. Taxa are listed according to whether they were present at few (two to four) or many (five or more, marked with *) study sites. Taxa common to all three regions which were generalists are also separated into those less common (four to 19 sites) or more common (more than 20 sites, marked with *). Generalist taxa recorded at fewer sites are documented in Appendix 5. (Q) indicates taxa for which a significant quadratic model indicates preference or avoidance of intermediate shrub cover levels.

Ivanhoe	Wanaaring-Louth	Cobar	Common Taxa
Plants	**Plants**	**Plants**	**Plants**
*Geijera parviflora**	*Dissocarpus paradoxus** (Q)	*Chenopodium melanocarpum**	*Acacia aneura*
Dodonaea viscosa ssp. *angustissima*	*Sclerolaena obliquicuspis*	*Maireana trichoptera**	*Salsola kali* var. *kali**
*Chenopodium cristatum** (Q)	*Enneapogon avenaceus**	*Eragrostis lacunaria**	*Sclerolaena diacantha**
*Enchylaena tomentosa**	*Lepidium phlebopetalum*	*Panicum effusum**	*Sclerolaena patenticuspis*
*Calandrinia pumila**	*Ptilotus gaudichaudii* var. *gaudichaudii*	*Oxalis corniculata**	*Calotis hispidula*
*Erodium crinitum**		*Pimelea trichostachya**	
Ptilotus gaudichaudii var. *parviflorus*			
Ptilotus obovatus			
Sida fibulifera			
Silene nocturna			
Tetragonia tetragonioides			
Vertebrates	**Vertebrates**	**Vertebrates**	**Vertebrates**
*Acanthiza uropygialis**	*Cracticus torquatus**	*Aprosmictus erythropterus*	*Colluricincla harmonica**
Cracticus nigrogularis	*Dromaius novaehollandiae**	*Nymphicus hollandicus*	*Merops ornatus*
*Petroica goodenovii**	*Grallina cyanoleuca**	*Melanodryas cucullata*	*Phaps chalcoptera*
Pygopus nigriceps	*Ctenotus regius**	*Phylidonyris albifrons*	*Pogona vitticeps*
Capra hircus	*Diplodactylus ciliaris*	*Poephila guttata*	
Vulpes vulpes	*Lerista muelleri*	*Pomatostomus temporalis**	
	*Lerista labialis**	*Pomatostomus ruficeps**	
	*Heteronotia binoei**	*Macropus fuliginosus*	
Invertebrates	**Invertebrates**	**Invertebrates**	**Invertebrates**
Acarina*	Mantodea*	Scolopendrida (Q)	Pseudoscorpionida*
*Camponotus nigriceps**	Invertebrate larvae*	*Camponotus* sp. nr. *aurocinctus*	Thysanura*
*Iridomyrmex*0002	*Melophorus**	*Myrmecia* sp. A	*Cerapachys* sp. A
*Iridomyrmex*0004	*Pheidole* sp. E*	*Myrmecia formosa*	*Iridomyrmex*0007
*Iridomyrmex*0010	*Rhytidoponera* sp. A*	*Paratrechina* sp. A*	*Iridomyrmex*0012
Solenopsis sp. A	*Tapinoma* sp. A*	*Pheidole* sp.*	*Rhytidoponera metallica**
Stigmacros aemula			

- ants of the species *Camponotus* sp. D were only caught in traps located under tree and shrub canopies ($r^2 = 0.256$, $p < 0.01$) in the Wanaaring-Louth region (most abundant under tree canopies), and only caught in traps located under tree canopies in the Cobar region ($r^2 = 0.193$, $p < 0.01$). Similarly, ants of the species *Crematogaster* sp. A were only caught in traps beneath shrub canopies in the Wanaaring-Louth region ($r^2 = 0.496$, $p < 0.01$), and were only caught in traps beneath tree canopies in the Cobar region ($r^2 = 0.193$, $p < 0.01$). This species also responded positively to increasing shrub cover at the site level (Table 4.4);

- Steindachner's Gecko *Diplodactylus steindachneri* were more abundant further from the closest woody shrub in the Ivanhoe region ($r^2 = 0.075$, $p = 0.004$), and decreased in abundance as woody shrub density increased in the Wanaaring-Louth region ($r^2 = 0.092$, $p < 0.01$). A decreaser response by this gecko to shrub cover was also detected at the site level in the Wanaaring-Louth region (see section 4.4.1, Steindachner's Gecko);
- Bugs (Hemiptera) increased in abundance as distance to the closest woody shrub cover increased in both the Ivanhoe region ($r^2 = 0.065$, $p = 0.005$) and the Wanaaring-Louth region ($p < 0.01$). Location of traps within woody shrub patches ($p < 0.01$) was the second attribute in the linear model in the Wanaaring-Louth region ($r^2 = 0.232$). In the Cobar region, bugs were found to decrease in abundance with increasing woody shrub cover ($r^2 = 0.121$, $p < 0.01$);
- Hymenopterans (Bees and Wasps, but not ants) were most abundant in traps located under tree or shrub canopies (most abundant under tree canopies, then canopies in general, then shrub canopies) and least abundant in traps not located under any canopy in the Wanaaring-Louth region ($p < 0.01$). A similar result was obtained in the Cobar region, with members of this invertebrate Order most abundant under canopies and least abundant in the open ($p < 0.01$). Other attributes were included in the linear models for these regions ($r^2 = 0.217$ and $r^2 = 0.215$, for Wanaaring-Louth and Cobar respectively). Increasing leaf litter cover was the most explanatory variable in the Ivanhoe region ($r^2 = 0.061$, $p = 0.008$). Hymenopterans also responded as increasers to shrub density in the Wanaaring-Louth region ($r = 0.637$, $p = 0.022$);
- the ant morphospecies *Iridomyrmex*0004 increased in abundance with increasing woody shrub cover in both the Wanaaring-Louth region ($r^2 = 0.096$, $p = 0.001$) and Cobar regions ($r^2 = 0.076$, $p = 0.004$). *Iridomyrmex*0004 (and three other *Iridomyrmex* morphospecies) also increased with shrub cover when analysed at the site scale in the Cobar region, (see section 4.4.2, Increaser ant genera). Ants of the morphospecies *Iridomyrmex*0013 were found to be more abundant in traps located in woody shrub patches in the Wanaaring-Louth region ($r^2 = 0.06$, $p = 0.007$). When woody shrub cover was included in the analysis, it was found to be the most explanatory variable for this morphospecies in this region ($r^2 = 0.177$, p < 0.01);
- in the Wanaaring-Louth region, ants of the species *Pheidole* sp. H were found to be most abundant in traps under shrub canopies ($r^2 = 0.199$, $p < 0.001$). In the Cobar region, increasing woody shrub cover was the only significant attribute in the linear model for this species ($r^2 = 0.085$, $p = 0.002$). *Pheidole* sp.. H also responded positively to increasing shrub cover at the site scale in these two regions (see section 4.4.2, *Pheidole* sp. H);
- *Rhytidoponera*0001 were most abundant in traps located in open areas between woody shrub patches in the Cobar region ($r^2 = 0.075$, $p = 0.004$). When woody shrub cover was included in this analysis, this morphospecies was found to decline in abundance as shrub

cover increased in this region (r^2 = 0.111, $p < 0.01$). A similar negative response to shrub cover was obtained at the site level in the Cobar region (r = -0.687, p = 0.014).

In some cases, contradictory results were obtained in different regions for some taxa. For example, mites (Acarina) were more abundant in traps within woody shrub patches in the Wanaaring-Louth region (r^2 = 0.210, $p < 0.01$), but decreased in abundance with increasing woody shrub cover in the Cobar region (r^2 = 0.18, $p < 0.01$). The negative response was also detected at the site level in the Cobar region (r = -0.627, p = 0.031)). Similarly, Book Lice (Psocoptera) were most abundant in traps located within woody shrub patches in the Wanaaring-Louth region (r^2 = 0.077, p = 0.002), but were most abundant at distance from the closest woody shrub in the Cobar region. In the Ivanhoe region this Order of invertebrates responded most to increasing leaf litter abundance near the pitfall trap (r^2 = 0.073, p = 0.004).

Many other fauna taxa responded significantly to other (non-shrub related) microhabitat attributes including groundcover plant abundance, and distance to the closest tree or log. Some taxa also responded to attributes that are influenced by the presence of woody shrubs, such as leaf litter cover. For some taxa, such microhabitat factors are likely to have had a greater influence on their relative abundance than woody shrub cover across the study sites and may provide useful ecological information regarding their habitat requirements.

4.4.7 Exotic species

Although not designed to investigate this issue, some limited information on the relative abundance of pest species in areas of different woody shrub cover can be obtained from this study. Feral Goats, European Rabbits and European Foxes were the most abundant exotic vertebrate species observed. Other exotic species observed or trapped in low numbers were Feral Cats, Pigs, House Mice and European Hares. Several introduced plant species were also recorded on the study sites, with Yellow Wood-sorrel *Oxalis corniculata* and Arabian Grass *Schismus barbatus* present in all three regions. Only one introduced species, Hairy-pod Cress *Harmsiodoxa blennodioides*, showed any significant relationship with woody shrub density – as a decreaser in the Wanaaring-Louth region (r = -0.552, p = 0.031).

These results indicate that although various pest species make use of woody shrub-encroached areas), most do not exhibit any particular response to woody shrub cover (Appendix 5). An investigation of this nature is not appropriate for assessing the use of habitats by larger, more mobile species, many of which are likely to modify their behaviour in response to human presence.

4.5 Conclusions

4.5.1 Flora and fauna diversity

Between 90 and 161 taxa were recorded per study site. Within each broad taxonomic group the total number of taxa recorded per region, and the average recorded per site increased with the progressing season. Conditions were still cold during the Ivanhoe survey in late October 1999. By late November temperatures in the Wanaaring-Louth region were considerably warmer and fauna activity levels were greater, however few young plants were present due to the below average conditions leading up to this survey. The Cobar survey in late January 2000 followed a period of above average conditions and coincided with an extensive period of sustained plant germination and growth, and recruitment of juvenile animals into the population. Hot temperatures and localised rain during this survey period maintained high activity levels.

Vertebrate fauna surveys of 122 sites conducted in a diversity of environments across western NSW over recent years have recorded between 9 and 67 vertebrate species per site during periods ranging from four consecutive days to approximately 24 days over two seasons. On average these surveys have recorded approximately 32 species per site (standard deviation = 14.24, Murray Ellis pers. comm.). The three surveys comprising this investigation each lasted 12 days (a mid-range effort in comparison with previous surveys), and recorded on average 31, 32 and 36 vertebrate fauna species per site (very close to this long-term average). It therefore appears that the vertebrate fauna diversity found at each 'woody weed' study site was comparable to those of other vegetation types, a result not anticipated for vegetation often thought to provide little habitat for native species.

A high proportion of taxa was recorded at a small number of study sites in each survey region. This proportion was greatest in the Ivanhoe region, where almost 30% of all taxa occurred on no more than one site. This is a common result for faunal sampling studies (Krebs 1985) and was anticipated for this investigation (Hassall and Associates 1999). Locally widespread taxa (present on multiple sites within a single region) and regionally widespread taxa (present within two or three survey regions) were detected in each region. A total of 50 vertebrate species, 30 flora taxa, 20 invertebrate 'Orders' and 45 ant taxa were recorded in all three regions.

4.5.2 Nature and magnitude of biodiversity change

Encroachment and proliferation of unpalatable woody shrubs in western NSW has undoubtedly influenced the abundance of many native species. Sites of differing shrub cover differed in composition of the flora and fauna taxa present, but not in the number of taxa present. Total richness did not vary significantly between areas of differing shrub cover within any of the survey regions, nor across the three regions collectively, and in most instances this was also true for each broad taxonomic group. Four possible relationships between richness and shrub cover could have been anticipated:

- a greater diversity in areas of low shrub cover, *or*

- in areas of high shrub cover, *or*
- in areas of intermediate shrub cover, *or*
- an even spread (the actual result).

The observed lack of response was not expected, despite the nature of richness analyses, which merge responses by individual taxa differing greatly in size, mobility and their ability to utilise available habitats. At a landscape scale, and excluding the influence of other factors such as water and nutrient availability, greatest richness would be expected in areas of maximum environmental complexity, i.e. at moderate woody shrub cover levels, where other structural components of the vegetation (trees, chenopods, perennial and annual grasses and forbs) are also present (Hassall and Associates 1999). A close proximity to other vegetation types, such as woodlands and grasslands, could increase this diversity, however proximity of sites to other vegetation types was not analysed.

Relatively few taxa responded significantly to woody shrub cover or density in each region. This is particularly true in the Ivanhoe region (approximately 90.5% of taxa exhibited no significant response to shrub cover or density), where the proportion of uncommon taxa recorded at only one site was highest, and survey conditions coolest. The relatively low number of study sites may also have made detection of some significant responses more difficult. However, it was in the Cobar region, where only 11 sites were sampled, that the greatest proportion of significant responses was recorded (75.3% of taxa analysed did not respond to shrub cover or density). Woody shrub cover or density explained more of the variation in abundance than any other habitat or disturbance attribute for even fewer taxa: only 3% of taxa in the Ivanhoe region, 10.5% in the Wanaaring-Louth region, 6.1% in the Cobar region and 9.5% of taxa common to all three regions. In addition to the more common increaser and decreaser relationships with shrub cover levels, response types by individual taxa included non-linear responses, such as an apparent preference for or avoidance of extreme or intermediate levels of shrub cover. Such response rates were particularly low, with 4.1% of taxa in the Ivanhoe region, 3.3% in the Wanaaring-Louth region and 5.4% in the Cobar region showing significant non-linear responses to shrub cover. Furthermore, many of these significant results were based on low abundances across the study sites. In comparison, many taxa which exhibited a very low correlation with shrub cover were quite common and well distributed across sites within the relevant survey region. This ‘generalist’ response to shrub cover was demonstrated by 15.2% of taxa in the Ivanhoe region, compared with 11.9% and 9.7% in the Wanaaring-Louth and Cobar regions respectively.

A common perception is that high woody shrub cover is detrimental to plant species palatable to stock. A few taxa, including the highly palatable Button Grass *Dactyloctenium radulans* and palatable Serrated Goodenia *Goodenia cycloptera* in the Wanaaring-Louth region, followed the expected trend. However, examples were also found of highly palatable taxa, such as Mulga Mitchell Grass *Thyridolepis mitchelliana* (Wanaaring-Louth region), and palatable species, such as Arabian Grass *Schismus barbatus* (Cobar region), which exhibited an increaser response to shrub cover. No palatable taxa responded consistently across survey regions. In fact, some edible taxa had contradictory responses across the regions, including the highly palatable Common Bottlewashers *Enneapogon avenaceus* and the less palatable Curly Windmill Grass *Enteropogon acicularis.* The low number of significant results is thought to reflect in part the low abundances of many plant taxa across the sites (as also seen for vertebrates and invertebrate taxa), but the conflicting results obtained show that generalities and perceptions need to be tested before being accepted.

Significant responses to shrub cover or proximity were detected at a finer (pitfall trap) scale for many faunal taxa, particularly ants and some invertebrate ‘Orders’. For some taxa, these results appear to reflect their broader-scale (site-level) responses to shrub cover, and allow for greater confidence that biological, rather than purely statistical, responses have been detected. As with the site-level analyses, examples were found of taxa which responded similarly in multiple regions, and others for which opposing responses were detected in different regions. Such results may reflect differing physical attributes of each region, such as soil type and structure.

4.5.3 Underlying causes

Survey regions, land units and study sites were selected in this investigation on the basis that they supported a diversity of woody shrub covers. Numerous other criteria influenced the selections, and aimed to reduce the variability between sites within each region. Despite this, sites varied in many ways that may have influenced the observed differences in abundance of taxa and guilds, necessitating the consideration of these potentially confounding factors when investigating responses to shrub cover. Results of the multivariate analyses confirm the influential role of other factors, at both the between-site and within-site scale. Some results reflect current ecological knowledge of certain taxa, whilst a small number are rather spurious and will necessitate the refinement of analyses to more relevant attributes. However, only those models that incorporate woody shrub cover or density have been included in this report.

Relationships between taxa, guilds or associations of taxa and woody shrubs were demonstrated directly by significant responses to woody shrub cover or density, and indirectly by significant responses to attributes which were themselves altered by the presence of shrubs. In the case of plants, a direct response is likely to be driven by competition with shrubs for water, nutrients or light. Such competition may explain the observed abundance declines shown by some individual plant taxa, annual taxa (Drought Avoiders), and Ground cover and understorey plant taxa, with increasing shrub cover in both the Wanaaring-Louth and Cobar regions. Obvious examples of faunal taxa which utilise shrubs and responded directly to shrub presence are Splendid Wrens *Malurus splendens* in the Wanaaring-Louth Region, and both Inland Thornbills *Acanthiza apicalis* and Yellow Thornbills *A. nana* in the Cobar region. Shrubs add to the structural complexity of vegetation, and provide a diversity of shelter, feeding, breeding and other microhabitats. Thus it is likely that the use of woody shrub encroached areas by many taxa may be unrelated to the shrub species present. Taxa which avoid open areas, and equally those which prefer open habitats, could be expected to respond to the presence of any shrub species in the landscape. Conversely, only a subset of shrub species or genera may be able to provide resources utilised by particular species. For example, seeds produced by the six designated 'woody weed' species vary considerably in morphology, which will affect what faunal species can utilise them.

Woody shrubs are quite large, deep-rooted and long-lived perennial species and as such can modify local environmental attributes over time, which in turn influence the presence and abundance of other taxa. For example, perennial plant cover reduces wind speed, increases shade (subsequently modifying the microclimate above and below the ground surface), may increase soil micro-flora and fauna activity, maintains nutrient levels (especially organic carbon), enhances soil stability, and improves microporosity (Harrington 1986, Tongway 1990, Tongway and Ludwig 1990). These and other modifications are known to be true for woody shrub species, and consequently may be expected to influence habitat quality, suitability and use by certain taxa, particularly plants (see details in section 5.4) and soil surface or leaf litter inhabiting invertebrates and vertebrates. In the Cobar region for example, the abundance of leaf litter and small logs (fallen shrub branches) were highly correlated with shrub cover and/or density. Mueller's Skink *Lerista muelleri*, blind snakes *Ramphotyphlops* spp. and several ant taxa responded more to these attributes than any other physical or disturbance features in this region. Indirect responses to shrub cover are also likely to be evident at the pitfall trap scale for some faunal species. The relative exposure of each pitfall trap and the leaf litter cover near each trap are two attributes influenced by shrub cover, both of which were found to be significant in multivariate models for particular terrestrial faunal taxa.

Some indirect responses by taxa to woody shrubs can be very difficult to confirm. The more links in the chain of responses from shrubs to environmental attributes to the taxa being assessed, the greater the degree of difficulty. For example, the observed decline in groundcover grasses, forbs and herbs with increased shrub cover in both the Wanaaring-Louth and Cobar regions may have been an indirect trigger for faunal response to woody shrubs. In all three regions the abundance of ground-feeding granivorous birds also declined within increasing shrub cover, potentially reflecting a decreased abundance of seed-producing grass and forb species consumed by the pigeons, parrots, finches and other species comprising this guild. These relationships require greater investigation, including more detailed assessments of the known diet of each bird species within this guild, the abundance of relevant seed-producing plant taxa during the survey periods, and an assessment of the assumption that grazing intensity was similar between sites within each survey region. This last issue is important because of previously identified relationships of grazing intensity to perennial grass biomass and survival, including the observation by Harrington (1986) that growth rates of perennial grasses recovering from overgrazing can be severely depressed by heavy grazing. Prior to this, Dawson and Boyland (1974, cited in Harrington 1986) had demonstrated that the principal cause of loss of perennial grass is the maintenance of high stocking rates through seasons of low rainfall. More recently, Robson (1995) found that grazing had a greater influence than woody shrub regrowth on pasture biomass following blade-plough treatment. Thus, if different grazing intensities occurred across the study sites within each region, this may have driven the response detected in grasses, rather than it being driven by woody shrubs.

Responses to shrub cover varied between regions for many faunal and floral taxa, indicating the interactive nature of environmental and habitat parameters. In the open Belah *Casuarina pauper* woodlands of the Ivanhoe region, Red-capped Robins *Petroica goodenovii* behaved as generalists with respect to shrub cover. A very different result was observed across the Wanaaring-Louth sites, where no more than a few scattered trees were present on or near most sites. In this region, these robins increased in abundance more with shrub cover than any other factor. Results for this region reflect observations in the sheep/wheat belt of NSW that Red-capped Robins prefer structurally complex vegetation where a healthy shrub understorey is present (Major *et al.* 1998; Sue Briggs, pers. comm.). Other woodland bird species, including Rufous Whistlers *Pachycephala rufiventris*, Chestnut-rumped Thornbills *Acanthiza uropygialis* and Singing Honeyeaters *Lichenostomus virescens*, also behaved as generalists in the Ivanhoe region but not elsewhere. The results for these woodland bird species in the Ivanhoe region may reflect the nature of Belah trees, which have many low branches on which birds can perch. Such branches may replicate some of the structural attributes of a shrubby understorey, thereby reducing the importance of shrubs in providing this structure, and rendering shrub cover less relevant for taxa such as small woodland birds.

Numerous factors not affected by woody shrub cover influence flora and fauna species to varying degrees. Most of the site and pitfall trap attributes were included in linear models for various taxa, guilds and taxa associations. Many of these results do not obviously relate to woody shrub cover or density and therefore are not included in this report. However, some may provide important ecological information for poorly known taxa regarding habitat requirements and disturbance impacts, thereby contributing to the growing body of knowledge regarding floral and faunal taxa. For example, responses to the distance of sites from water accessible by stock can be compared and contrasted to results obtained by Landsberg *et al.* (1997) in a recent investigation of the effects of artificial water points on a broad diversity of flora, vertebrate and invertebrate taxa within rangeland Australia.

Between 75.3 and 90.5% of faunal and floral taxa recorded in each region did not respond significantly to shrub cover or density. However, non-response does not indicate non-use and many of these taxa are known or are likely to actively use habitats provided by shrubs and/or shrubby areas, in conjunction with other habitats available to them. For others, the use of shrubby areas may occur in spite of the presence of shrubs, and as such may continue as long as the relevant critical habitat attributes remain available for each individual taxon. For more mobile taxa, the proximity, diversity, quality and configuration of suitable habitats are likely to influence their presence or absence at any particular site (Henle *et al.* 1996). Taxa which range less widely are more likely to be influenced by the presence, abundance and quality of microhabitat attributes.

For many taxa considered in this investigation, particularly ants and plants, detailed biological and ecological information is lacking, rendering it difficult to interpret some of the responses (and non-responses) to shrub cover. For others, such as invertebrate 'Orders', meaningful interpretation is hampered by the broad taxonomic level under consideration. A potential explanation could be suggested from published ecological studies for only a small proportion of taxa. For some taxa, a more detailed exploration of available literature will be required before the results obtained to date may be understood and utilised with confidence.

4.5.4 Future research

Analysis of the data collected in the course of this study has focused to date on responses to woody shrubs by individual taxa, or groups of taxa exhibiting similar ecological requirements. A small number of similar analyses have also been conducted on associations of taxa identified through PATN analyses. However, more detailed analysis is required for the identification of assemblages or communities of taxa which responded similarly to shrub cover or density. Ordination analyses are appropriate for the identification of such assemblages.

Refinement of analyses conducted to date may allow greater clarification of individual responses (or non-responses) to shrub cover. Of greatest priority are analyses that focus on the most relevant and appropriate physical and disturbance variables for individual taxa, guilds and associations of taxa. Additional clarification may be possible through the inclusion of woody shrub attributes (species composition and richness, height and canopy openness) in analyses for some taxa or guilds. The identification of generalist responses to shrub cover by guilds and taxa associations will complement generalist results obtained to date, as will the determination of generalist responses to shrub density by both these groups and individual taxa. Capture rates for some abundant invertebrate taxa may also allow for non-responses to be detected at the pitfall trap scale, however pitfall trap microhabitat attributes will first need to be assessed as to their degree of correlation with woody shrub cover. In conducting the above guild analyses, some groups not analysed to date may be included. Of particular importance are groups of groundcover and understorey plants categorised according to their palatability to stock.

Additional insights into the effects of woody shrubs on biodiversity may be obtained through the re-interpretation of existing studies. Examples include those listed in the literature review conducted at the commencement of this investigation (Hassall and Associates 1999), and unpublished data sets brought to the attention of the authors during the course of the investigation (e.g. David Eldridge, pers. comm.).

Despite the diversity of landforms, soil and vegetation types, and shrub species considered in the course of this study, distinctly different regions of the Western Division are also affected by shrub encroachment and proliferation. Outcomes of the present survey would consequently be greatly enhanced by investigations in additional regions. However, follow-up assessments of the original sites during different seasons and seasonal conditions would be of arguably greater benefit. Faunal investigations previously conducted in western NSW have highlighted the importance of repeat surveys of study sites in obtaining more complete assessments of taxa present and identifying those taxa which utilise study sites frequently (e.g. Smith *et al.* 1998, Mazzer *et al.* 1998, see also Ayers *et al.* 2001). In undertaking repeat assessments of the present sites, surveys could be timed to coincided with specific events in the lifecycle of particular shrub species (e.g. flowering of nectar-producing species), which would have the added benefit of increasing the likelihood of detecting plants which germinate, flower or fruit outside of those seasons studied to date.

In the absence of additional data regarding the effects of woody shrubs on biodiversity, the application of general ecological principals in conjunction with available information regarding habitats and species present in particular regions will continue to supplement information available from the present investigation. Similarly, insights into the potential impacts of shrub control techniques on particular flora and fauna taxa or groups may be gained from further interpretation of the present results regarding responses to shrub cover and density, as well as responses by taxa to other physical or disturbance attributes. For example, taxa that responded to the amount of leaf litter present may be impacted by the use of fire to reduce shrub densities. Equally, existing information regarding known ecological requirement of particular taxa can be used to identify those species that may be heavily impacted by particular management strategies. However, such information is lacking for most invertebrate taxa, and there are many vertebrates and plant species which remain poorly understood. To maximise returns from limited research funds, attention must be focused where the maximum benefits are obtained, and this is likely to be in the area of determining the effects of shrub control practices on biodiversity. In the process, our understanding of individual taxa is also likely to be greatly increased.

5. Landscape function results and discussion

5.1 Overview of the regions

In the sections below, the terms 'obstructions', patches, resource sources and sinks are frequently used. Definitions of these terms, and explanations of their importance to landscape function, are provided in section 2.1.6.

5.1.1 Ivanhoe

Most obstructions to overland water flow in the Ivanhoe region were log piles with associated accumulations of soil and organic material, leaf litter trains formed as a result of water flow or ponding, or patch types functioning as resource sinks (Figure 5.1, Appendix 9.1). The logs were mostly from Belah *Casuarina pauper* or other trees (e.g. Mulga *Acacia aneura*) and were present on all sites. All sites varied in their Belah cover and log distribution, thus the location of obstructions along the transects varied considerably depending on where the transects ran with respect to this cover. Leaf litter accumulations were often caught amongst *Sclerolaena* plants. Patches which acted as resource sinks were predominantly those dominated by a relatively dense canopy of Wilga *Geijera parviflora* or Western Rosewood *Alectryon oleifolius*, dense Belah clumps, or combinations of these, together with some woody shrubs and small chenopods such as *Sclerolaena* or Cannonball *Dissocarpus paradoxus* (Appendix 9.3). Soil surfaces within these treed patches were quite variable, particularly with respect to the presence of leaf litter cover. Litter accumulations in turn prevented the formation of protective physical crusts, consequently some soil samples in these patch types slaked rapidly when tested for crust cohesion. The growth of biological cryptogamic crusts was also reduced by higher litter loads, and therefore tended to be patchy. Despite the absence of continuous protective crusts and an often minimal cover of low perennial plants, little erosion or reworking of sediments was evident, indicating that the soils in these patches were sheltered by the litter layers, overstorey and low-hanging Belah branches (Table 5.1).

Woody shrub-dominated patches (Turpentine Patches) displaying soil surface features different to other patch types were identified on only three sites. These were usually where the woody shrub cover was particularly high, although Belah trees and other plant species (e.g. *Sclerolaena*) were also occasionally present (Figure 5.2). Some of these patches were very small, restricted to the immediate vicinity of the shrubs, (such as those on site 9), and therefore contributed relatively little to the weighted soil surface condition (SSC) site index scores (Appendix 9.2). Most showed little evidence of sediment accumulations, and all were identified as resource source areas (Table 5.1).

Most other resource source patch types in the Ivanhoe region sites were characterised by an intact soil crust and good cryptogamic cover, both of which imply minimal trampling by stock. Some had an open Belah canopy and scattered woody shrubs, which offered little protection from rainsplash to the soils (Figure 5.3, Table 5.1). Despite average (and

Figure 5.1 Resource sink dominated by Wilga tree and logs. Perennial understorey plant cover was generally low in such patches. A small litter train can be seen in the foreground, on a resource patch largely devoid of vegetation.

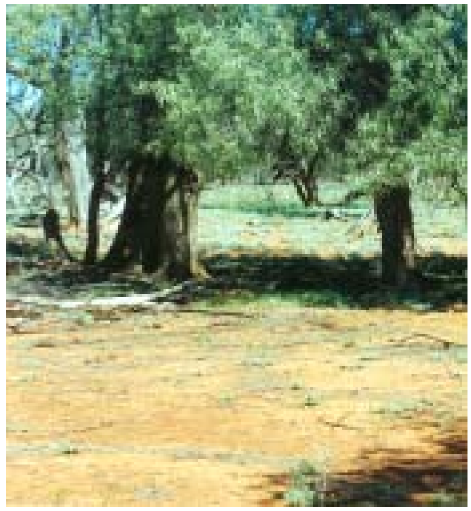


Figure 5.2 Woody shrub dominated patches tended to resemble other resource source areas despite minor differences in leaf litter and cryptogamic crust cover. Little sediment accumulation was detected beneath these shrubs. Sheep trails (foreground, right photo) represented the least intact crusts in most sites, however few showed signs of active erosion.

Figure 5.3 Resource source patch types were identified in open areas as well as under the open Belah canopy. These are both 'bare' patch types, featuring very sparse perennial plant cover. Note the very low slope, minimal erosion and deposition of sediments. A surface obstruction (log) is visible in the background (right photo). A 'low veg' resource source patch is depicted in centre of the upper photo in Figure 3.2.

improving) seasonal conditions experienced prior to the surveys (section 3.2.1), groundcover vegetation was not dense on any of the Ivanhoe sites. Source patch types not dominated by woody shrubs were broadly categorised according to the amount of low (ground cover and understorey) vegetation present, as either “Bare” patch types or “Low veg” patch types (Appendix 9.3). *Sclerolaena*, Canonball and medic were the principal understorey plants present in these patches.

Characteristics of those soil surface features which differentiate the main patch categories are listed in Table 5.1. In general there is a trend of increasing litter cover and degree of incorporation into the soil, decreasing cryptogamic cover and increasing microtopography from bare to vegetated resource source areas, to those which function as resource sinks. Most patches showed little evidence of erosion, and on only one site was a patch of loose deposited sediments identified (site 1), hence these attributes are excluded from Table 5.1. Soil cohesion varied from stable to unstable in all patch categories and thus is also excluded from Table 5.1. This overlap is thought to reflect three broad observations:

- many patch types exhibited a moderate stability on many sites;
- the least stable soils included those from scalds, as well as loose friable soils beneath litter piles (see above);
- crust cohesion varied less between patch types on some sites than others (for example, all patch types on Site 1 exhibited stable crusts).

Table 5.1 Soil surface features of the main patch categories identified on the Ivanhoe study sites. Patch categories are characterised by dominant vegetation and functional status as either resource source or sink. Patch types included within each category are indicated in Appendix 9.3. Patch types excluded from this comparison are tree-dominated resource source patches on site (site 10). Objectives of the features are explained in Table 2.2.

Feature	**Treed resource sink patch types**	**Woody shrub source patches**	**‘Low veg’ source patch types**	**‘Bare’ source patch types**
soil cover (predominantly low perennial plants)	low to moderate (2-15%)	low (2-5%)	low to moderate (2-15%)	usually low (2-5%)
litter (cover & incorporation)	usually moderate – good cover with some decay	variable cover; some decay	low (to moderate) cover; minimal decay	low to moderate cover; minimal decay
cryptogam cover	patchy or absent	low to moderate	variable cover, mostly high	usually high (absent from sandy patches)
soil microtopography	slight to moderate (3-15mm)	slight to moderate (3-15mm)	slight (3-8mm)	slight (3-8mm)
soil crust broken-ness	thin and fragile on loose friable soils; hard and intact elsewhere	quite hard and continuous	quite hard and continuous	quite hard and continuous

5.1.2 Wanaaring-Louth

Most obstructions to overland water flow in the Wanaaring-Louth region were logs and other debris, hummocks of soil that form under shrubs or trees, or patches functioning as resource sinks (Figure 5.4, Appendix 9.1). The principal patch types which showed evidence of resource accumulation were associated with Western Rosewood *Alectryon oleifolius* or Gidgee *Acacia cambagei* trees, or dense clumps of woody shrubs (Appendix 9.4). Soil surface features in these patch types were quite variable (Table 5.2). Resource sinks dominated by trees were usually characterised by loose friable soils which appeared relatively rich organically.

Distinct woody shrub patches were identified on nine of the 12 study sites, and functioned as resource sinks on five of these sites (Figure 5.5, Appendix 9.4). These shrub-dominated patches predominantly occurred where the shrub cover was particularly high, and were termed 'Woody Weed' Patches, Turpentine Patches, Hopbush Patches or Open Turpentine Patches to reflect species composition or density. Where mounds of accumulated soils occurred beneath woody shrubs, these patches were identified as Hummocks, and soil surface features were assessed separately (Figure 5.6, Table 5.2). On many sites woody shrubs were also present in patch types dominated by other features, including both resource source and sink areas. Where their presence made no obvious impact to the soil surface features, separate patches were not distinguished. Attributes of woody shrub source and sink patches are listed separately in Table 5.2.

Soil erosion was a common feature in the Wanaaring-Louth region, with evidence of sheet erosion on most sites, and scalds, pedestals and terracettes on some sites (Figure 5.7). Quite severe gullying associated with vehicle tracks was observed close to one site, and a large slumped area was located on another site. Sediment deposition was also a common feature in many areas, particularly as thin accumulations of sand, presumably aeolian in origin. Together these attributes made differentiation between some patch types difficult, and explain the diverse status of many soil surface features within individual patch categories, as well as the high degree of overlap between categories (Table 5.2). The differential effects of fluvial and aeolian processes on soil surfaces within the landscape also made it difficult to determine the functional status of particular patch types. For example, Woollybutt tussocks and the areas of bare exposed soil which separate them were readily identified as sources of sediments, based on the observation that the tussocks frequently showed signs of pedestalling, and sheet erosion was common between these tussocks. However, accumulation of sediments within individual tussocks from the same process as occurs beneath shrubs and trees (hummocking) was also evident, and the tussocks also appeared to form small obstructions to overland water flow. Similarly, the domed hummocks which form beneath shrubs or trees due to the trapping and accumulation of airborne sediments (and may therefore be classed as resource sinks), also function as run-off areas from which water and other resources flow to other areas. Furthermore, many hummocks had intact soil crusts with relatively small amounts of loose (recent) sediment deposits. Each of these patch types was classed as a resource source area, based on a visual assessment that fluvial processes were dominant amongst those currently affecting the soil surfaces. These decisions are supported by those of Tongway and Ludwig (1996) that surface water flow is the principal means of

Figure 5.4 Resource sink beneath a clump of Rosewood trees. Soil crusts in such patches tended to be physically fragile, making soil cohesion difficult to assess. Minor re-working of sediments was evident within many resource sink patches.

Figure 5.5 Woody shrub dominated resource sinks frequently exhibited a high leaf litter cover and many fallen shrub branches. 'Bare' resource source patches are evident in between these patches. See also Figure 3.3.

Figure 5.6 The hummock beneath this large Turpentine shrub is more than 30 cm higher than the surrounding soil surface (some were even larger). Although formed by the accumulation and accretion of airborne sediments, few included deposits of loose sediments. Soil crusts often resembled those of other resource source patches. A 'low veg' resource patch with sparse Woollybutt tussocks is evident in the foreground. These patches frequently showed evidence of erosion, interspersed with light sandy deposits.

Figure 5.7 Sheet erosion was common in many resource source patch types, resulting in hard, physically crusted surfaces. However, thin deposits frequently occurred over these surfaces (right photo).

resource transfer in similar semiarid landscapes of south-eastern Australia.

Distinctions between patches functioning as resource source areas were made predominantly on the basis of their location relative to other patch types, differences in the amount of low (ground cover and understorey) vegetation, the degree of soil surface crusting and in the amount of loose sediments present (Figure 5.8, Appendix 9.4). Despite being classified as resource source areas, many such patches featured accumulations of eroded sediments due to the differing influences of aeolian and fluvial processes, as well as the measurement scale utilised in the LFA procedure (small patches <1m in size, such as individual Woollybutt tussocks, are not sampled separately and were therefore lumped within broader patch types). Biological soil crust organisms cannot grow on loose sediments and were therefore absent from many such patch types. Cryptogamic crusts were well developed on some harder crusted soils. Patches with the poorest soil surface condition tended to have few obstructions and hard, flat ground, resulting in poor capture of leaf litter material, and very poor soil cohesion. Many exhibited active erosion, minimal cryptogamic cover and breaks in the soil crust. Pedestalling was common around individual plants, particularly Woollybutt tussocks, despite their sizeable root zone. Some patches where water tended to pond were characterised by a flaky soil crust. In general these soil surface features indicate that many soils in this region were degraded, and many patch types ‘leaked’ resources.

The below average seasonal conditions experienced in this region during the six months preceding the Wanaaring-Louth survey rendered the late November 1999 period inappropriate for assessing the full potential for groundcover growth in this landscape. However, ground cover did vary between patch types, enabling them to be broadly categorised as either “Bare” patch types or “Low veg” patch types (Appendix 9.4). For example, “Low veg” patches include areas of bare crusted soils, deposits of loose sediments, shallow ponding areas and scalds. Crusted refers predominantly to the presence of physical soil crusts, although biological crusts may also be present.

Characteristics of those soil surface features which differentiate the main patch categories are listed in Table 5.2. In general there are trends of increasing litter cover and degree of incorporation into the soil, and increasing microtopography from bare to vegetated resource source areas, to those which function as resource sinks. As seen in the Ivanhoe region, no clear trend in the amount of soil cover was evident, perhaps reflecting the below average seasonal conditions in this region. Although evident in all patch categories, erosion tended to be minor in resource sinks and relatively greater in source areas. Deposition was evident in all patch categories due to the action of both fluvial and aeolian processes, even in resource source areas. The common presence of deposited sediments accounts for the variability in presence of cryptogamic cover within many patch categories. Although soil microtopography was predominantly slight (<8mm) across most patch types, the greatest measures were recorded in treed resource sinks, and the smallest in scalds and other bare source areas. Soil cohesion varied considerably in all patch categories, and most patch types exhibited either unstable or moderately stable soil crusts. Very unstable soils were only detected in bare source areas. Some friable soils beneath litter piles could not be tested. Relatively few soils were found to be very

Table 5.2 Soil surface features of the main patch categories identified in the Wanaaring-Louth study sites. Patch categories are characterised by dominant vegetation and functional status as either resource source or sink. Patch types included within each category are indicated in Appendix 9.4. Patch types excluded from this comparison are a single treed resource source patch beneath long-dead Belah trees (site 23). Objectives of the features are explained in Table 2.2.

Feature	Treed resource sink patch types	Woody shrub resource sink patch types	Woody shrub source patch types	Hummocks	'Low veg' source patch types	'Bare' source patch types
soil cover (predominantly low perennial plants)	low (to moderate) cover (2-15%)	low to moderate cover (2-15%)	low (2-5%)	low (to moderate) cover (2-15%)	variable cover (low to high) (2-50%)	low (2-5%)
litter (cover & incorporation)	moderate cover (range: low to high); decay often evident	moderate cover; some decay; (some high with considerable decay	low to moderate cover; some decay	low to moderate cover; some decay	low cover; some decay	low cover; minimal decay
cryptogam cover	absent	variable (absent, patchy, to high)	moderate to high	variable (patchy to high)	variable (absent, patchy, to high)	variable (absent, patchy, to high)
erosion and deposition	some reworking evident; thin sediment veneer	some erosion; deposition uncommon	some erosion and deposition	some reworking; thin sediment veneer	erosion common; deposition often evident	both often evident
soil microtopography	slight to high (3-25mm)	slight to moderate (3-15mm)	slight (3-8mm)	slight to moderate (3-15mm)	slight (3-8mm)	nil to moderate (0-15mm)
soil crust broken-ness	thin and fragile, or non-existent on loose friable soils	quite hard and continuous	quite hard and continuous	quite hard and intact	hard beneath loose sediments	hard beneath loose sediments
soil cohesion when wet (slake test)	predominantly moderate (range: stable to unstable)	moderate to unstable	stable to unstable	predominantly moderate (range: stable to unstable)	stable to unstable	moderate to very unstable

stable, however the proportion was greatest in treed resource sinks and intermediate in woody shrub, hummock and ‘low veg’ source patch types. No bare source areas exhibited stable or very stable crusts.

5.1.3 Cobar

Most obstructions to overland water flow in the Cobar region were areas of mounded soils, logs and other debris, or patches functioning as resource sinks (Appendix 9.1). Patches which functioned as resource sinks were often associated with trees (e.g. Yarran *Acacia homalophylla*, Wilga *Geijera parviflora*, Hooked Needlewood *Hakea tephrosperma*, Red Box *Eucalyptus intertexta*, Bimble Box *Eucalyptus populnea* and Western Rosewood *Alectryon oleifolius*), dense woody shrubs, or grassy patches in the open grassland sites (Figure 5.8, Appendix 9.5). However, not all patch types associated with trees, shrubs or grass functioned as areas of resource accumulation. Soil surface features varied considerably both within and between patch types (Table 5.3), with those dominated by trees usually characterised by organically rich soils with a loose, friable texture.

Woody shrub-dominated patches where the soil surface features differed from other patches were identified on eight of the 11 sites (Table 5.3). These were usually where the woody shrub cover was particularly high, and were termed ‘Woody Weed’ Patches, Dense ‘Woody Weed’ Patches, Open ‘Woody Weed’ Patches or Hopbush Patches, to reflect species and density differences. All functioned as resource sinks, except one patch type with more open shrub cover (site 27). Where the presence of woody shrubs made no obvious impact to the soil surface features, separate patches were not distinguished. Small accretionary mounds were associated with woody shrub patches (as well as logs and a patch associated with a dead Mulga tree) on several sites. Although much smaller than the hummocks observed in the Wanaaring-Louth region, these 1-2 cm high mounds appear typical of such soil accumulations in terms of greater resource availability and groundcover growth under suitable conditions (Ludwig and Tongway 1995, Ludwig *et al*. 1997). Above average seasonal conditions experienced during the six months preceding the Cobar region survey allowed for good groundcover growth in this region. These mounds were frequently observed to support a higher density of groundcover plant species than nearby run-off patches, and were often dominated by *Austrostipa*, other grasses and *Calotis* species (Figure 5.9).

Resource source areas included hard crusted patches with variable amounts of low perennial plant cover, open grassy patches, areas of bare loose sediment and scalds. Soil surface features consequently varied enormously between these patches (Table 5.3). Most source patch types (other than mounds and the woody shrub-dominated patch) were broadly categorised on the amount of low (ground cover and understorey) vegetation present, as either “Bare” patch types or “Low veg” patch types (Figures 5.10 and 5.11, Appendix 9.5).

Characteristics of those soil surface features that differentiate the main patch categories are listed in Table 5.3. In general there are trends of increasing soil cover, and a general increase in the amount of litter and its degree of incorporation from ‘bare’ to vegetated resource source areas, to those which function as resource sinks. Minimal erosion was recorded across all patch categories, except for some scalding evident in some bare source patch types, hence this attribute is excluded from Table 5.3. Most other features were highly variable, with considerable overlap evident between patch categories. For example, soil cohesion was stable or moderately stable across most patch types. Similarly, the cover of cryptogamic soil crusts varied with the amount of deposited sediments, soil cover and litter cover. As in the Ivanhoe region, the least stable soils included those from scalds and other bare patch types, as well as loose friable soils beneath litter piles.

Figure 5.8 Resource sink patches included those dominated by trees, (such as Wilgas, as shown) and dense perennial grass swards (see also Figure 3.4). Soil surface features in treed patches tended to be similar to those of other regions, with friable, weakly crusted soils common. Despite a vastly different appearance, soil surface condition in these two patch types was very similar.

Figure 5.9 Many resource sinks dominated by woody shrubs featured accumulations of leaf litter and small fallen branches, variable understorey cover, some soil mounding, and intact soil crust.

Table 5.3 Soil surface features of the main patch categories identified on the Cobar study sites. Patch categories are characterised by dominant vegetation and functional status as either resource source or sink. Patch types included within each category are indicated in Appendix 9.5. Patch types excluded from this comparison are treed resource source patches (sites 34, 35) and woody shrub source patches (site 27). Objectives of the features are explained in Table 2.2.

Feature	Treed resource sink patch types	Woody shrub resource sink patch types	Perennial grass resource sink patch types	'Grassy' source patch types	'Low veg' source patch types	'Bare' source patch types
soil cover (predominantly low perennial plants)	low to high (more frequently low) (2-50%)	variable (low to high) (2-50%)	moderate to high (5-50%)	low to moderate cover (2-15%)	low (2-5%)	low (2-5%)
litter (cover & incorporation)	moderate cover; decay often evident	often high cover; minimal decay	low to moderate; some decay	low to moderate cover; some decay	low cover; some decay	variable cover; minimal decay
cryptogam cover	patchy or absent	high to absent	mostly high (some low)	moderate to high	high	variable (absent to high)
deposition	some deposition	some mounding and loose deposits	minimal deposition	patchy deposition	some patchy deposition	patchy deposition
soil microtopography	mostly moderate (slight to high) (3-25mm)	slight to high (3-25mm)	slight to moderate (3-15mm)	slight to moderate (3-15mm)	slight (3-8mm)	variable (moderate to nil) (0-15mm)
soil crust brokenness	often thin and fragile on loose friable soils; elsewhere hard and intact (less common)	quite hard and intact	intact and relatively soft	hard and intact	quite hard and intact	very variable (mostly hard and intact)
soil cohesion when wet (slake test)	stable to unstable	stable to moderate	stable	stable	stable to moderate	moderate to very unstable

Figure 5.10 Resource source patches included 'low veg' patches such as grassy patches and veg crusted patches

Figure 5.11 'Bare' resource source patches included crusted patches with variable cryptogamic cover and scalds.

5.2 Landscape organisation

The landscape organisation assessment data for each of the 35 sites is summarised in Appendix 9.1 as the number of obstructions per 10 m of transect, total obstruction width (m/10m), average fetch length (m), and the obstruction index (the ratio between total obstruction length and transect length). The main types of obstructions are also listed. Obstruction width was not measured for several run-on patches in the Ivanhoe region, thus analysis of this variable in relation to the level of woody shrub cover or density was not possible.

Analysis of each of these measures in relation to level of woody shrub cover and density revealed no significant relationships in either the Wanaaring-Louth or Cobar regions. This is despite the fact that dense woody shrub patches formed some of the obstructions in both regions. In the Ivanhoe region woody shrub patches did not function as obstructions on any of the study sites, however some relationships were detected between the obstruction organisation and woody shrub cover in this region. Although the number of obstructions/10 m was not significantly correlated with woody shrub cover, the average fetch length (log transformed) increased with increasing woody shrub cover ($r = 0.729$, $p = 0.017$) and density ($r = 0.749$, $p = 0.015$), as illustrated in Figure 5.12a. Correspondingly, the obstruction index was negatively correlated with woody shrub cover ($r = -0.833$, $p = 0.001$, Figure 5.12b) and density ($r = -0.788$, $p < 0.001$). Decreases in surface obstruction abundance associated with increased density of woody shrubs have been observed in the past, however this has tended to relate to groundcover and other understorey species (Ludwig *et al.* 1997). Such a relationship was not recorded in the Ivanhoe region, possibly as a consequence of the removal of understorey vegetation by herbivores. However, this scenario is presumed unlikely due to the intact nature of the soil crusts in this region, a feature which indicates minimal trampling of the soil surface. Location and size of dense tree patches or logs (the dominant obstructions in this region) are unlikely to be influenced by woody shrub cover. In fact, given the relative age of trees and shrubs, with higher shrub cover only possible where dense treed patches are smaller and further apart, the reverse may be true. Alternatively, there may be some indirect relationship between the obstruction features and woody shrub cover that has not yet been considered. These relationships also need to be considered in the context of the LFA process, in that transects are principally located with respect to environmental gradients and hence may undersample the obstruction occurrence on site.

In general, these significant results indicate that overland water flow would travel further before being slowed by obstructions, and would thus gain greater momentum and erosive power, and have less opportunity to infiltrate. However, in the Ivanhoe survey region the ground slope was extremely low and local flow paths could only be detected through careful examination of the ground surface and litter accumulations. Overland water flow would be relatively slow during most rainfall events, and consequently erosion would be quite limited, except perhaps in the vicinity of gilgais, which provide local topography for water flow throughout this region. This is reflected in the intact nature of the soil crust and good cryptogam cover over extensive areas. These conclusions are supported by those of Mutchler and Greer (1980, cited in John 1983), that slope length has a minimal effect on erosion from low slopes. Quantitative assessments of soil loss from low slopes (~1%) in semi-arid regions have indicated that soil loss rates are low unless the soil surface has previously been disturbed, such as by vehicles (Johns 1983). Furthermore,

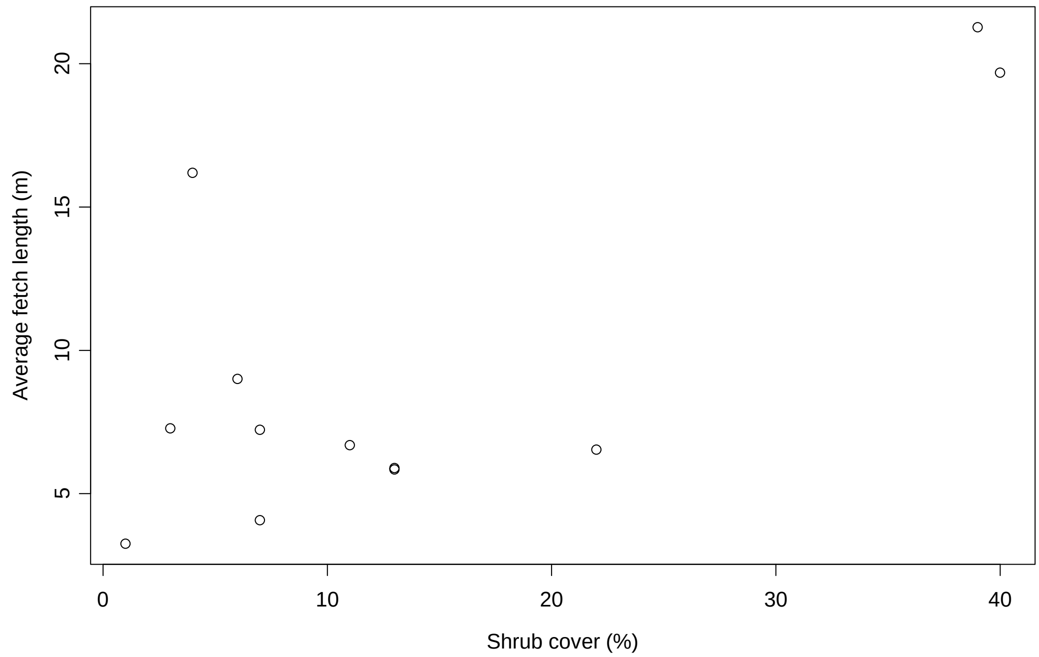


Figure 5.12a The correlation between average fetch length and woody shrub cover in the Ivanhoe region is primarily driven by the greater fetch length at sites of high woody shrub cover.

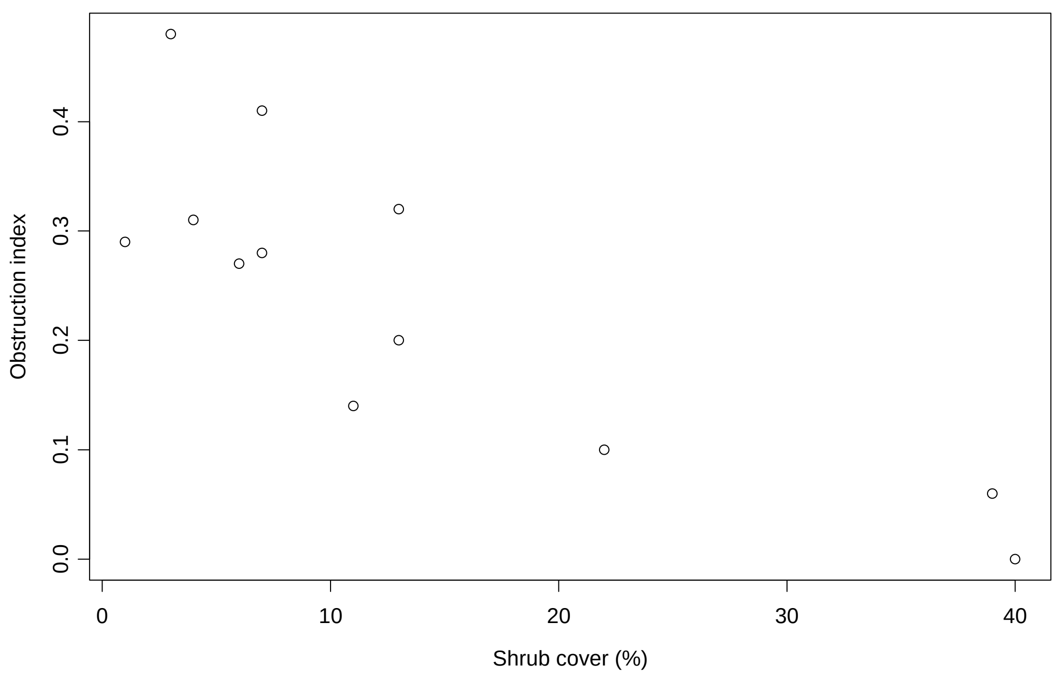


Figure 5.12b The number of obstructions was not significantly correlated with shrub cover in the Ivanhoe region. Consequently, the negative relationship between obstruction index (the ratio between total obstruction length and transect length) and woody shrub cover indicates that obstructions become proportionally shorter as shrub cover increases.

the erosive power of overland flow on such slopes is trivial compared to that of rain splash erosion (Moss *et al.* 1979, cited in John 1983). Run-off from an arid limestone hillside was found to be below the threshold value of flow energy generally needed to detach soil particles from the soil crust of an uncultivated soil (Yair *et al.* 1979, cited in Johns 1983).

5.3 Soil surface condition (SSC)

5.3.1 Site-level

The weighted mean SSC index scores for each of the 35 study sites are given in Appendix 9.2 and summarised in Table 5.4. The absolute range of scores was greatest for all three indices in the Wanaaring-Louth region, and the mean of these scores were lower in this region for soil stability and nutrient cycling status. These results, as well as the identification of more patch types per site in this region than elsewhere, reflect the widespread reworking and deposition of soil material observed there (note that the 14 lowest stability scores included all 12 Wanaaring-Louth sites). The highest maximum and mean weighted scores were recorded in the Cobar region (as well as the highest individual patch scores), reflecting the high groundcover levels and fairly intact soil surfaces in this region. Intact soils, good cryptogamic cover and relatively low leaf litter cover typified the Ivanhoe region, where intermediate scores were obtained. These regional trends may also reflect the seasonal conditions experienced in each region preceding the surveys, in that conditions were below average in the Wanaaring-Louth region, average in the Ivanhoe region, and well above average in the Cobar region (see section 3.2.1).

Table 5.4 Mean weighted soil surface condition indices for each survey region. The range of mean scores is in brackets. Weighted mean scores for each study site are provided in Appendix 9.2.

Survey region	Soil stability	Infiltration	Nutrient cycling status
Ivanhoe	57.75 (53.74 – 60.08)	37.67 (34.25 – 44.38)	23.28 (20.24 – 27.90)
Wanaaring-Louth	52.02 (46.54 – 56.44)	38.10 (28.62 – 42.60)	21.76 (17.18 – 27.41)
Cobar	63.11 (59.33 – 66.16)	40.16 (35.59 – 45.82)	25.30 (21.56 – 29.29)

Analysis of the weighted indices with respect to woody shrub cover across the 35 study sites showed negligible differences (Soil Stability: r = -0.012, p = 0.946; Nutrient Cycling Status: r = -0.079, p = 0.651; Infiltration: r = -0.017; p = 0.924). This is not unexpected given the vast diversity of broad soil types across the three regions, as well as the variability observed within individual sites in each region. A similar result was obtained when each of the three indices was analysed across sites within each survey region. No relationships between any of the three weighted indices and either woody shrub cover or density were found for the either the Ivanhoe or Cobar regions, or for two of the three indices in the Wanaaring-Louth region. However, increasing woody shrub density contributed most to the best explanatory model for increasing soil stability in the Wanaaring-Louth region (r^2 = 0.434, p = 0.020, Figure 5.14). No other variables contributed significantly to this model. The strength of this relationship in the

Wanaaring-Louth region may reflect the generally poor soil stability of this region (see above), in turn reflecting the inherent susceptibility of red earth soils to erosion when vegetation cover is reduced (Tongway and Smith 1989). More refined analyses excluding those factors which contribute to the SSC indices (including cryptogamic cover and solid litter cover) have yet to be undertaken.

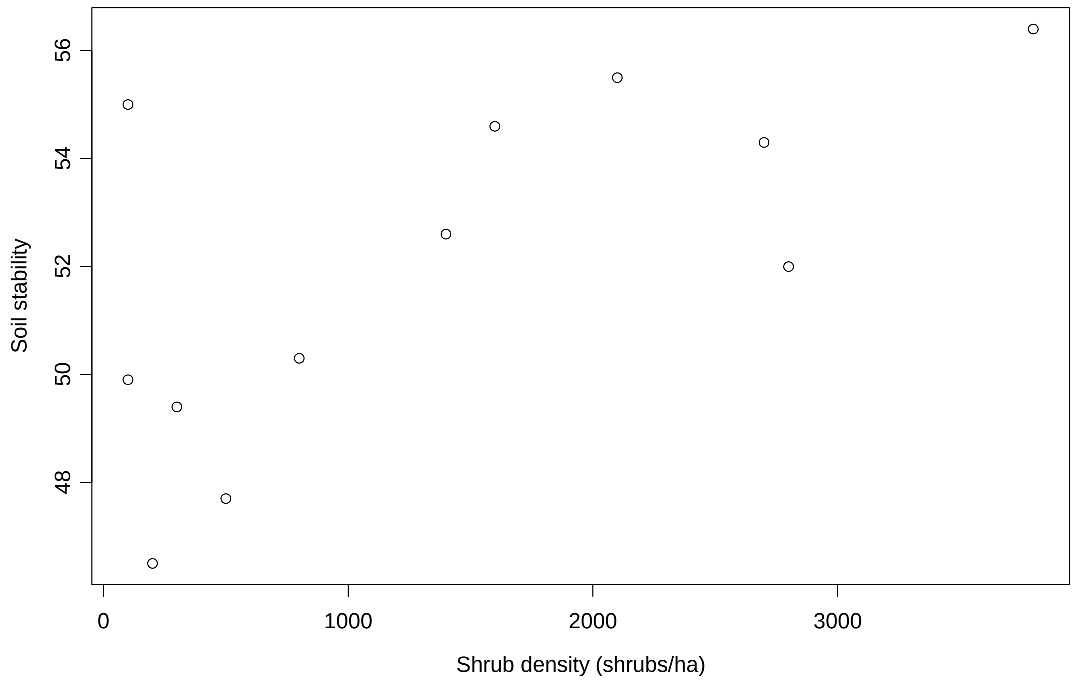


Figure 5.13 Soil stability increased with woody shrub density in the Wanaaring-Louth region, indicating that these shrubs can play an important functional role in degraded landscapes.

The above statistical results imply that the SSC indices have been little modified by the presence of woody shrubs. However, it has yet to be clarified whether this is because individual soil surface features are not modified by shrub cover, or because some are modified, but these cancel out others when combined to form the SSC indices, thus creating the appearance of minimal difference between sites. Furthermore, the data presented in Table 5.4 show a low dynamic range for each index within each region (theoretical values range from 0 to 100), reflecting in part the selection of sites within a single land unit from the diversity present in each region. These small differences between sites with varying levels of woody shrub cover may also be due to the influence of other factors (either natural, such as season, through the effect on perennial plant cover, or human-induced, such as grazing) preventing the expression of a difference due to shrub cover. Similarly, the impacts of historical events are unknown, being difficult to detect with a single ‘snapshot’ sampling technique. For example, the various sites may have undergone different changes in their landscape function indices through time, before converging on a new equilibrium point. This conclusion is consistent with the assumption by Noble (1997) that many shrub-affected landscapes have probably reached a new and relatively stable state in which the vegetation and current landuse practices are roughly in balance.

No site attributes were highly correlated (> |0.8|) with any of the three SSC indices in any of the three survey regions, nor across the three regions collectively. Infiltration and Nutrient Cycling Status were themselves highly correlated in the Cobar region ($r = 0.95$, $p < 0.001$), despite only one attribute (soil surface microtopography) contributing to both of these indices. Although this result may relate to the higher ground cover, including perennial grass cover, in the Cobar region, it is more likely to reflect the complexity of landscape function in this region, and the important influence of multiple soil surface features.

5.3.2 Patch-level

Consideration of the index scores for individual patch types in each region revealed a different trend to that seen in the weighted site-level scores (section 5.3.1). Although the highest patch index scores were recorded in the Cobar region, the trend was for a greater range of sores in this region, an intermediate range in the Wanaaring-Louth region and the narrowest range in the Ivanhoe region.

Patch type names were intended for within-site use only, being predominantly used as broad descriptive terms. They did not necessarily reflect a similarity of soil surface features between study sites (either within or between regions). Results of statistical comparisons of patch types of similar name between sites for each region reflect this dissimilarity, with the variability so great that any potential trends between different patch types were masked. Consequently, all further soil surface condition analyses were conducted separately between patch types within each study site. However, trends in the relative condition of patch types were detected and are discussed separately for each region.

Analysis of the three SSC indices and woody shrub cover or density was not possible on the patch-scale because shrub cover/density were determined per study site. Consequently, the mean scores for each of the three indices were compared between patch types (which varied in the presence of woody shrubs) on each site using linear models and multiple comparisons. For each region, the mean SSC index scores and standard errors are presented for each patch type within each site, and the within-site analysis results for each index versus these patch types, are summarised in Appendices 9.3 to 9.5. Score classifications as ‘high’, ‘moderate’ and ‘low’ are defined in the caption for Appendix 9.2.

5.3.2.1 Ivanhoe

The Turpentine Patches identified on three of the 12 study sites were found to have moderate to high soil stability and infiltration, and moderate to low nutrient cycling status. Comparison of the mean SSC indices in these Turpentine Patches to the other patch types on the same sites (Appendix 9.3) revealed that infiltration and nutrient cycling status values for the Turpentine Patches were consistently lower than those of nearby treed run-on patches. They also tended to be higher than, or very similar to crusted run-off patches (crusted refers predominantly to the presence of physical soil crusts, although biological crusts may also be present), despite considerable variability within some patch types. Soil stability was also very variable within each patch type, and did not vary significantly in the Turpentine Patches from that of most other patch types. However, the trend was for lower average stability than treed patches, and a similar stability to open crusted patches. On Site 10, the identified Turpentine Patches differed little from the crusted run-off patches in terms of any of the three mean SSC indices, despite some obvious differences on which the shrubby patches were distinguished (such as a higher cover of low perennial plants). These two patch types could have been amalgamated without loss of information about their relative functional status.

Ranking of all patches from the 12 sites in the Ivanhoe region in terms of each SSC index in turn (using scores from Appendix 9.3) revealed a similar trend, despite the wide variability in SSC index scores between different sites. Variability between sites was lowest for nutrient cycling status, consequently the trend of decreasing condition from trees patches to woody shrub patches and patches with low vegetation, to bare patches, was clearest. Results for infiltration were similar, although each patch category exhibited a greater spread of scores. Soil stability varied more between sites, and the only clear trend was for greater stability in some treed patches, and lowest stability in the sandy depositional patch.

Fully functional landscapes are highly patchy and, ideally, capture all resources (Ludwig *et al.* 2000). In the absence of data regarding the potential functional status of either the Wilkurra land system, or its component land units, it is only possible to draw general conclusions about the above site-level and patch level soil surface condition results. The limited perennial plant cover (grasses and groundcover species) was perhaps the best indicator that function was likely to have been below its potential, despite the minimal evidence of erosion and deposition of sediments. Greater perennial cover reduces raindrop impact, provides stemflow, obstructs surface flow, reduces run-off, provides biopores and consequently increases infiltration (Ludwig *et al.* 1997). Under the conditions prevailing during the survey period, it is therefore likely that the functional status was generally moderate, in the continuum from dysfunctional to fully functional, at both the site and patch scale. Perennial groundcover was not correlated with shrub cover in this region, and woody shrub dominated patches and sites were of intermediate functional status within the observed range. It is likely that the scarcity of perennial plant cover also reduced the pastoral potential of these sites at this time.

5.3.2.2 Wanaaring-Louth

Woody shrub-dominated patches exhibited moderate to high soil stability that varied little between sites, regardless of whether they functioned as resource source or sink areas. Nutrient cycling status was far less consistent, varying from low to high between patches and sites depending predominantly on the amount of leaf litter material present, its degree of decomposition, and the amount of cryptogamic cover (these factors are intimately linked). All woody shrub resource source patch types were at the lower end of this range.

Slight differences in surface microtopography, leaf litter cover, soil cohesion and perennial ground cover distinguished woody shrub dominated patches from treed resource sink patches and hummocks in terms of infiltration. Infiltration was lowest in two of the four resource source shrub patch types.

Patch types with lower soil surface condition than shrub-dominated patches tended to be resource source patches (Table 5.5). These varied enormously in terms of most soil surface features (Table 5.2), meaning that there was more of a continuum of functional status, than distinctive differences between many of these patch types (indicative of a system under some functional stress, David Tongway pers. comm.). Greater understorey and groundcover by perennial plant species tended to coincide with better soil surface condition, however sheeting and scalding were common between individual plants. Consequently, the soil surface condition was often only marginally better in such patch types compared with bare open patches. Previous studies in semi-arid Australia have demonstrated the importance of individual plant tussocks as obstructions to overland water flow and small scale resource sinks (Ludwig and Tongway 1995), which also decrease the degree of run-off (Pressland and Lehane 1982).

Comparison of the mean SSC indices for shrub-dominated patches to the other patch types on the same sites (Appendix 9.4) revealed a trend of decreasing condition (in terms of all three indices) from treed resource sink patch types, to woody shrub sink patches, to hummocks, then resource source patch types with low vegetation (such as Woollybutt tussocks and *Sclerolaena*) and finally source patch types with very little vegetation (Table 5.5). Ranking of all patches from the 12 sites in the Wanaaring-Louth region in terms of each SSC index in turn (using scores from Appendix 9.4) revealed a similar trend, despite the wide variability in SSC indices between different sites. As seen in the Ivanhoe region, trends were clearest for the nutrient cycling index, indicating a general overall decline in condition from treed run-on patches, to woody shrub run-on patches, to hummocks, then patches with low vegetation and bare patches. Although infiltration and soil stability tended to be more variable between sites, the same general trend was evident.

The common occurrence of accretionary hummocks beneath shrubs, trees, logs and individual grass tussocks across this region indicated that some eroded soils were being retained within the local landscapes. Large hummocks, (such as those which develop from fluvial, aeolian or rainsplash deposition around dead or fallen Mulga trees), have been shown to have significantly higher water infiltration rates, nutrient and seed concentrations. As such, these mounds function as hotspots of groundcover growth following an appropriate trigger such as rainfall (Tongway *et al.* 1989, Ludwig *et al.* 1997). Measurements from the present investigation concur with these earlier findings, with better soil surface conditions identified on hummocks relative to other resource source areas, however condition was usually better again on resource sink patch types (Table 5.5). Hummocks beneath woody shrubs were quite large (up to approximately 50 cm high), indicating that in the absence of good perennial ground cover, these shrubs play an important role in maintaining a level of functionality in these landscapes. In more dysfunctional landscapes, a higher proportion of eroded sediments leave the local system

Table 5.5 Comparison of the mean soil surface condition between the main patch categories and woody shrub-dominated patches (WSP) on the nine Wanaaring-Louth region study sites. For each patch category, the number of sites also including woody shrub-dominated patches is indicated. Patch category characteristics are presented in section 5.1.2.

Soil surface condition index	Treed run-on patch types (8 sites)	Hummocks (6 sites)	'Low veg' run-off patch types (8 sites)	'Bare' run-off patch types (7 sites)
Soil stability	* mostly high, some moderate * higher than WSP on 5 sites	* moderate * slightly lower than WSP on 6 sites (varied little between sites)	* mostly moderate, some high * lower than WSP on 7 sites	* moderate * lower than WSP on 7 sites (almost every patch), despite enormous variability
Nutrient cycling status	* high * higher than WSP on 7 sites	* mostly moderate, some low * slightly lower than WSP on 5 sites	* moderate to low * lower than WSP on 7 sites	* mostly low, some moderate * lower than WSP on 7 sites (almost every patch)
Infiltration	* high * higher than WSP on 5 sites	* mostly high, some moderate * lower than WSP on 5 sites	* high to moderate * lower than WSP on 7 sites	* mostly moderate * lower than WSP on 7 sites (almost every patch)

and are deposited in external resource sinks (Ludwig *et al.* 1997), and hummock formation occurs on a larger scale. An example of this occurs in degraded (e.g. overgrazed) chenopod shrublands. If most or all of the bluebush and saltbush have been lost, wind erosion causes severe deflation and the country is typified by Dillon Bushes *Nitraria billardieri* astride large mounds/hummocks of wind blown soil particles, with the intervening areas occupied by annual grasses and forbs. In the land condition assessment system developed by the Western Australian Department of Agriculture (Payne *et al.* 1987), such degraded country is classified in terms of wind erosion as 'severe'. Generally speaking, the height of hummocks above the surrounding ground surface is not a true indication of the amount of soil that has been lost from the landscape as a whole, because the material caught around obstacles is only a proportion of that removed from the areas in between.

As discussed for the Ivanhoe region, the potential functional status of the Avondale land system (Plains land unit) is unknown, and consequently an assessment of its relative functional status during the survey period is only possible in broad terms. The 12 study sites, and many of the patch types therein, clearly 'leak' resources such as water and soil, and as such the landscape function appears to be markedly poorer than that observed in the Ivanhoe region.

5.3.2.3 Cobar

Woody shrub-dominated patches were identified on eight of the 11 study sites. Almost all were resource sinks, and were found to have high soil stability, moderate nutrient cycling status and high infiltration. The resource source patches of crusted ground with scattered woody shrubs on Site 27 had high stability, low nutrient cycling status and moderate infiltration, and therefore had comparable soil surface condition to the bare crusted areas of other sites.

Comparison of the mean SSC indices in these patches to the other patch types on the same sites (Appendix 9.5) revealed a trend of decreasing condition (in terms of all three indices) similar to that observed in the Wanaaring-Louth region. Treed resource sink patch types had the best soil surface condition, followed by woody shrub sinks, then grassy and other resource source patch types with low vegetation and finally resource source patch types with very little vegetation (Table 5.6). Patches of sandy deposition, and scalds had the poorest soil surface conditions in terms of all three indices.

Sites with the lowest woody shrub cover were essentially open grasslands, with very few shrubs and a small number of isolated trees. Resource sink patches of dense perennial grass cover on the least shrubby site were comparable in terms of all three SSC indices to the treed or woody shrub resource sink patches elsewhere. This is consistent with the work of Jones (2000a) which shows that a landscape dominated by perennial grasses functions more effectively in terms of water use than a tree-dominated landscape. Perennial grass tussocks provide very effective obstructions to overland water flow and their large mass of fibrous roots are very effective in aiding infiltration of water into the soil (Pressland and Lehane 1982, Ludwig and Tongway 1995) and retaining that water at a level from which it can be used by the ground cover plants (Jones 2000a). Soil chemical values under tussocks growing in red-earth soils have also been shown to be significantly higher for organic carbon, total organic nitrogen and pH than between-grasses (Tongway and Ludwig 1994). Resource source patches on these grassland sites had similar soil surface conditions to those of shrubbier sites. Isolated trees on these grassland sites had quite different soil surface features to those of other sites, tending to be resemble bare patch types. There were no large woody shrub patches on these sites.

Ranking of all patches from the 11 sites in the Cobar region in terms of each SSC index in turn (using scores from Appendix 9.5) revealed similar trends to those in the within-site comparisons above, despite the wide variability in SSC indices between different sites. Trends were clearest for the nutrient cycling and infiltration indices, indicating that condition was best in treed run-on patches and perennial grass patches, then progressively declined to woody shrub run-on patches, then run-off patches with low vegetation, and finally bare run-off patches. Although soil stability tended to be more variable between sites (particularly between treed, woody shrub and grassy patches), the same broad trend was evident. Those treed run-on patches with lower mean stability were either Wilgas or Needlewoods.

Table 5.6 Comparison of the mean soil surface condition between the main patch categories and woody shrub-dominated patches (WSP) on the eight Cobar region study sites. For each patch category, the number of sites also including woody shrub patches is indicated. Patch category characteristics are presented in section 5.1.3.

Soil surface condition index	Treed run-on patch types (8 sites)	'Grassy' run-off patch types (4 sites)	'Low veg' run-off patch types (4 sites)	'Bare' run-off patch types (5 sites)
Soil stability	* good * higher than WSP on 6 sites	* usually good, sometimes moderate * lower than WSP on 4 sites	* good * lower than WSP on 3 sites	* usually moderate (poor to good) * lower than WSP on 5 sites
Nutrient cycling status	* usually good, sometimes moderate * higher than WSP on 7 sites	* usually moderate, sometimes poor * lower than WSP on 4 sites	* poor to moderate * lower than WSP on 4 sites	* poor to moderate * lower than WSP on 5 sites
Infiltration	* mostly good * higher than WSP on 7 sites	* moderate to good * lower than WSP on 4 sites	* moderate * lower than WSP on 4 sites	* moderate * lower than WSP on 5 sites

Baseline functional status data are unavailable for either the Boulkra land system, or the Lower Ridge Crests and Upper Slopes land unit. Despite the presence of scalds and some sediment deposits, the 11 sites tended to be dominated by intact soil crusts and moderate to high perennial ground cover in many patch types. In general, these sites appear to be predominantly 'conservative' and more functional that those observed in either the Ivanhoe or Wanaaring-Louth regions.

5.4 Conclusions

Increased densities of woody shrubs have previously been observed to feature relatively few surface obstructions, due to lower abundances of understorey plants that trap and retain resources (Ludwig *et al.* 1997). Although a trend of declining cover abundance of understorey and groundcover plants with increasing woody shrub cover was detected in the Wanaaring-Louth and Cobar regions, no relationship with obstruction abundance or spacing was detected in either of these regions. In contrast, in the Ivanhoe region, which was the only region where groundcover plant cover was not found to vary significantly with shrub cover, surface obstructions to overland water flow became further apart and relatively smaller as woody shrub cover increased. Furthermore, the predominant obstructions in this region (logs and treed resource sinks) are unlikely to be affected by woody shrub cover. Consequently, it is concluded that woody shrub cover or density in themselves did not alter the basic ability of sites to capture and retain resources in any of the survey regions. The long-term effects of shrub cover on this ability may differ and would require future investigation.

It is probable that in an unaltered landscape, the type, number, size and spacing of obstructions within a region are fairly characteristic of the land unit in which they are located, reflecting the combination of topography, soil and vegetation. This view is supported by the scaling rule approach of Ludwig *et al.* (2000) to landscape patches and processes. Persistence of obstructions in modified landscapes depends on their vulnerability to natural phenomena (e.g. fire, drought), the longevity of any plants contributing to the obstructions, and their vulnerability to the new impacts (e.g. grazing, trampling, changed fire regimes). Recruitment of many longer-lived tree and shrub species in semi-arid rangelands of eastern Australia is thought to be suppressed by current management practices (e.g. Auld 1995). Consequently, the observed predominance of treed resource sinks and logs as obstructions across all three survey regions, and the uncommon occurrence of obstructions dominated by groundcover vegetation, is a pattern which may alter with time. Unless replaced, the death of older trees that currently form the focus of many resource sinks, will result in a reduction of these large patch types in the long term. This has implications not only in the ability of landscapes to trap resources, but also in the nutrient concentrations retained, given that larger resource sinks (e.g. tree groves) have been shown to retain proportionally more nutrients than intermediate (e.g. scrub thickets) or small sinks (e.g. grass clumps) (Tongway and Ludwig 1994, Ludwig and Tongway 1995). The functional role of woody shrub-dominated patches may differ in such landscapes lacking in obstructions dominated by trees, logs and groundcover vegetation.

Woody shrub patch types did not consistently function as either resource source or sink areas. This varied from region to region, and even within regions and sites. When patch types were assembled into broad patch categories, comparison of the soil surface condition indices within each study site indicated a consistent trend of declining nutrient cycling status, infiltration, and to a lesser extent stability, from treed resource sink patch types, to woody shrub resource sink patches, to all resource source patch types. In addition, perennial grassland patch types (assessed on only one site in the Cobar region) were found to have comparable soil surface condition to the best treed resource sink patch types. Within the different resource source patch categories, those with greater coverage of understorey and groundcover vegetation (including grassy patches and vegetated crusted patches) tended to have better soil surface condition than bare patch types. Loose soil deposits and scalds had the poorest condition. Treed and woody shrub resource source patch types were comparable to other source patch types. Similar trends were obtained when all patch types within each individual survey region were compared.

Fewer relationships were detected when the weighted soil surface condition indices were analysed with woody shrub cover and density across the study sites in each region. Only soil stability in the Wanaaring-Louth region was found to be positively correlated with woody shrub density. There were no negative correlations between soil surface condition indices and woody shrub cover or density. The combined effects of comparing sites which varied quite markedly in soil surface condition, and calculating weighted means from scores for different patch types, appears to have blurred the trends evident at the finer (within-site) scale.

Collation of the landscape organisation and soil surface condition results enables conclusions to be drawn regarding the functional status of survey regions and study sites:

- functional status was generally moderate, and varied relatively little in the Ivanhoe region. This can be considered a moderately 'conservative' landscape, which although not eroding, is unlikely to retain surface water due to low levels of perennial groundcover;
- in the Wanaaring-Louth region functional status was more variable but generally poorer. Capture and retention of both soils and surface water is poor, defining this as a 'leaky' landscape;
- functional status tended to be highest in the Cobar region, but was also variable. This is a predominantly 'conservative' landscape, typified by less erosion and denser perennial groundcover.

These differences are thought to reflect regional landform, soil and vegetation traits (land unit features), the relative seasonal conditions (and hence perennial groundcover growth) in the three regions, the widespread erosion and deposition of soil materials evident in the Wanaaring-Louth region, regional management trends, and the location of the Ivanhoe sites within open Belah woodland (trees are the longest living, most deeply rooted plants and usually contribute strongly to landscape function, David Tongway, pers. comm).

These within and between site comparisons collectively indicate that landscape function was not significantly different between different levels of woody shrub cover either on the scale of hectares, nor in the immediate vicinity of the woody shrubs themselves. Shrubby patches often exhibited moderate to high soil stability, infiltration capacity and nutrient cycling ability, with their contribution to soil stability particularly evident in the Wanaaring-Louth region. Increased leaf litter occurrence and decomposition, good soil microtopography, soil accumulation and an unbroken soil crust typify woody shrub-dominated patches. Perennial plant cover tended to be low in shrubby patches, but was markedly better on the Cobar region patches, reflecting the better seasonal conditions. With the exception of treed resource sink patch types and perennial grass swards, soil surface conditions of woody shrub patches were usually considerably better than other patch types. An important qualification of this comparison is that whereas woody shrub and treed patch types tend to be quite small, and are generally separated by larger run-off areas, perennial grasslands can be very extensive. This result is reflected in the observation that of the 35 study sites, the Cobar region study site with extensive perennial grass patches had the highest overall infiltration and nutrient cycling status scores, and second highest stability score. Maximum stability was measured on a Cobar region site with approximately 16% woody shrub cover and 1 388 woody shrubs per hectare, and a good cover of *Austrostipa*, *Calotis* and other grass and ground cover species.

Previous studies of landscape function in semi-arid rangelands allow inferences to be made regarding patch types identified in this investigation. Soils in resource sinks with good soil surface condition are likely to have high organic matter content, greater biological activity, higher nutrient levels (total and available nitrogen, organic carbon and exchangeable cations), higher soil respiration, cooler soil temperatures, a greater concentration of soil pores (including macropores) which conduct water into the subsoil, contain more stable soil aggregates, and support a greater richness and diversity of soil mesofauna, such as collembola, mites and ants (Tongway and Ludwig 1990, Greene 1992, Ludwig and Tongway 1995, Tongway and Ludwig 1996). Resource source areas tend not to feature these attributes, for example soil macropores tend to be largely absent in many run-off areas (Greene 1992). In particular, the importance of vegetation cover and biomass have previously been recognised in terms of their contribution to soil nutrient maintenance, protection of the soil surface from rainsplash erosion and surface sealing (crust formation) effects, improved structural stability and infiltration rates. Shrubs and small trees have been shown to have a particularly positive influence on infiltration rates. For example, infiltration rates beneath the shrub *Boscia coriaceae* were approximately 20 times greater than that measured on a sealed soil surface (Scholte 1989, cited in Greene 1992), and were approximately 10 times higher beneath Mulga trees *Acacia aneura* than in run-off zones (Greene 1992).

Inferences regarding relative run-off and soil loss rates in woody shrub and other patch types can be made from results of a study by Johns (1983) on gently sloping ridges in the Cobar pediplain. Run-off and soil loss rates were measured during a five year period of above-average rainfall in “thickets” (dense patches of shrubs surrounding large eucalypts) and relatively sparsely shrubbed grazed “interthicket” areas. Run-off was shown to be negligible from thickets and approximately 26% from interthickets. Long term soil loss rates of exclosed thicket areas were equivalent to 25 mm per 1000 years, compared with 55mm per 1000 years for grazed interthickets (Johns 1983). These results have important implications as to the likely impacts of erosion on soil nutrient concentrations, given the observation that organic matter, nitrogen and organic phosphorus are concentrated in the upper few centimetres of topsoil in many semi-arid areas (Beadle and Tchan 1955, Charley and Cowling 1968). For example, eroded red earths from the mulga lands of south-western Queensland were found to have a lower phosphorus level in the surface soil, a lower pH at depth, and an inverse electrical conductivity profile implying major differences in mineral cycling, compared with nearby mulga or grassland areas. Of relevance is the observation that land invaded by Turkey Bush *Eremophila gilesii* did not differ in nutrient characteristics from these mulga or grassland areas (Baker *et al.* 1992).

In interpreting the results of the present investigation, it needs to be remembered that study sites were selected with strict criteria in mind. Consequently, the range of patch types assessed may not have included all those present in each region and the above comparisons have been made between relatively similar areas. No attempt was made to assess the full dynamic range of patch types by incorporating the "best" (least degraded, most functional) and "worst" (most degraded, most dysfunctional) country in each region. However, a broad diversity of patch types has been considered in each region, allowing realistic estimates of potential functional status to be made. It is also important to note that the above results reflect the scale at which the LFA process was undertaken in this investigation. Small (<1m) features, including individual perennial understorey plants (e.g. grass tussocks), were not assessed, and consequently their relative functional status cannot be compared with that of other larger patch types. Previous studies have demonstrated that the fine-scale control of resources can be determined by the density, morphology, and spatial distribution of perennial plants and plant communities (Tongway and Ludwig 1994). More recently, Jones (2000b) has highlighted the importance of perennial grasses to the transfer and availability of water at a landscape scale.

The three survey regions encompassed a wide range of landforms, soils and vegetation types. However, distinctly different environments have been encroached by woody shrubs elsewhere in the Western Division, including ridge and steep slopes in the hard red country of the Cobar area, and floodplain areas. Application of these results to such diverse areas must be made with caution. The frequent statement by Western Division land managers that woody shrubs cause scouring and erosion, and the observation that ground beneath woody shrubs may remain bare for years (Ludwig *et al.* 1997) support the need for continued investigation into the effects of woody shrub cover on landscape function to confirm the generality of the results of this study. Long-term investigations are required to increase understanding of the impacts of woody shrubs on functional status during different seasons, despite the similarity of results obtained by this investigation in regions undergoing quite different seasonal conditions. Observations in the Wanaaring-Louth region that perennial groundcover appeared to have relatively little influence on soil surface condition contradict those from previous studies, and may reflect the poor seasonal conditions, and the generally fragile soils in this region.

As cited in the Project Objectives (section 1.1.3), the effects of shrub control practices on landscape function also require further investigation. Purvis (1986) has demonstrated that property-scale landscape manipulations can result in increased landscape functional status as well as increased livestock productivity (see also Purvis 1988, Bastin 1991). To date, only limited information relevant to landscape function is available on shrub control efforts. An investigation of bladeploughing and grazing treatments on soil properties have demonstrated a short-term improvement in soil hydrology following bladeploughing (Eldridge and Robson 1997). Increased plant cover and initial development of a biological soil crust on bladeploughed plots, and the development of a thin physical soil crust on untreated plots, were suggested as potentially influential to these results. In addition to longer term investigations of bladeploughing sites, alternative shrub treatment methodologies (e.g. fire, herbicides, goat browsing) require comprehensive investigation, incorporating seasonal, shrub species and regional effects. Of particular importance is the need to assess impacts of multiple treatment strategies, reflecting current regional shrub management practices. The effects of treatments need to be assessed in light of all relevant management considerations, not simply landscape function in isolation, and must occur at scales appropriate to these considerations.

6. Conclusions and recommendations

This study set out to investigate the difference in biodiversity and landscape function as a result of different levels of shrub cover within the Western Division of NSW. Few investigations have focused on these issues to date, thus little direct information is available. However, a considerable amount of relevant information is available from studies focused on related issues.

6.1 Research conclusions

6.1.1 Flora and fauna

To date, our results indicate the following:

- each 2 ha study site supported a broad diversity of taxa, with low numbers of exotic species. Vertebrate fauna diversity was comparable to that of other sites previously surveyed in western NSW;
- within each survey region a number of flora, vertebrate and invertebrate taxa were recorded solely or predominantly within that region;
- a number of taxa were present in all three regions, some frequently encountered and others limited to only one or two sites per region;
- greatest similarity in species compositions was between the Wanaaring-Louth and Cobar regions, with many taxa common to both;
- vertebrate fauna and flora composition at study sites was most similar between sites in the same geographic region, rather than between sites with similar woody shrub cover from different regions. Ant compositions showed a similar, although weaker, result;
- the number of taxa varied between survey regions and study sites, but did not vary significantly with respect to woody shrub cover. Similarly, there were few significant trends in the richness of each broad taxonomic group (flora, all vertebrates, birds, mammals, reptiles, invertebrate ‘Orders’ and ants) with respect to shrub cover. These results hold true for individual survey regions, as well as across the three regions collectively;
- most taxa, guilds and taxa associations did not respond significantly to woody shrub cover. In part this reflects the relatively high proportion of uncommon taxa (recorded at few sites), and relatively small number of abundant taxa. The small number of sites in each region may also have influenced this result. In the Ivanhoe region, where less than 10% of taxa showed a significant response to shrub cover, low activity levels may have affected capture and hence response rates;
- woody shrub cover or density explained more of the variation in abundance than any other habitat or disturbance attribute for an even smaller proportion of taxa. Once again, this was lowest in the Ivanhoe region (only 3%), but was not great in any of the survey regions;
- the level of response to woody shrub cover was similar for introduced vertebrate and plant species to that for indigenous taxa;

- diverse response types were identified amongst the comparatively small number of taxa or groups which did respond significantly to increasing woody shrub cover or density, including:
    - increasing abundance,
    - decreasing abundance,
    - preference for intermediate covers,
    - avoidance of intermediate covers,
    - preference for one cover extreme,
    - avoidance of one cover extreme.
- of the many taxa that did not respond significantly to woody shrub cover or density, a small number exhibited a very low correlation, or generalist response;
- detailed biological and ecological information is lacking for many taxa considered in this investigation, particularly ants and plants, rendering interpretation of some of these responses (and non-responses) difficult. For others, such as invertebrate 'Orders', the taxonomic level under consideration is too broad to allow meaningful interpretation. Confident explanation of results was possible for relatively few taxa. Speculation and tenuous interpretation has been avoided for other taxa;
- regional differences in species responses to changing levels of woody shrub cover may reflect broad differences in landform, soil type, vegetation, seasonal conditions and management histories. Those few taxa or groups that exhibited similar responses to shrub cover or density in more than one region, despite these environmental and habitat differences, are worthy of greater attention. The same is true of faunal taxa which responded similarly at broader (site-level) and finer (pitfall trap-level) scales;
- in each survey region, numerous attributes were found to influence the abundance of particular taxa to a greater extent than woody shrub cover. Some of these reflect known species requirements or habitat preferences for particular taxa. However, knowledge of the biology of many species, particularly the invertebrates, is poor. Consequently, these results can provide some facts about these species as a starting point in documenting their biology.

6.1.2 Landscape function

To date, our results indicate the following:

- woody shrub cover had a neutral or positive effect on landscape function in the three survey regions. These results may reflect the scarcity of extensive perennial grasslands and structurally complex treed patches (which tended to exhibit significantly higher landscape function status), and the relative abundance of more open resource source patch types in the current landscape;
- a significant increase in the average distance between obstructions and shrub cover and density was detected in the Ivanhoe region, however the influence of woody shrubs on the spacing of trees and logs (the dominant obstructions) is unlikely to be causal. Thus, the basic ability of sites to capture and retain resources (based on obstruction number, size and spacing) did not appear to be significantly affected by woody shrub cover in any of the survey regions, regardless of whether woody shrub-dominated patches functioned predominantly as resource source or sink patches.

Note, however that fine-scale resource control over areas <1m in size was not assessed,

- relative soil surface condition of the broad patch categories within each study site (and to a less obvious extent across each survey region) declined in terms of nutrient cycling status, infiltration, and to a lesser degree stability, from treed resource sink patch types, to woody shrub resource sink patches, to resource source patch types. Source patch types with greater coverage of understorey and groundcover vegetation tended to have better soil surface condition than bare patch types. Perennial grassland patch types (assessed on only one site) were found to have comparable soil surface condition to treed resource sinks,
- woody shrub and treed resource source patch types had soil surface condition comparable to other source patch types,
- landscape function tended to be better (and most variable) in the Cobar region, intermediate (and least variable) across the Ivanhoe sites, and markedly poorer in the Wanaaring-Louth region. Landform, soil type and vegetative differences, seasonal conditions and landscape degradation are thought to have influenced these results to varying degrees,
- the Ivanhoe sites were generally conservative with regard to soil, but less so in relation to water capture and retention,
- the Wanaaring-Louth sites tended to be 'leaky' with regard to both water and soil. Shrub density appears to have an important positive influence on soil stability in this region.
- the Cobar sites were predominantly conservative in relation to both soil and water.

6.2 Recommendations

6.2.1 Management recommendations

Management of woody shrub-encroached landscapes has traditionally reflected the perception that shrubs negatively impact on pasture production, stock management, biodiversity and landscape function. Results of the present investigation refute the magnitude of the impact on the latter two attributes, thereby re-identifying the 'woody weed problem' as a predominantly production-orientated problem. Specifically, the above Research Conclusions may be summarised into three broad results: 'woody weeds' have biodiversity values, with many taxa utilising shrub-encroached areas; most taxa (between 75 and 90%) do not respond significantly to woody shrub cover or density; and, shrub cover has a neutral or positive effect on landscape function. These results do not indicate that no taxa are affected by the density of shrubs, nor that landscape function was not previously better or could not be enhanced in these regions. Extension of these results to other locations are limited by the 'snapshot' type approach of this study, the small number of survey regions, and the incomplete assessment of the full range of shrub cover levels present in each region. However, in its favour, this investigation has incorporated a broad diversity of flora and fauna taxa, in conjunction with soil surface attributes, from very diverse regions across a broad geographical area. Consequently, management implications of the above results are not limited to the regions, vegetation types or landscapes in which this research was undertaken.

What are the implications of these results? At their simplest, they indicate that shrub patches of differing densities and scales have biodiversity and landscape function values that must be considered in conjunction with other landscape management issues. The results also indicate that some taxa are highly unlikely to persist in the longer term in areas dominated by the continued encroachment and proliferation of shrubs. In the past, the wide-scale eradication of woody shrubs has been advocated as being beneficial from a production, soil conservation and biodiversity point of view. It is now apparent that regardless of the achievability or appropriateness of this goal for other purposes, it is not a justifiable landscape-scale goal for maintenance of landscape function and conservation of the maximum possible diversity of flora and fauna taxa. From a landscape function point of view, the eradication of woody shrubs may result in an increase in the proportion of resource source patch types with lower landscape functionality, depending on the seasonal conditions and management practices subsequent to shrub removal. It is the establishment of more highly functional patch types (extensive perennial grasslands and structurally complex treed patch types), rather than the eradication of woody shrubs, per se, which will result in an overall increase in landscape functional status. Resource source patch types, especially those with a poor cover of understorey plants, have the lowest functional status and can therefore undergo the greatest increase in functional status. The establishment and maintenance of healthy perennial grasses would also produce production benefits and favour some elements of the biota. Finally, the results of this investigation confirm the complexity of these landscapes and the diversity of management considerations confronting land managers.

When incorporating biodiversity considerations into the management of shrub-encroached landscapes, the diversity and scale of responses to increasing shrub cover exhibited by elements of the native biota indicate that there is no single management regime suitable for all taxa across all regions. A mosaic of woody shrub densities maintained or established within the mix of broader vegetation, soil and landform types, is likely to best accommodate this diversity of responses. Maintenance of a patchy shrub cover will maximise habitat and ecotone diversity, reduce distances between habitat patches for those taxa that rely on resources provided by shrubby areas, but allow for continued persistence of those species detrimentally affected by the continued encroachment and intensification of woody shrub species. Many taxa make use of woody shrubs, or shrubby areas, despite their non-response to shrub cover levels. This use is likely to be influenced by the diversity, quality and configuration (proximity, size, shape and connectivity) of other habitat types to shrubby areas. A crucial step in maintaining a diversity of habitats is the retention of open areas with few or no shrubs. Not only are such areas vital for growth of native pasture species (an important component of the biodiversity), but their persistence is likely to be crucial for the continued existence of decreaser species and other taxa which depend on such habitats. It is important to stress that local environmental attributes and composition of the biota must be examined when land managers and planning bodies consider these issues.

Woody shrub patches can function as obstructions which trap resources, increase soil stability and exhibit greater soil surface condition than surrounding resource source areas, particularly in the absence of ground cover of grasses and forbs. Perennial grasslands, tree groves, individual trees, other shrubs, and even grass tussocks fulfil similar roles from a landscape function point of view, with larger, more extensive patches (e.g. perennial grasslands) contributing relatively more than individual plants. Management of shrub encroached landscapes needs to occur in such a manner that obstructions to overland water flow (including resource sinks) are retained or increased at a variety of scales, and soil surface condition does not decline. Maintenance of an intact soil crust, minimisation of potential rainsplash impact, reduction of soil exposure to erosive forces, and maximisation of resource capture (water, sediments, nutrients, seeds) are paramount to preserving landscape functionality.

In reality, few (if any) landscapes encroached by woody shrubs are managed for biodiversity and landscape function purposes alone. Most are production-orientated landscapes and as such shrub management is driven by pastoral and economic considerations. However, management of landscapes prone to woody shrub encroachment and proliferation does not simply entail the management of woody shrubs. Soil protection and landscape function, groundcover growth (including pasture species), stock management, habitat management for flora and fauna (biodiversity), as well as the ongoing management of shrub establishment, are complex and interactive issues that cannot be treated in isolation. A large body of information relevant to the management of rangeland areas exists in the form of accumulated knowledge (e.g. floral and faunal taxa distributions), and previous investigations, on issues such as landscape processes in semi-arid environments, soil types and vulnerabilities to degradation, biotic and abiotic disturbance impacts (e.g. fire, grazing, feral animals), and rehabilitation of degraded environments. Research of woody shrubs has considered issues such as factors influencing germination, establishment and survival of woody shrubs, the efficacy and cost of various control measures, and the impacts of woody shrubs on pastoral enterprises. Many of these studies have been undertaken in those areas most affected by shrub encroachment and proliferation, and encompass a diversity of shrub species in addition to the six designated 'woody weed' species. An enormous amount of information pertinent to particular regions of western NSW resides within western government departments in the form of reports, research papers and data, and some is also currently being collated at a regional scale as part of various planning processes (e.g. regional vegetation planning, catchment management planning). Despite the compilation of some extensively researched summaries in recent years (e.g. Ludwig *et al.* 1997 and Noble 1997), and efforts by groups such as the Woody Weeds Task Force to distribute such information, much of it remains under-utilised by most land managers. Considerable effort is clearly required to further address this issue before real gains can be expected in the successful integrated management of woody shrubs across western NSW.

In establishing management aims for shrub-encroached landscapes, the desired state or endpoint needs to be determined in some detail, and at multiple scales (e.g. local and regional). These goals, and the reasons for establishing them, determine the management regime to be implemented, and both the goals and methods of achieving them must be realistic and economically feasible. It is important to remember that these environments are dynamic functioning ecosystems. Resources will be required to not only achieve, but also maintain the desired goals. The importance of scale is relevant not only in terms of financial constraints, but also when considering environmental attributes (patterns of landscape features and the processes in operation), as well as the organisms that occupy these landscapes. Ludwig *et al.* (2000) discuss these latter points in some detail, and provide an example of how scaling rules can be applied to integrate these issues and reduce their complexity. It is imperative that management goals be developed with the input of sound base-level data regarding the resources and processes in operation within each local area or region. The role of on-ground assessments is not to be underestimated in this process, particularly for the determination of landform, soils, vegetation types and conditions, habitats, microhabitats, landscape functional status, and the status of shrub dynamics. Information gained in this way can then be interpreted in the light of local management knowledge and existing information. Ongoing monitoring is a crucial component in the process of establishing, revising and attaining management goals for shrub-encroached landscapes. This need not be an onerous task, and can be as simple as being observant and keeping records on attributes such as those assessed during initial on-ground inspections, as well as those relevant to the desired goals (e.g. recruitment and condition of perennial pasture species). An important component of the monitoring process is determining whether the benefits of any actions undertaken continue to outweigh the costs.

6.2.2 Future research

Expansion of this investigation to incorporate additional regions of different physical and vegetative attributes and a wider range of woody shrub cover levels (particularly higher), or a re-assessment of the 35 sites subject to this investigation, would add considerably to the results obtained to date. Previous flora and fauna surveys in western NSW have illustrated the importance of repeat investigations to allow the more complete determination of species composition, and for information gathering about the relative frequency with which individual species utilise a site. Detection of rare and uncommon species which are encountered less frequently is also more likley with more detailed investigation. Consequently, extension of the present investigation would provide a more balanced outcome, less affected by weather and seasonal influences. Of greater importance to an investigation of this nature, on-going monitoring of study sites would allow investigation of landscape function, flora and fauna as woody shrub cover change on each study site. Location and layout details have been recorded for each study site, and all vertebrate pitfall traps remain in place. Should the survey sites be re-opened in the future, it is recommended that contrasting seasons and seasonable conditions prior to survey, be targeted in each region. In particular, at least some investigations should be conducted whilst shrub species are in flower (primarily *Eremophila* and *Senna* species), or fruiting. Such investigations would inevitably be a long-term and expensive process. A valuable expansion of the landscape function investigation conducted to date would be the fine-scale (< 1m) contribution of individual groundcover plants to the functional status of sites differing in woody shrub cover.

In planning the present investigation, the potential impacts of woody shrub control practices on biodiversity and landscape function was included by the Woody Weed and Biodiversity Project Steering Committee as an objective (Objective 3b, see section 1.1.3). To a small extent, predictions for such an investigation can be drawn from the present results, both in terms of individual species responses to woody shrub cover, and also to other habitat attributes that may be altered by fire, blade ploughing or other control measures (e.g. large trees, ground cover, leaf litter). Prohibitively, many years would be required to undertake a well-replicated research study to investigate this issue: to establish sites, conduct pre-treatment monitoring, then undertake the specified treatments and commence monitoring at sufficient intervals over an appropriate timeframe. In the interim, it is recommended that experimental woody shrub treatment plots previously established across the Western Division be reassessed and compared with nearby untreated areas to provide some information on this issue (appropriate control plots may already exist in some regions). Some such plots were established decades ago and files or reports specifying treatment locations and details may be difficult to locate. It is important to tap into the dwindling resource of personnel with detailed knowledge of these projects within government departments and research organisations. Re-interpretation of existing information regarding particular plots or other investigations may also be possible in the light of landscape function principals to provide additional information for relatively low expense.

To assist with management planning for shrub-encroached landscapes, the spacing and configuration of woody shrub densities mosaics, as recommended above (section 6.2.1), require investigation. These factors are likely to influence the long-term population viability of those taxa with strong responses to shrub cover or density. Some taxa that showed no response at the site scale may respond on a broader, landscape scale. Analysis of the data collected during the present investigation in relation to landscape-scale patterns of woody shrub distribution and densities (and other habitat types) may reveal broad scale impacts on the biota. Landscape-focused investigations will be important in the continued identification of regional habitat requirements for individual taxa and taxa groups.

To further elucidate the effects of woody shrub cover on biodiversity or landscape function, additional analyses using data collected during the present investigation are required, including:

- ordination (gradient analysis) analysis of flora and fauna data to identify species communities or assemblages associated with different levels of shrub cover (e.g. low, medium, high), thereby simplifying the multitude of individual taxa responses;
- refinement of the analyses conducted to date to include only those site attributes of relevance to each taxon, guild and taxa association;
- more detailed investigation of some results obtained to date, for example, the possible link between ground-feeding seed-eating birds and groundcover/understorey plant species;
- grouping of plant taxa on the basis of palatability to stock, native and introduced wild herbivores, for analysis with respect to shrub cover. Similar analyses can also be undertaken for flora groups based on life forms (e.g. chenopods, grasses, forbs/herbs);

- determination of the proportion of increaser and decreaser taxa in different levels of woody shrub cover;
- analysis of environmental and habitat complexity within sites of differing woody shrub cover, for comparison with flora and fauna diversity;
- statistical comparison of soil surface condition results within broad patch categories (e.g. treed resource sinks, perennial grassland sinks, woody shrub resource sinks, vegetated resource source patches, bare source patches). This is the closest analysis possible to that comparing soil surface condition and woody shrub cover;
- additionally, there is the potential for analysis of biodiversity/landscape function interactions, although this not relevant to the objectives of the present investigation.

Additional information could also be obtained through the analysis of data collected during the course of other investigations. Some of these were referred to within the literature review for this project (Hassall and Associates 1999).

6.3 Information availability

Results from this investigation are available for use by individual land managers, as well as Regional Vegetation Committees, Catchment Management Committees, the Woody Weed Code of Practice Committee, government agencies, scientific organisations and the broader community. The focused nature of this project means that this information will supplement rather than completely replace the need to draw on general ecological principles for understanding of these issues.

A less detailed community-orientated report intended for wider circulation has been prepared as part of this project (Ayers *et al.* 2001). The raw data collected during the course of this investigation will be made available approximately three years after project completion (refer to Appendix 10).

References

Andersen, A. N. 1991. The ants of southern Australia. A guide to the Bassian Fauna. CSIRO. Australia.

Andersen, A. N. 1997. Functional groups and patterns of organization in North American ant communities: a comparison with Australia. *J. Biogeog.* **24:** 433 – 460.

Anon. 1901. Report of the Royal Commission to Inquire into the condition of the crown tenants, Western Division of New South Wales. Government Printer. Sydney.

Auld, T. D. 1995. The impact of herbivores on regeneration in four trees from arid Australia. *Rangel. J.* **17(2):** 213 – 227.

Ayers, D., Melville, G., Szigethy-Gyula, J., Read, D., Rees, R. and Atkinson, A. 2001. Woody weeds and biodiversity in western New South Wales. WEST 2000. Dubbo.

Baker, D. E., Miles. R. L and Eldershaw, V. J. 1992. Vegetation cover classes and soil nutrient status of the mulga lands of south-west Queensland. *Rangel. J.* **14(1):** 40 – 48.

Bastin, G. 1991. Rangeland reclamation on Atartinga station, Central Australia. *Aust. J. Soil and Water Cons.* **4(2):** 18 – 25.

Beadle, N. C. W. and Tchan, Y. T. 1955. Nitrogen economy in semi-arid plant communities. Part 1. The environment and general considerations. *Proc. Linn. Soc. NSW.* **80:** 62 – 70.

Beale, I. F. 1973. Tree density effects on yields of herbage and tree components in south western Queensland mulga (*Acacia aneura*) shrub. *Trop. Grasslds.* **7:** 135 – 142.

Belbin, L. 1991. The analysis of pattern in bio-survey data. *In* Margules, C. R., Austin, M. P. (Ed.). The nature conservation: cost effective biological surveys and data analysis. CSIRO.

Belbin, L. 1995. PATN. Pattern analysis package. Technical reference. CSIRO. Division of Wildlife and Ecology.

Blakers, M., Davies, S. J. J. F. and Reilly, P. N. 1984. The atlas of Australian birds. Royal Australasian Ornithologists Union. Melbourne University Press.

Booth, C. A., King, G. W. and Sanchez-Bayo, F. 1996a. Establishment of woody weeds in western New South Wales. 1. Seedling emergence and phenology. *Rangel. J.* **18(1):** 58 - 79.

Booth, C. A., Sanchez-Bayo, F. and King, G. W. 1996b. Establishment of woody weeds in western New South Wales. 2. Growth and competitive potential. *Rangel. J.* **18(1):** 80 – 98.

Bouskila, A. and Dickman, C. R. *in press.* Species diversity of vertebrate communities in arid lands. *In* Shachak, M., Pickett, S. T. A., Gosz, M. and Perevolotsky, A. (Eds.). Biodiversity in dry lands: toward a unified framework for research and management. Oxford University Press. Oxford.

Brooke, G. and McGarva, L. 1999. The glove box guide to plants of the NSW rangelands. NSW Agriculture.

Bureau of Meteorology. 1986. Rainfall district deciles – Australia. Australian Government Printing Service. Canberra.

Catana, A. J. 1963. The wandering quarter method of estimating populating density. *Ecology*. **44**: 349 - 360.

Chapman, A. D. 1991. Australian plant name index. Australian Flora and Fauna Series. Number 12 – 15. Australian Government Printing Service. Canberra.

Charley, J. L. and Cowling, S. W. 1968. Changes in soil nutrient status resulting from overgrazing and their consequences in plant communities of semi-arid areas. *Proc. Ecol. Soc. Aust.* **3:** 28 – 38.

Cogger, H. G. 1996. Reptiles and Amphibians of Australia. Fifth edition. Reed Books. Sydney.

Cunnningham, G. M., Mulham, W. E., Milthorpe, P. L. and Leigh, J. H. 1992. Plants of western New South Wales. Inkata Press. Melbourne.

Date, E. M. and Paull, D. P. 2000. Fauna survey of the north-west cypress/ironbark forests. Report prepared for State Forests of New South Wales.

Dawson, N. M. and Boyland, D. E. 1974. Western Arid Region Land Use Survey. Part 1. Technical Bulletin No. 12. Division of Land Utilization. Queensland Department of Primary Industry.

Department of the Environment, Sport and Territories. 1996. The National Strategy for the conservation of Australia's biological diversity**.** Department of the Environment, Sport and Territories.

Eldridge, D. J. and Robson, A. D. 1997. Bladeploughing and exclosure influence soil properties in a semi-arid Australian woodland. *J. Rangel. Manage.* **50:** 191 – 198.

Ford, H. A. 1989. Ecology of birds: an Australian perspective. Surrey Beatty and Sons Pty Limited.

Ford, H. A., Noske, S. and Bridges, L. 1986. Foraging of birds in eucalypt woodlands in north-eastern New South Wales. *Emu.* **86:** 168 – 179.

Friedel, M. H. and James, C. D. How does grazing of native pastures affect their biodiversity?. *In* Bradstock, R.A., Auld, T.D., Keith, D.A., Kingsford, R.T., Lunney, D. and Sivertsen, D.P. (Eds.). Conserving biodiversity: threats and solutions. Surrey Beatty and Sons. Chipping Norton.

Greene, R. S. B. 1992. Soil physical properties of three geomorphic zones in a semi-arid Mulga woodland. *Aust. J. Soil Res.* **30:** 55 - 69.

Greenslade, P. J. M. 1979. A guide to ants of South Australia. Special Educational Bulletin Series. South Australian Museum.

Hall, P., Melville, G. and Welsh, A. *in press*. Bias correction and bootstrap methods for a spatial sampling scheme. *Bernoulli*.

Harden, G. J. (Ed.). 1990-1994. Flora of New South Wales. Volumes 1-4. New South Wales University Press. Kensington.

Harland, R. (Ed.). 1993. Managing for woody weed control in western NSW Task Force Cobar, 10-16 June, 1992. Woody Weeds Task Force.

Harrington, G. N. 1986. Critical factors in shrub dynamics in eastern mulga lands. *In* Sattler, P. S. (Ed.). The mulga lands. Royal Society of Queensland.

Harrington, G. H. 1991. Effects of soil moisture on shrub seedling survival in a semi-arid grassland. *Ecology.* **72(3):** 1138 – 1149.

Hassall and Associates Pty Ltd. 1999. Woody weeds and biodiversity: a review of previous and current work. Unpublished report for WEST 2000.

Henle, K., Poschlod, P., Margules, C. and Settele, J. 1996. Species survival in relation to habitat quality, size, and isolation: summary conclusions and future directions. *In* Settele, J., Margules, C. R., Poschlod, P. and Henle, K. (Eds). Species survival in fragmented landscapes. pp 373 – 381. Kluwer Academic Publications. The Netherlands.

Higgins, P. J. (Ed.). 1999. Handbook of Australian, New Zealand and Antarctic Birds. Volume 4: Parrots to Dollarbird. Oxford University Press. Melbourne.

Hill, G. J. E. 1981. A study of habitat preferences in the Grey Kangaroo. *Aust. Wild. Res.* **8:** 245 – 254.

Holmes, R. T. and Recher, H. F. 1986. Search tactics of insectivorous birds foraging in an Australian eucalypt forest. *The Auk*. **103:** 515 – 530.

Inter-Departmental Committee. 1969. Report of the Inter-departmental committee on scrub and timber growth in the Cobar-Byrock district and other areas of the Western Division of N.S.W. Government Printer. Sydney.

Irons, N. M. and Quinlan, E. E. 1988. A review of information relevant to the Mulga rangelands of western New South Wales. Technical Report No. 5. Soil Conservation Service of NSW.

Johns, G. G. 1983. Runoff and soil loss in a semi-arid invaded Poplar Box (*Eucalyptus populnea*) woodland. *Aust. Rangel. J.* **5(1):** 3 – 12.

Jones, C. 2000. The great salinity debate: part I. Controlling the salinisation process. *Stipa Newsl.* **13:** 8 – 12.

Jones, C. 2000b. The great salinity debate: part II. Why the recharge-discharge model is fundamentally flawed. *Stipa Newsl.* **14:** 6 – 11.

Krebs, C. J. 1985. Ecology. The experimental analysis of distribution and abundance. Third Edition. Harper and Row, Publishers, Inc. New York.

Landsberg, J., James, C. D., Morton, S. R., Hobbs, T. J., Stol, J., Drew, A. and Tongway, H. 1997. The effects of artificial sources of water on rangeland biodiversity. CSIRO Division of Wildlife and Ecology.

Ludwig, J. A. and Tongway, D. J. 1995. Spatial organisation of landscapes and its function in semi-arid woodlands, Australia. *Landscape Ecology.* **10(1):** 51 – 63.

Ludwig, J., Tongway, D., Freudenberger, D., Noble, J. and Hodgkinson, K. 1997. Landscape ecology, function and management: principles from Australia's Rangelands. CSIRO. Australia.

Ludwig, J. A., Wiens, J. A. and Tongway, D. J. 2000. A scaling rule for landscape patches and how it applies to conserving soil resources in savannas. *Ecosystems.* **3:** 84 – 97.

MacNally, R. 2000. Coexistence of a locally undifferentiated foraging guild: avian snatchers in a southeastern Australian forest. *Austral Ecol.* **25:** 69 – 82.

Major, R., Christie, F. and Gowing, G. 1998. The value of remnant vegetation for birds in the New South Wales wheatbelt. Final report for the Environmental Trusts. Australian Museum.

Mazzer, T., Ellis, M., Smith, J. Ayers, D., Cooper, M., Wallace, G. and Langdon, A. 1998. The fauna of western New South Wales: the southern mallee region. NSW NPWS.

McCullagh, P. and Nelder. J. A. 1989. Generalised Linear Models. Second edition. Chapman and Hall. London.

McCullough, D. R. and McCullough, Y. 2000. Kangaroos in outback Australia. Comparative ecology and behaviour of three coexisting species. Columbia University Press. New York.

McDonald, R. C., Isbell, R. F., Speight, J. G., Walker, J. and Hopkins, M. S. 1998. Australian soil and land survey field handbook. Second edition. CSIRO. Australia.

Melbourne, B. A. 1999. Bias in the effect of habitat structure on pitfall traps: an experimental evaluation. *Aust. J. Ecol.*. **24:** 228 – 239.

Moreno, C. E. and Halffter, G. 2001. On the measure of sampling effort used in species accumulation curves. *J. Applied Ecology*. **38(2):** 487 - 490.

Moss, A. J., Walker, P. H. and Hutka, J. 1979. Raindrop stimulated transportation in shallow water flow: an experimental study. *Sediment Geol.* **22:** 165- - 184.

Mutchler, G. K. and Green, J. D. 1980. Effects of slope length on erosion from low slopes. *Trans. Amer. Soc. Agric. Eng.* **23:** 866 – 70.

Noble, J. 1994. Pasture response to shrub reduction in contrasting land classes and landscape units. *In* Daly, R. and Ludwig, J. (Eds). Restoration of degraded rangelands. Report to the National Soil Conservation Program.

Noble, J. C. 1997. The delicate and noxious scrub: CSIRO studies on native tree and shrub proliferation in the semi-arid woodlands of eastern Australia. CSIRO. ACT.

Noble, J. C. and Hodgkinson, K. C. 1992. The woody weed problem in Australian rangelands: assessment, ecology and prospects for management. *In* Woody Weeds Task Force. Proceedings of a national workshop co-ordinated by the Woody Weeds Task Force Cobar, 10-16 June, 1992.

NSW National Parks and Wildlife Service. 1999. NSW Biodiversity Strategy. NSW National Parks and Wildlife Service.

Oliver, I. and Beattie, A. J. 1995. Invertebrate morphospecies as surrogates for species: a case study. *Conservation Biology*. **10(1):** 99 – 109.

Oliver, I., Beattie, A., Holmes, A., Dangerfield, M. and Gillings, M. 1999. Land systems as surrogates for biodiversity. Key Centre for Biodiversity and Bioresources. Final report to the Resource and Conservation Assessment Council.

Page, M., Beeton, R. J. S. and Mott, J. J. 2000. Grass response to shrub removal in two semi-arid vegetation communities. *Rangel. J.* **22(2):** 220 – 234.

Payne, A. L., Curry, P. J. and Spencer, G. F. 1987. An inventory and condition survey of rangelands in the Carnarvon Basin. W. A. Technical Bulletin No. 73. W. A. Department of Agriculture.

Poore, M. E. D. 1955. The use of the phytosociological methods in ecological investigations. I. The Braun-Blanquet system. *J. of Ecology*. **43:** 226 – 244.

Pressey, R. L. and Taffs, K. H. 2001. Sampling of land types by protected areas: three measures of effectiveness applied to western New South Wales. *Biol. Cons.* **101:** 105 – 117.

Pressland, A. J. 1976. Possible effects of removal of Mulga on rangeland stability in south western Queensland. *Aust. Rangel. J.* **1:** 24 – 30.

Pressland, A. J. and Lehane, K. J. 1982. Runoff and the ameliorating effect of plant cover in the mulga communities of south western Queensland. *Aust. Rangel. J.* **4(1):** 16-20.

Purvis, B. 1986. Nurture the land: my philosophies of pastoral management in central Australia. *Aust. Rangel. J.* **8(2):** 110 - 117.

Purvis, B. 1988. The story of Umberumbra. *Range Manage. Newsl.* **August 1988:** 13 – 20.

Reader's Digest. 1986. Complete book of Australian birds. Reader's Digest. Sydney.

Recher, H. F. and Davis, W. E. 1997. Foraging ecology of a Mulga bird community. *Wildl. Res.* **24:** 27 – 43.

Recher, H. F., Gowing, G., Kavanagh, R., Shields, J. and Rohan-Jones, W. 1983. Birds, resources and time in a tablelands forest. *In* Purdie, R. W. and Noble, I. R. (Eds.). Mountain ecology in the Australian region. *Proceedings of the Ecological Society of Australia.* Volume 12.

Recher, H. F., Holmes, R. T., Schulz, M., Shields, J. and Kavanagh, R. 1985. Foraging patterns of breeding birds in eucalypt forest and woodland of southeastern Australia. *Aust. J. Ecol.* **10:** 399 – 419.

Robinson, N. J. 1997. Preservation of biodiversity on grazing lands. *In* Hale, P. and Lamb, D. (Eds.). Conservation outside nature reserves. Centre for Conservation Biology. The University of Queensland.

Robson, A. D. 1995. The effects of grazing exclusion and blade-ploughing on semi-arid woodland vegetation in north-western New South Wales over 30 months. *Rangel. J.* **17(2):** 111 – 127.

Scanlan, J. C. and Burrows, W. H. 1990. Woody overstorey impact on herbaceous understorey in *Eucalytpus* spp. communities in central Queensland. *Aust. J. Ecol.* **15:** 846 – 849.

Scholte,T. S. 1989. Vegetation-soil relations in an areas with sealed Chromic Luvisols, Kenya. *Arid Soil Res. and Rehab.* **3:** 337 – 348.

Scriven, R. N. 1988. A review of information relevant to the Belah and bluebush rangelands of western New South Wales. Technical Report No. 10. Soil Conservation Service of NSW.

Seddon, J., Briggs, S. and Doyle, S. 2001. Birds in woodland remnants of the central wheat/sheep belt of New South Wales. Report to the Natural Heritage Trust. NSW National Parks and Wildlife Service. Sydney.

Shattuck, S. O. 1999. Australian ants. Their biology and identification. Monographs on invertebrate taxonomy; Vol. 3. CSIRO Publishing. Collingwood.

Slater, P. 1974. A field guide to Australian birds. Volume 2: Passerines. Rigby. Adelaide.

Smith, J. E. 1997. Ecological patterns in a terrestrial bird community in arid north-western New South Wales. Unpublished PhD thesis. University of New England.

Smith, J., Ellis, M., Ayers, D., Mazzer, T., Wallace, G., Langdon, A. and Cooper, M. 1998. The fauna of western New South Wales: the southern mallee region. NSW NPWS.

Stanger, M., Clayton, M., Schodde, R., Wombey, J. and Mason, I. 1998. CSIRO list of Australian vertebrates. A reference with conservation status. CSIRO Publishing. Victoria.

Tongway, D. and Hindley, N. 1995. Manual for soil condition assessment of tropical grasslands. CSIRO. Canberra.

Tongway, D. J. and Ludwig, J. A. 1990. Vegetation and soil patterning in semi-arid mulga lands of eastern Australia. *Aust. J. Ecol.* **15:** 23 – 34.

Tongway, D. J. and Ludwig, J. A. 1994. Small-scale resource heterogeneity in semi-arid landscapes. *Pac. Con. Biol.* **1:** 210 – 208.

Tongway and Ludwig. 1996. Rehabilitation of semiarid landscapes in Australia. I. Restoring productive soil patches. *Restor. Ecol.* **4(4):** 3880-0397.

Tongway, D. J. and Smith , E. L. 1989. Soil surface features as indicators of rangeland site productivity. *Aust. Rangel. J.* **11(1):** 15 – 20.

Tongway, D. J., Ludwig, J. A. and Whitford, W. G. 1989. Mulga log mounds: fertile patches in the semi-arid woodlands of eastern Australia. *Aust. J. Ecol.* **14:** 263 - 268.

Tunstall, B. R., Torsell, B. W. R., Moore, R. M., Robertson, J. A. and Goodwin, W. F. 1981. Vegetation change in poplar box *Eucalyptus populnea* shrub woodlands. *Aust. J. Agric. Res.* **23:** 405 – 410.

Walker, P. J. 1991. Land systems of western New South Wales. Soil Conservation Service of New South Wales. Technical Report No. 25.

Walker, J., Moore, R. M. and Robertson, J. A. 1972. Herbage response to tree and shrub thinning in *Eucalyptus populnea* shrub woodlands. *Aust. J. Agric. Res.* **23:** 405 – 410.

Willott, S. J. 2001. Species accumulation curves and the measure of sampling effort. J. *Applied Ecology.* **38(2):** 484 - 486.

Woody Weeds Task Force. 1990. Woody weeds in western N.S.W. Background statement. Information Sheet 5.

Woody Weeds Task Force. 1992. Proceedings of a national workshop co-ordinated by the Woody Weeds Task Force Cobar, 10-16 June, 1992.

Yair, A., Sharon, D. and Lavee, H. 1979. Trends in runoff erosion process over an arid limestone hillside, Northern Negev, Israel. *In* The hydrology of areas of low precipitation. Proc. Canberra Symp. December 1979. International Association of Hydrological Sciences Publ. No. 128. pp 35 – 50.

Appendix 1: Assessment of potentially confounding factors

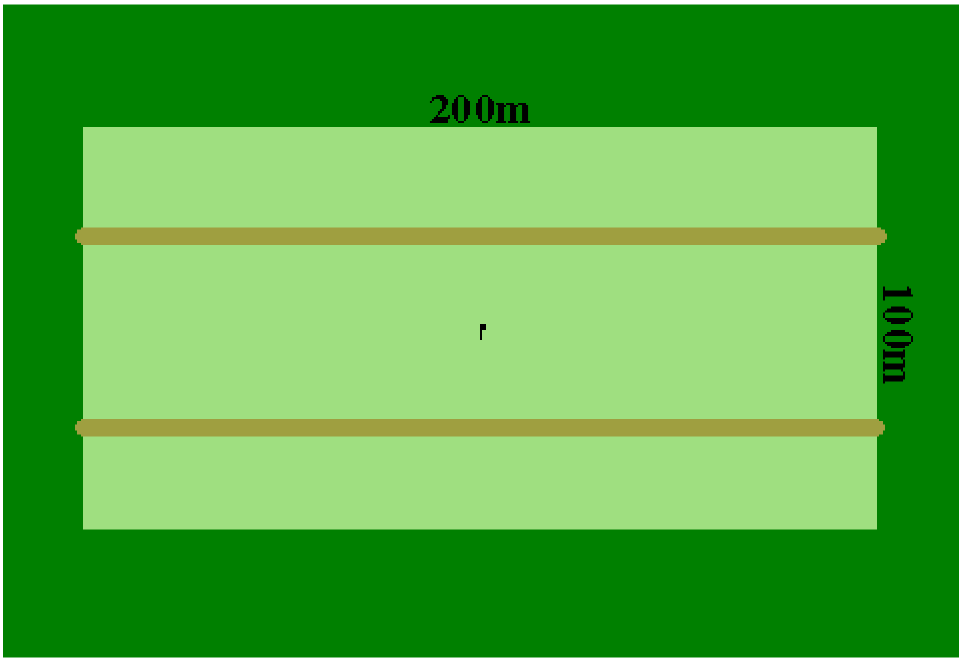
Site and pitfall trap attributes measured at each study site. Variable format is indicated (factor vs numeric). A diagrammatic representation of a study site depicting the location of the microhabitat attribute transects is depicted below.

Attributes	Measurement method	Type of variable
Landscape-scale attributes		
Altitude	Assessed from topographic maps. Altitude estimated from contour lines and spot heights.	Numeric
Morpho-terrain	Assessed as per the Australian Soil and Land Survey Field Handbook (Landform chapter). Relevant categories listed in Appendix 3.	Factor
Element	Assessed as per the Australian Soil and Land Survey Field Handbook (Landform chapter). Relevant categories listed in Appendix 3.	Factor
Pattern	Assessed as per the Australian Soil and Land Survey Field Handbook (Landform chapter). Relevant categories listed in Appendix 3.	Factor
Distance from water (km)	Assessed from maps or using GPS. Distance to closest watering point from site centre.	Numeric
Distance to water for stock (km)	Assessed from maps or using GPS. Distance to closest accessible watering point from site centre.	Numeric
Physical attributes		
Soil depth	Estimated for site. Two categories - deep and shallow.	Factor
Surface texture	Relates to soil permeability. Assessed for site as per Tongway and Hindley (1995). Two infiltration rate categories: slow (=sandy clay loam to sandy clay); and moderate (=sandy loam to silt loam).	Factor
Soil texture	Estimated using bolus formation as part of Landscape Function Analysis process. Averaged where more than one estimate made.	Numeric
Stability	Average Landscape Function Analysis Soil Stability score calculated for site (weighted to reflect relative abundance of each patch type on site).	Numeric
Infiltration	Average Landscape Function Analysis Infiltration score calculated for site (weighted to reflect relative abundance of each patch type on site).	Numeric
Nutrient cycling status	Average Landscape Function Analysis Nutrient Cycling Status score calculated for site (weighted to reflect relative abundance of each patch type on site).	Numeric

Attributes	Measurement method	Type of variable
Woody shrub attributes		
Height	Estimated for each measured shrub on site to nearest 5 cm, and averaged for site. Only those individuals deemed part of the shrub layer (between 30 cm and 4 m inclusive) were measured.	Numeric
Canopy openness	Estimated for each measured shrub on site according to the Australian Soil and Land Survey Field Handbook (Vegetation chapter), and averaged for site.	Numeric
Woody shrub species	No. of species, and most dominant species, recorded per site.	
Disturbance features		
Fire severity	Broadly estimated based on presence/absence of physical evidence of fire on and close to site. Time elapsed since last fire, and intensity estimated for site. Intensity only analysed.	Numeric
Logging severity	Broadly estimated based on presence/absence of physical evidence of tree-felling, ringbarking, lopping and tree-pushing on site. Time elapsed since last "logging", and intensity estimated for site. Intensity only analysed.	Numeric
Grazing severity	Broadly estimated based on presence/absence of physical evidence of grazing on site. Time elapsed since last grazing, and intensity estimated for site. Intensity only analysed.	Numeric
Rabbit disturbance	Broadly estimated based on presence/absence of physical evidence of rabbit disturbance (diggings, scratching, burrows) on site. Time elapsed since last rabbit disturbance, and intensity estimated for site. Intensity only analysed.	Numeric

Attributes	Measurement method	Type of variable
Microhabitat attributes		
No. of logs on ground 5-15cm (sm. logs)	Assessed in two 4 m wide strips extending lengthwise along site. Maximum diameter of all logs occurring partially or wholly within each strip was measured. Those with a maximum diameter of 5-15 cm were counted, and summed for the site.	Numeric
No. of logs on ground 15-25cm	Assessed in two 4 m wide strips extending lengthwise along site. Maximum diameter of all logs occurring partially or wholly within each strip was measured. Those with a maximum diameter of 15-25 cm were counted, and summed for the site.	Numeric
No. of logs on ground >25cm	Assessed in two 4 m wide strips extending lengthwise along site. Maximum diameter of all logs occurring partially or wholly within each strip was measured. Those with a maximum diameter of >25 cm were counted, and summed for the site.	Numeric
No. tree holes	Assessed in two 4 m wide strips extending lengthwise along site. The number (and dimensions) of holes in trees occurring within each strip was measured, and summed for the site.	Numeric
No. tree cracks	Assessed in two 4 m wide strips extending lengthwise along site. The number (and dimensions) of cracks in trees occurring within each strip was measured, and summed for the site.	Numeric
No. tree spouts	Assessed in two 4 m wide strips extending lengthwise along site. The number (and dimensions) of spouts in trees occurring within each strip was measured, and summed for the site.	Numeric
Shedding bark on ground (P/A)	Assessed in two 4 m wide strips extending lengthwise along site. Accumulations of shed bark on the ground occurring partially or wholly within each strip were noted.	Numeric
Shedding bark on tree (P/A)	Assessed in two 4 m wide strips extending lengthwise along site. Presence of shedding bark on trees occurring partially or wholly within each strip was noted.	Numeric
Flowering species (P/A)	Assessed in two 4 m wide strips extending lengthwise along site. Identities of flowering plant species occurring within each strip were noted.	Numeric
Fruiting species (P/A)	Assessed in two 4 m wide strips extending lengthwise along site. Identities of fruiting or seeding plant species occurring within each strip were noted.	Numeric
Mistletoe (P/A)	Assessed in two 4 m wide strips extending lengthwise along site. Presence of mistletoe on trees occurring within each strip was noted.	Numeric
% WW branches dead	Assessed in two 4 m wide strips extending lengthwise along site. Proportion of dead branches on the woody shrubs present within each strip was estimated, and averaged for site.	Numeric

Attributes	Measurement method	Type of variable
Microhabitat attributes (cont'd)		
Cracking soils (P/A)	Assessed in two 4 m wide strips extending lengthwise along site. Presence of cracking soil within each strip was noted. (None present on any site.)	Numeric
Rocks and caves (P/A)	Assessed in two 4 m wide strips extending lengthwise along site. Presence of rock outcrops and caves within each strip was noted. (None present on any site.)	Numeric
Cryptogamic cover (%)	Assessed in two 4 m wide strips extending lengthwise along site. Proportion of ground with continuous cryptogamic cover within each strip was estimated, and averaged for the site.	Numeric
Solid litter cover (%)	Assessed in two 4 m wide strips extending lengthwise along site. Proportion of ground with continuous leaf litter cover within each strip was estimated, and averaged for the site.	Numeric
Tree crown separation	Estimated (as the ratio of the mean distance between tree crowns relative to the mean crown size) for each site half, and averaged for the site.	Numeric
Leaf litter accumulations (P/A)	Assessed in two 4 m wide strips extending lengthwise along site. Presence of leaf litter accumulations within each strip was noted.	Numeric
Stags (P/A)	Assessed for site. Presence of stags on site was noted.	Numeric
Surface rock (%)	Assessed in two 4 m wide strips extending lengthwise along site. Proportion of ground with loose rock cover within each strip was estimated, and averaged for the site.	Numeric
Pitfall trap attributes		
Distance to closest woody shrub	Measured between pitfall trap and closest woody shrub stem.	Numeric
Trap location	Location of trap with respect to shrub density. Two categories - within clump, and open area.	Factor
Ground cover (%)	Estimated within 1 m quadrat located to north of pitfall trap (thereby avoiding disturbance immediately surrounding pitfall trap).	Numeric
Leaf litter (%)	Estimated within 1 m quadrat located to north of pitfall trap (thereby avoiding disturbance immediately surrounding pitfall trap).	Numeric
Distance to closest tree (m)	Measured between pitfall trap and closest tree stem. Assessed for invertebrate pitfall traps only.	Numeric
Distance to closest log (m)	Measured between pitfall trap and closest log. Assessed for invertebrate pitfall traps only.	Numeric
Canopy	Subjective assessment as to location of trap beneath canopy of tree, shrub. Assessed for invertebrate pitfall traps only.	Factor



Diagrammatic representation of a study site, indicating location of the site attribute assessment transects. The 100 m-wide buffer is not to scale.

Appendix 2: Guilds and taxa associations

Guild names reflect the ecological attributes that describe the guild; those for birds and ants reflect the literature drawn on to determine guild composition (refer to sections 2.1.4.2 –flora; 2.1.5.3 – mammals and reptiles; 2.1.5.1 – birds; 2.1.5.5 – ants). Taxa associations were identified from PATN analyses conducted on each taxonomic group for each survey region, or across the three regions for the Three regions associations, (refer to section 2.2.1).

Guilds

Flora

Drought Avoiders Plant Guild

Alternanthera species A
Alyssum linifolium
Atriplex suberecta
Brachyscome lineariloba
Calandrinia pumila
Calotis hispidula
Carrichtera annua
Carthamus lanatus
Chamaesyce drummondii
Chenopodium cristatum
Chenopodium melanocarpum
Cucumis myriocarpus
Cuphonotus andraeanus
Dactyloctenium radulans
Daucus glochidiatus
Erodium crinitum
Erophila verna ssp. *verna*
Gnephosis arachnoidea
Goodenia havilandii
Gypsophila tubulosa
Harmsiodoxa blennodioides
Hordeum leporinum
Lepidium papillosum
Lepidium pseudohyssopifolium
Leptorhynchos baileyi
Leptorhynchos tetrachaetus
Medicago laciniata
Millotia greevesii var. *greevesii*
Nicotiana goodspeedii
Pentaschistis airoides
Pimelea trichostachya
Plantago turrifera
Portulaca intraterranea
Ptilotus gaudichaudii
Ptilotus gaudichaudii var. *gaudichaudii*
Ptilotus gaudichaudii var. *parviflorus*
Rhodanthe floribunda
Rostraria pumila
Schismus barbatus
Sclerolaena birchii
Silene nocturna
Sisymbrium erysimoides
Sisymbrium orientale
Sonchus oleraceus
Spergularia marina
Tetragonia tetragonioides
Tragus australianus
Tribulus terrestris
Urochloa subquadripara
Vittadinia pustulata
Vulpia myuros
Zygophyllum ammophilum
Zygophyllum glaucum
Zygophyllum iodocarpum
Zygophyllum ovatum
Chloris pectinata
Enneapogon avenaceus
Heliotropium species A
Lepidium phlebopetalum
Solanum cleistogamum
Brachyachne ciliaris
Salsola kali var. *kali*
Convolvulus microsepalus
Chenopodium desertorum ssp. anidiophyllum
Bracteantha viscosa
Sauropus trachyspermus
Chenopodium desertorum ssp. *microphyllum*
Chenopodium desertorum
Vittadinia cuneata

Drought Endurers Plant Guild

Abutilon sp.
Abutilon fraseri
Abutilon otocarpum
Amphipogon caricinus var. *caricinus*
Amyema sp.
Amyema linophyllum ssp. *orientale*

Amyema lucasii
Amyema miquelii
Amyema miraculosum ssp. *boormanii*
Amyema quandang
Amyema quandang var. *quandang*
Apophyllum anomalum
Araujia sericiflora
Aristida behriana
Aristida contorta
Aristida jerichoensis var. *jerichoensis*
Aristida jerichoensis var. *subspinulifera*
Astroloma sp.
Atriplex eardleyae
Atriplex limbata
Atriplex stipitata
Austrodanthonia caespitosa
Austrodanthonia setacea
Austrostipa acrociliata
Austrostipa nitida
Austrostipa nodosa
Austrostipa scabra
Austrostipa scabra subsp. *scabra*
Austrostipa tuckeri
Boerhavia dominii
Bothriochloa macra
Brachycome ciliaris var. *ciliaris*
Brachyscome ciliaris
Bulbine alata
Bulbine spp.
Calotis cuneifolia
Calotis lappulacea
Cheilanthes sieberi ssp. *sieberi*
Chloris truncata
Citrullus colocynthis
Convolvulus erubescens
Cullen tenax
Dichanthium sericeum
Digitaria brownii
Digitaria hystrichoides
Dissocarpus paradoxus
Einadia nutans ssp. *eremaea*
Einadia nutans ssp. *nutans*
Einadia nutans ssp. *oxycarpa*
Elymus scaber
Elymus scaber var. *scaber*
Enchylaena tomentosa
Enneapogon nigricans
Enteropogon sp.
Enteropogon acicularis
Eragrostis sp.
Eragrostis eriopoda
Eragrostis lacunaria
Fimbristylis dichotoma
Glossogyne tannensis
Glycine sp.
Glycine clandestina
Goodenia cycloptera
Goodenia fascicularis
Hibiscus sturtii var. *grandiflorus*
Jasminum lineare
Linum marginale
Lysiana exocarpi
Lysiana exocarpi ssp. *exocarpi*
Lysiana exocarpi ssp. *tenuis*
Lysiana murrayi
Lysiana subfalcata
Maireana sp.
Maireana enchylaenoides
Maireana georgei
Maireana humillima
Maireana lobiflora
Maireana sclerolaenoides
Maireana trichoptera
Maireana triptera
Marsdenia australis
Minuria leptophylla
Monachather paradoxa
Olearia calcarea
Olearia pimeleoides
Oxalis corniculata
Panicum effusum
Panicum queenslandicum var. *queenslandicum*
Panicum subxerophilum
Parsonsia eucalyptophylla
Paspalidium constrictum
Phyllanthus lacunellus
Pimelea microcephala ssp. *microcephala*
Podolepis capillaris
Ptilotus atriplicifolius var. *atriplicifolius*
Ptilotus exaltatus var. *exaltatus*
Ptilotus obovatus
Ptilotus obovatus var. *obovatus*
Rhagodia spinescens
Rhyncharrhena linearis
Rumex brownii
Salvia verbenaca
Scaevola spinescens
Sclerolaena bicornis
Sclerolaena convexula
Sclerolaena diacantha
Sclerolaena eriacantha
Sclerolaena lanicuspis
Sclerolaena longicuspis
Sclerolaena obliquicuspis
Sclerolaena patenticuspis
Sclerolaena tricuspis
Sida sp.
Sida ammophila
Sida corrugata
Sida cunninghamii
Sida fibulifera

Sida intricata
Sida trichopoda
Solanum esuriale
Solanum ferocissimum
Spartothamnella puberula
Sporobolus caroli
Swainsona affinis
Templetonia egena
Templetonia sulcata
Teucrium racemosum
Themeda australis
Thyridolepis mitchelliana
Tripogon loliiformis
Triraphis mollis
Velleia paradoxa
Vittadinia condyloides
Vittadinia cuneata var. *cuneata*
Vittadinia cuneata var. *hirsuta*
Wahlenbergia communis
Wahlenbergia luteola
Zygophyllum eremaeum

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Vertebrate fauna

Arboreal Geckoes
Diplodactylus ciliaris
Diplodactylus intermedius
Gehyra variegata
Oedura marmorata
Eremiascincus richardsonii
Egernia inornata
Lerista labialis
Lerista muelleri
Lerista punctatovittata
Ctenophorus pictus
Pogona vitticeps
Tiliqua occipitalis
Trachydosaurus rugosus
Varanus gouldii
Varanus varius

Terrestrial Geckoes
Heteronotia binoei
Diplodactylus steindachneri
Diplodactylus vittatus
Nephrurus levis
Rhynchoedura ornata

Burrowing Reptiles
Ramphotyphlops bituberculatus
Ramphotyphlops sp.
Menetia greyii

Small Terrestrial Skinks
Ctenotus allotropis
Ctenotus leonhardii
Ctenotus regius
Ctenotus schomburgkii
Ctenotus sp.
Morethia boulengeri

Large Terrestrial Lizards
Ctenophorus nuchalis

Arboreal Skinks
Cryptoblepharus carnabyi
Egernia striolata

Macropods
Macropus fuliginosus
Macropus giganteus
Macropus rufus

Birds

Scientific Name	Common Name	Tree and Shrub Canopy-feeding Insectivores			Ground-feeding Insectivores				Ground-feeding Granivores		Honey-eaters	Aerial-feeders	Raptors	Scavengers	Herbivores and Omnivores
		Bark	Foliage		Probers	Pursuers	Pouncers	Gleaners	Non-passerine	Passerine					
			Gleaners	Snatchers											
Dromaius novaehollandiae	Emu							✓	✓						✓
Coturnix novaezelandiae	Stubble Quail								✓						
Aquila audax	Wedge-tailed Eagle												✓		
Accipiter fasciatus	Brown Goshawk												✓		
Falco peregrinus	Peregrine Falcon												✓		
Falco cenchroides	Australian Kestrel												✓		
Turnix velox	Little Button-quail								✓						
Turnix varia	Painted Button-quail								✓						
Phaps chalcoptera	Common Bronzewing								✓						
Ocyphaps lophotes	Crested Pigeon								✓						
Cacatua leadbeateri	Pink Cockatoo														✓
Cacatua roseicapilla	Galah								✓						
Nymphicus hollandicus	Cockatiel								✓						
Aprosmictus erythropterus	Red-winged Parrot								✓						
Psephotus haematonotus	Red-rumped Parrot								✓						

Scientific Name	Common Name	Tree and Shrub Canopy-feeding Insectivores			Ground-feeding Insectivores				Ground-feeding Granivores		Honey-eaters	Aerial-feeders	Raptors	Scavengers	Herbivores and Omnivores
		Bark	Foliage		Probers	Pursuers	Pouncers	Gleaners	Non-passerine	Passerine					
			Gleaners	Snatchers											
Psephotus varius	Mulga Parrot								✓						✓
Barnardius barnardi	Mallee Ringneck								✓						
Northiella haematogaster	Blue Bonnet								✓						
Melopsittacus undulatus	Budgerigar								✓						
Cuculus pallidus	Pallid Cuckoo		✓												
Chrysococcyx osculans	Black-eared Cuckoo		✓												
Chrysococcyx basalis	Horsfield's Bronze-Cuckoo		✓												
Tyto alba	Barn Owl												✓		
Podargus strigoides	Tawny Frogmouth												✓		
Aegotheles cristatus	Australian Owlet-nightjar											✓	✓		
Halcyon pyrrhopygia	Red-backed Kingfisher					✓									
Merops ornatus	Rainbow Bee-eater											✓			
Climacteris picumnus	Brown Treecreeper	✓						✓							
Climacteris affinis	White-browed Treecreeper	✓													
Malurus cyaneus	Superb Blue Wren							✓							

Scientific Name	Common Name	Tree and Shrub Canopy-feeding Insectivores			Ground-feeding Insectivores				Ground-feeding Granivores		Honey-eaters	Aerial-feeders	Raptors	Scavengers	Herbivores and Omnivores
		Bark	Foliage		Probers	Pursuers	Pouncers	Gleaners	Non-passerine	Passerine					
			Gleaners	Snatchers											
Malurus splendens	Splendid Wren		✓					✓							
Malurus lamberti	Variegated Wren		✓	✓											
Pardalotus striatus	Striated Pardalote		✓												
Gerygone fusca	Western Gerygone		✓	✓			✓					✓			
Smicrornis brevirostris	Weebill		✓												
Acanthiza nana	Yellow Thornbill		✓												
Acanthiza apicalis	Inland Thornbill		✓												
Acanthiza uropygialis	Chestnut-rumped Thornbill		✓												
Acanthiza reguloides	Buff-rumped Thornbill	✓	✓					✓							
Acanthiza chrysorrhoa	Yellow-rumped Thornbill							✓							
Aphelocephala leucopsis	Southern Whiteface							✓		✓					
Melithreptus brevirostris	Brown-headed Honeyeater		✓								✓				
Plectorhyncha lanceolata	Striped Honeyeater										✓				
Phylidonyris albifrons	White-fronted Honeyeater										✓				
Lichenostomus virescens	Singing Honeyeater		✓	✓							✓				

Scientific Name	Common Name	Tree and Shrub Canopy-feeding Insectivores			Ground-feeding Insectivores				Ground-feeding Granivores		Honey-eaters	Aerial-feeders	Raptors	Scavengers	Herbivores and Omnivores
		Bark	Foliage		Probers	Pursuers	Pouncers	Gleaners	Non-passerine	Passerine					
			Gleaners	Snatchers											
Manorina flavigula	Yellow-throated Miner		✓					✓			✓				
Acanthagenys rufogularis	Spiny-cheeked Honeyeater		✓								✓				
Philemon citreogularis	Little Friarbird										✓				
Ephthianura aurifrons	Orange Chat					✓									
Ephthianura tricolor	Crimson Chat		✓			✓		✓							
Petroica goodenovii	Red-capped Robin						✓								
Melanodryas cucullata	Hooded Robin			✓			✓								
Pomatostomus temporalis	Grey-crowned Babbler		✓		✓										
Pomatostomus superciliosus	White-browed Babbler		✓		✓										
Pomatostomus ruficeps	Chestnut-crowned Babbler				✓			✓							
Pomatostomus halli	Hall's Babbler				✓										
Daphoenositta chrysoptera	Varied Sitella	✓													
Oreoica gutturalis	Crested Bellbird							✓							
Pachycephala rufiventris	Rufous Whistler		✓	✓								✓			
Colluricincla harmonica	Grey Shrike-thrush	✓	✓		✓			✓							

Scientific Name	Common Name	Tree and Shrub Canopy-feeding Insectivores			Ground-feeding Insectivores				Ground-feeding Granivores		Honey-eaters	Aerial-feeders	Raptors	Scavengers	Herbivores and Omnivores
		Bark	Foliage		Probers	Pursuers	Pouncers	Gleaners	Non-passerine	Passerine					
			Gleaners	Snatchers											
Myiagra inquieta	Restless Flycatcher						✓					✓			
Grallina cyanoleuca	Australian Magpie Lark				✓			✓							
Rhipidura leucophrys	Willie Wagtail		✓			✓		✓				✓			
Coracina maxima	Ground Cuckoo-shrike					✓									
Coracina novaehollandiae	Black-faced Cuckoo-shrike	✓		✓			✓								
Lalage sueurii	White-winged Triller		✓					✓							
Artamus personatus	White-breasted Woodswallow											✓			
Artamus superciliosus	White-browed Woodswallow											✓			
Artamus cinereus	Black-faced Woodswallow						✓	✓				✓			
Cracticus nigrogularis	Pied Butcherbird		✓	✓			✓								
Cracticus torquatus	Grey Butcherbird		✓	✓			✓								
Gymnorhina tibicen	Australian Magpie				✓			✓							
Corvus bennetti	Little Crow													✓	
Corvus coronoides	Australian Raven													✓	

Scientific Name	Common Name	Tree and Shrub Canopy-feeding Insectivores			Ground-feeding Insectivores				Ground-feeding Granivores		Honey-eaters	Aerial-feeders	Raptors	Scavengers	Herbivores and Omnivores
		Bark	Foliage		Probers	Pursuers	Pouncers	Gleaners	Non-passerine	Passerine					
			Gleaners	Snatchers											
Corcorax melanorhamphos	White-winged Chough				✓			✓							
Struthidea cinerea	Apostlebird							✓							
Chlamydera maculata	Spotted Bowerbird														
Anthus novaeseelandiae	Richard's Pipit					✓		✓							
Poephila bichenovii	Double-barred Finch									✓					
Poephila guttata	Zebra Finch									✓					
Dicaeum hirundinaceum	Mistletoebird														
Cinclorhamphus mathewsi	Rufous Songlark						✓	✓							

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Ants

Dominant Dolichoderinae

*Iridomyrmex*0001
*Iridomyrmex*0002
*Iridomyrmex*0003
*Iridomyrmex*0004
*Iridomyrmex*0005
*Iridomyrmex*0006
*Iridomyrmex*0007
*Iridomyrmex*0008
*Iridomyrmex*0009
*Iridomyrmex*0010
*Iridomyrmex*0011
*Iridomyrmex*0012
*Iridomyrmex*0013
*Iridomyrmex*0014
*Iridomyrmex*0015

Subordinate Camponotini

*Calomyrmex*0001
Camponotus ephippium
Camponotus sp. A
Camponotus nigriceps
Camponotus sp. B
Camponotus sp. C
Camponotus sp. nr. *aurocinctus*
Camponotus sp. nr. *capito*
Camponotus sp. D
Camponotus tricoloratus
Camponotus whitei
Opisthopsis rufithorax
Polyrhachis sp. A

Hot Climate Specialists

Melophorus sp. A
Melophorus
Meranoplus sp. A
Meranoplus sp. B
Meranoplus sp. C
Meranoplus sp. D
Meranoplus sp. E
Meranoplus sp. F
Meranoplus sp. G
Meranoplus sp. H
Meranoplus sp. I
*Meranoplus*0010
Meranoplus sp. K
*Meranoplus*0012
Monomorium sp. M
Monomorium sp.

Cold Climate Specialists

Dolichoderus sp. A
*Notoncus*0001
*Stigmacros*0001
Stigmacros sp. A
*Stigmacros*0003
Stigmacros sp. B
Stigmacros aemula
Stigmacros elegans
Stigmacros sp. C
Stigmacros aciculata
Stigmacros pilosella

Cryptic Species

Hypoponera sp. A
Brachyponera lutea
*Cerapachys*0005
Solenopsis sp. A
*Solenopsis*0002

Opportunists

Cardiocondyla sp. A
*Cardiocondyla*0002
Paratrechina sp. A
*Rhytidoponera*0001
Rhytidoponera metallica
*Rhytidoponera*0003
Rhytidoponera sp. A
Tapinoma sp. A
Doleromyrma sp. A
Tapinoma sp. B

Generalized Myrmicinae

Crematogaster sp. A
Crematogaster sp. B
Crematogaster sp. C
Pheidole sp. A
Pheidole sp. B
Pheidole sp. C
Pheidole sp. D
Pheidole sp. E
Pheidole sp. F
Pheidole sp. G
Pheidole sp. H
*Pheidole*0010
Pheidole sp.

Specialist Predators

Anochetus armstrongi
Cerapachys sp. A
Cerapachys sp. B
*Cerapachys*0003
*Cerapachys*0004
Colobostruma sp. A
Epopostruma sp. A
Myrmecia sp. A
Myrmecia formosa
Myrmecia sp. B
Odontomachus sp.A

Taxa associations

Flora

Ivanhoe Plant Association A
Acacia aneura
Flindersia maculosa
Acacia loderi
Ptilotus obovatus
Alectryon oleifolius ssp. *canescens*
Geijera parviflora
Sclerolaena diacantha
Austrostipa scabra subsp. *scabra*
Medicago laciniata
Dissocarpus paradoxus
Senna artemisioides ssp. *filifolia*
Austrostipa nitida
Senna artemisioides ssp. *helmsii*
Maireana sclerolaenoides
Sclerolaena obliquicuspis
Sisymbrium erysimoides
Apophyllum anomalum

Cobar Plant Association A
Abutilon sp.
Linum marginale
Atriplex suberecta
Fimbristylis dichotoma
Leptorhynchos tetrachaetus
Eragrostis eriopoda
Maireana lobiflora
Minuria leptophylla
Austrostipa tuckeri
Tribulus terrestris
Carthamus lanatus
Digitaria brownii
Enneapogon nigricans
Sida intricata
Eremophila mitchellii
Thyridolepis mitchelliana
Solanum ferocissimum

Cobar Plant Association B
Aristida contorta
Calotis lappulacea
Sclerolaena diacantha
Sclerolaena birchii
Aristida jerichoensis var. *subspinulifera*
Calotis cuneifolia
Bothriochloa macra
Geijera parviflora
Eremophila deserti
Themeda australis

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Vertebrate fauna

Ivanhoe Vertebrate Association A
Cacatua roseicapilla
Tadarida australis
Merops ornatus
Corcorax melanorhamphos
Acanthiza uropygialis
Climacteris affinis
Ctenotus schomburgkii
Acanthiza nana
Mus musculus

Ivanhoe Vertebrate Association B
Gerygone fusca
Macropus giganteus
Pygopus nigriceps
Philemon citreogularis
Capra hircus

Ivanhoe Vertebrate Association C
Cacatua leadbeateri
Ephthianura tricolor
Oryctolagus cuniculus
Macropus fuliginosus
Grallina cyanoleuca
Pogona vitticeps
Acanthiza apicalis
Daphoenositta chrysoptera

Ivanhoe Vertebrate Association D
Ocyphaps lophotes
Rhipidura leucophrys
Diplodactylus steindachneri
Varanus gouldii
Manorina flavigula
Chrysococcyx osculans
Macropus rufus
Pomatostomus temporalis
Struthidea cinerea
Lerista punctatovittata

Cobar Vertebrate Association A
Pachycephala rufiventris
Malurus splendens
Acanthiza uropygialis
Colluricincla harmonica
Acanthiza apicalis
Oreoica gutturalis
Acanthiza chrysorrhoa
Pomatostomus ruficeps
Manorina flavigula
Pygopus nigriceps
Morethia boulengeri
Acanthagenys rufogularis

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Ants

Ivanhoe Ant Association A
Anochetus armstrongi
Camponotus sp. C
Crematogaster sp. C
Rhytidoponera metallica
Pheidole sp.A
*Iridomyrmex*0001
Opisthopsis rufithorax
Camponotus ephippium
Melophorus
Tapinoma sp. A
Camponotus nigriceps
*Iridomyrmex*0005
*Iridomyrmex*0009
Pheidole sp. B
Crematogaster sp. A
*Rhytidoponera*0001
Pheidole sp. H
*Iridomyrmex*0007
*Iridomyrmex*0008
Pheidole sp. F
Meranoplus sp. A
Camponotus sp. A
Camponotus sp. B
*Stigmacros*0001
Meranoplus sp. B
Crematogaster sp. B
*Iridomyrmex*0003
Meranoplus sp. C
Pheidole sp. G
Cerapachys sp. A
Meranoplus sp. E
Stigmacros elegans

Wanaaring-Louth Ant Association A
Anochetus armstrongi
*Iridomyrmex*0005
Pheidole sp.
*Iridomyrmex*0004
Pheidole sp. F
Pheidole sp. H
Pheidole sp. A
Rhytidoponera metallica
*Pheidole*0010
*Cerapachys*0004
*Iridomyrmex*0013
*Iridomyrmex*0012
*Rhytidoponera*0001
*Iridomyrmex*0001
*Iridomyrmex*0011
*Iridomyrmex*0006
Melophorus
Pheidole sp. G
Pheidole sp. E

Wanaaring-Louth Ant Association B
*Calomyrmex*0001
Meranoplus sp. C
Camponotus nigriceps
Camponotus sp. B
Camponotus sp. nr *aurocinctus*
Camponotus sp. nr. capito
Camponotus ephippium
Tapinoma sp. A
*Iridomyrmex*0010
Meranoplus sp. A
*Iridomyrmex*0008
Rhytidoponera sp. A
Myrmecia sp. B
Pheidole sp. C
*Iridomyrmex*0009
Polyrhachis sp. A
Camponotus tricoloratus
Cerapachys sp. A
Pheidole sp. B
Meranoplus sp. D
Meranoplus sp. E

Cobar Ant Association A
Anochetus armstrongi
*Rhytidoponera*0001
Tapinoma sp. A
Pheidole sp. A
Camponotus ephippium
Pheidole sp. G
Meranoplus sp. E
Camponotus nigriceps
Meranoplus sp. H
*Iridomyrmex*0010
Pheidole sp. B
Pheidole sp. H
Camponotus sp. B
Meranoplus sp. A
Rhytidoponera sp. A
*Iridomyrmex*0004
Paratrechina sp. A
Pheidole sp. F
Pheidole sp. D

Pheidole sp. C

Cobar Ant Association B

*Iridomyrmex*0001
*Iridomyrmex*0005
Meranoplus sp. C
*Iridomyrmex*0008
Pheidole sp.
*Iridomyrmex*0009
Melophorus
Rhytidoponera metallica
Pheidole sp. E
*Iridomyrmex*0012
*Iridomyrmex*0006
*Iridomyrmex*0011
*Iridomyrmex*0014

Cobar Ant Association C

Camponotus sp. A
Camponotus sp. C
*Iridomyrmex*0013
*Iridomyrmex*0015
Meranoplus sp. G
*Stigmacros*0001
Camponotus sp. nr. *aurocinctus*
Odontomachus sp. A
Stigmacros sp. C
Stigmacros sp. A
*Rhytidoponera*0003
Camponotus sp. D
Meranoplus sp. D
Brachyponera lutea

Three Region Ant Association A

Anochetus armstrongi
*Rhytidoponera*0001
Tapinoma sp. A
Camponotus ephippium
Camponotus nigriceps
Pheidole sp. B
*Iridomyrmex*0004
Pheidole sp. F
Pheidole sp. H
*Iridomyrmex*0010
Pheidole sp. C
Camponotus sp. B
Meranoplus sp. A
Rhytidoponera sp. A
*Rhytidoponera*0003
Camponotus sp. C
Crematogaster sp. A
*Iridomyrmex*0007
*Iridomyrmex*0015
Meranoplus sp. E
Meranoplus sp. H
Paratrechina sp. A
Pheidole sp. D
*Pheidole*0010
Camponotus sp. A
*Stigmacros*0001
*Iridomyrmex*0003
Stigmacros sp. B
Crematogaster sp. B
*Stigmacros*0003
Meranoplus sp. B
Solenopsis sp. A
*Calomyrmex*0001
Camponotus sp. nr. *aurocinctus*
Camponotus sp. nr. *capito*
*Iridomyrmex*0013
Polyrhachis sp. A
Meranoplus sp. D
Stigmacros sp. A
Camponotus sp. D
Camponotus tricoloratus
Cerapachys sp. A
Cerapachys sp. B
Myrmecia sp. B
Meranoplus sp. I
*Notoncus*0001

Three Region Ant Association B

*Cerapachys*0004
Crematogaster sp. C
*Iridomyrmex*0005
*Iridomyrmex*0008
Pheidole sp.
Pheidole sp. A
Pheidole sp. G
Meranoplus sp. C
*Iridomyrmex*0009
Melophorus
Pheidole sp. E
Rhytidoponera metallica
*Iridomyrmex*0012
*Iridomyrmex*0001
*Iridomyrmex*0006
*Iridomyrmex*0011
*Iridomyrmex*0014

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Invertebrate Orders

Cobar Invertebrate Orders Association A	**Three Regions Invertebrate Orders Association A**	**Three Regions Invertebrate Orders Association A**
Isopoda	Acarina	Diplopoda
Psocoptera	Collembola	Mantodea
Scolopendrida	Formicidae	Scolopendrida
Thysanura		Scutigerida
Mantodea		Phasmatodea
		Scorpionida
		Lithobiida
		Neuroptera

Appendix 3: Summary of potentially confounding factors

3.1 Macro-scale variation within each survey region

Attributes that could potentially influence the detectability or occurrence of flora or fauna taxa, or the landscape functionality, on the study sites were recorded for analysis and consideraion during interpretation of results (see section 2.1.3). Potentially confounding factors varied between the regions, reflecting topographic, soil and vegetation differences. However, one factor encountered in all regions was the extreme patchiness of the woody shrub cover. Despite the consistency of this factor, it is regarding as an inconsistency between sites because of the greater patchiness on low shrub cover sites, and greatly reduced patchiness on sites of high cover. Shrub patches were not encountered at a scale which was easily accommodated by the combined site/buffer size of 12 ha. This represented one of the greatest difficulties encountered during the site selection process. Similarly, all Ivanhoe sites exhibited marked variability in the Belah cover, with touching canopies in some patches, areas with light cover and completely open patches elsewhere. The number, size and configuration of these patches varied greatly between sites.

3.1.1 Systematically assessed site differences

Many factors deemed to be potentially confounding were quantitatively assessed on each study site, as described in Appendix 1. Data for each of these predictor variables are summarised for each region in Table A3.1.

Table A3.1 Summary of site attributes by region. Mean and range values are provided for numeric attributes. For factor variables the number of sites within each category are listed. Results for disturbance are restricted to intensity.

Attribute	Ivanhoe	Wanaaring-Louth	Cobar
Landscape-scale attributes			
Altitude	92.1 (85 - 105)	92.9 (90 - 100)	190.5 (180 - 205)
Morpho terrain	Flat:12	Crest:1; Flat:9; Simple slope:1; Upper slope:1	Flat:9; Mid-slope:2
Element	Drainage depression:1; Plain:11	Hill crest:1; Hill slope:2; Plain:9	Hill slope:2; Plain:9
Pattern	Sand plain:12	Sand plain:11; n/a:1	n/a
Direct distance from water (km)	3.0 (1.95 - 5.2)	2.9 (1.5 - 4.9)	2.3 (1.1 - 4.3)
Distance to water for stock (km)	3.6 (2 - 5.2)	3.4 (2 - 5.4)	2.6 (1.2 - 4.3)
Physical attributes			
Soil depth	Deep:12; Shallow:0	Deep:12; Shallow:0	Deep:9; Shallow:2
Surface texture	Loam: 12	Loam:9; Sand:3	Loam:10; Sand:1
Soil texture (=infiltration rate into soil)	Slow:8; Moderate:4	Slow:2; Moderate:10	Slow:9; Moderate:2
Stability	57.75 (53.7 - 60.1)	52.02 (46.5 - 56.4)	63.11 (59.3 - 66.2)

Attribute	Ivanhoe	Wanaaring-Louth	Cobar
Soil texture (cont'd)			
Infiltration	37.67 (34.2 - 44.4)	38.1 (28.6 - 42.6)	40.16 (35.6 - 45.8)
Nutrient cycling status	23.28 (20.2 - 27.9)	22.56 (17.2 - 30.6)	25.31 (21.6 - 29.3)
Woody shrub attributes			
Mean shrub height (cm)	190.6 (165.9 - 234.3)	170.12 (101.4 - 226.9)	134.2 (111.9 - 163.6)
Mean canopy openness (%)	50.4 (46.5 - 54.3)	49.0 (44.5 - 52.5)	52.5 (49.5 - 57.9)
Disturbance features			
Fire severity	none:4; light:6; light-mod:1; mod:1	none:6; light:6	none:4; light:4; mod:3
Logging severity	none:3; light:6; mod:3	none:6; light:2; mod:4	none:8; light:2; mod:1
Grazing severity	light:12	light:7; mod:5	light:10; severe:1
Rabbit disturbance	none:3; light:8; n/a:1	none:6; light:3; mod:2; mod-severe:1	none:1; light:8; mod:1; severe:1
Microhabitat attributes			
No. of logs on ground 5-15cm (sm. logs)	41.9 (14 - 72)	78.4 (13 - 226)	55.7 (3 - 129)
No. of logs on ground 15-25cm	16.6 (3 - 39)	6.2 (0 - 18)	2.4 (0 - 9)
No. of logs on ground >25cm	7 (2 - 17)	1.2 (0 - 5)	0.4 (0 - 2)
No. tree holes	3.6 (0 - 8)	1.3 (0 - 6)	1.5 (0 - 15)
No. tree cracks	3.7 (0 - 16)	0.4 (0 - 4)	0.2 (0 - 2)
No. tree spouts	1.5 (0 - 5)	0 (0 - 0)	0 (0 - 0)
Shedding bark on ground (P/A)	absent:4; present:8	absent:7; present:5	absent:5; present:6
Shedding bark on tree (P/A)	absent:2; present:10	absent:7; present:5	absent:5; present:6
Flowering species (P/A)	absent:0; present:12	absent:1; present:11	absent:0; present:11
Fruiting species (P/A)	absent:0; present:12	absent:0; present:12	absent:0; present:11
Mistletoe (P/A)	absent:4; present:8	absent:11; present:1	absent:4; present:7
% WW branches dead	2.8 (0.1 - 9)	1.6 (0 - 7.5)	10.9 (0 - 79)
Cracking soils (P/A)	absent:12; present:0	absent:12; present:0	absent:11; present:0
Rocks and caves (P/A)	absent:12; present:0	absent:12; present:0	0:11; 1:0
Cryptogamic cover (%)	83.2 (65 - 90)	31.6 (0.5 - 92.5)	81.6 (50 - 97.5)
Solid litter cover (%)	6.2 (3 - 17.5)	11.1 (0.5 - 50)	6.8 (0.5 - 22.5)
Tree crown separation	3.1 (2 - 6)	7.0 (0 - 18)	4.8 (0 - 10)
Leaf litter accumulations (P/A)	absent:0; present:12	absent:2; present:10	absent:1; present:10
Stags (P/A)	absent:1; present:9; n/a: 2	absent:6; present:6	absent:3; present:8
Surface rock (%)	0.0 (0 - 0.1)	0.0 (0 - 0.1)	0.8 (0 - 5)

Correlation matrices involving all the numeric predictor variables revealed woody shrub cover and density were highly correlated (r>|0.80|) in all regions except for the Wanaaring-Louth region (Table A3.2). This result reflects the observation in the Wanaaring-Louth region that both high and low cover sites varied as to whether they were dominated by fewer larger-canopied shrubs, or more smaller-canopied shrubs. This was less evident in the Ivanhoe and Cobar regions. No other site attributes were highly correlated with woody shrub cover or density in the Ivanhoe or Wanaaring-Louth survey regions, nor in the three regions collectively. In the Cobar region the number of 'small logs' (5-15 cm maximum diameter) increased with increasing woody shrub cover (r = 0.85, p = 0.001) and density (r = 0.84, p = 0.001). These small logs were predominantly dead shrub branches that had fallen to the ground. Similarly, the percentage cover of solid leaf litter present across the Cobar sites was positively correlated with woody shrub density (r = 0.82, p = 0.002).

Table A3.2 Correlations between numeric site attributes and woody shrub cover (WSC) and woody shrub density (WSD) in each survey region, and across the three regions collectively. * indicates where correlation was determined for fewer than 12 sites (Ivanhoe) or 35 sites (Three-regions) due to missing data.

	Ivanhoe		**Wanaaring-Louth**		**Cobar**		**Three-regions**	
	WSC	**WSD**	**WSC**	**WSD**	**WSC**	**WSD**	**WSC**	**WSD**
Woody shrub cover and density								
WSC	1.000	0.955	1.000	0.794	1.000	0.946	1.000	0.887
WSD	0.955	1.000	0.794	1.000	0.946	1.000	0.887	1.000
Landscape-scale attributes								
altitude	-0.343	-0.259	0.585	0.423	0.174	0.396	-0.075	0.105
distance from water (km)	-0.230	-0.222	-0.114	-0.018	0.436	0.460	0.025	0.035
Physical atttributes								
soil texture	-0.176	-0.278	-0.387	-0.293	-0.294	-0.338	-0.131	-0.227
stability	0.260	0.137	0.448	0.660	-0.257	-0.392	-0.017	0.091
infiltration	-0.205	-0.323	0.491	0.514	-0.476	-0.393	-0.020	-0.021
nutrients	-0.236	-0.325	0.244	0.268	-0.397	-0.298	-0.086	-0.039
Disturbance features								
fire severity	-0.061	0.062	0.120	0.007	0.409	0.201	0.131	0.115
logging severity	0.025	-0.011	-0.455	-0.513	0.290	0.203	-0.065	-0.129
grazing severity	n/a	n/a	-0.103	-0.160	-0.130	-0.218	-0.055	-0.126
rabbit disturbance	0.109*	0.14*	0.346	0.201	-0.553	-0.474	-.029*	-.057*
Microhabitat attributes								
no. of logs on ground 5-15 cm	0.140	0.199	0.510	0.340	0.855	0.840	0.497	0.425
no. of logs on ground 15-25 cm	0.097	-0.015	-0.210	-0.287	0.580	0.418	0.053	-0.073
no. of logs on ground >25 cm	-0.299	-0.243	-0.191	-0.183	0.112	0.044	-0.139	-0.175

	Ivanhoe		Wanaaring-Louth		Cobar		Three-regions	
	WSC	**WSD**	**WSC**	**WSD**	**WSC**	**WSD**	**WSC**	**WSD**
Microhabitat attributes (cont'd)								
no. tree holes	0.009	0.007	-0.156	-0.290	-0.314	-0.272	-0.177	-0.217
no. tree cracks	-0.003	-0.143	-0.253	-0.290	-0.317	-0.266	-0.057	-0.160
no. tree spouts	0.018	-0.117	n/a	n/a	n/a	n/a	-0.008	-0.110
shedding bark on ground (P/A)	-0.735	-0.708	-0.272	-0.340	0.432	0.476	-0.215	-0.154
shedding bark on tree (P/A)	-0.585	-0.402	-0.272	-0.340	0.518	0.457	-0.103	-0.050
flowering speies (P/A)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
fruiting speies (P/A)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
mistletoe (P/A)	-0.680	-0.680	n/a	n/a	0.688	0.570	-0.143	-0.065
% WW branches dead	0.098	-0.003	0.647	0.728	-0.223	-0.174	-0.108	-0.058
cracking soils (P/A)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
rocks/caves (P/A)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
cryptogamic cover (%)	0.310	0.233	0.167	0.162	-0.564	-0.740	-0.090	-0.074
solid litter cover (%)	-0.254	-0.158	0.577	0.445	0.672	0.821	0.408	0.360
tree crown separation	0.069*	0.004*	0.066893	-0.012	0.1502	0.1602	0.091*	0.047*
leaf litter accumulations (P/A)	n/a	n/a	0.555	0.483	n/a	n/a	0.325	0.259
stags (P/A)	-.172*	-.078*	-0.50962	-0.534	-0.159	-0.266	-.296*	-.283*
% surface rock	n/a	n/a	0.306	0.185	-0.180	-0.183	-0.121	-0.075

Those attributes that exhibited a very low correlation ($-0.1<r<0.1$) with woody shrub cover and density in each region are listed in Table A3.3. Only fire intensity had a very low correlation with woody shrub density in more than one region (Wanaaring-Louth: r = 0.007, p = 0.982, and Ivanhoe r =-0.06, p = 0.848). As might be expected in a woodland environment, the abundances of all tree cavity attributes were poorly correlated with woody shrub cover in the Ivanhoe region.

3.1.2 Descriptive site differences

In addition to those attributes which were systematically assessed on each study site (described above), other site differences which could potentially influence the detectability or occurrence of flora or fauna taxa, or landscape functionality, on the study sites were recorded descriptively (Table A.3.4). Although most sites in the Wanaaring-Louth region were located in the Plains land unit of the Avondale land system, some were located in the Rises land unit. This distinction did not correspond with either woody shrub cover or soil texture differences. The degree of erosion and soil deposition (including hummock formation) also varied considerably between sites in this region. Hummocks were recorded during the landscape function assessments. In the Cobar region grass and tree cover varied with woody shrub cover. Although all sites contained some individual woody shrubs, the two most open sites were of an open grassland nature. Greatest tree cover occurred on the site with highest shrub cover.

Table A3.3 All other highly correlated attributes (r > abs(0.8)) within each survey region.

Correlated attributes	r
Ivanhoe	
no. small logs and no. tree cracks	0.831
no. tree cracks and dead woody shrub branches	0.908
crypto cover and solid litter	-0.940
Wanaaring-Louth	
small logs and solid litter	0.842
solid litter and soil texture	-0.886
shedding bark on ground and shedding bark on tree	1.000
Cobar	
tree cracks and tree holes	0.998
cryptogamic cover and solid litter	-0.883
infiltration and nutrients	0.946
3 regions	
none	n/a

Table A3.4 Potentially confounding factors between study sites within each survey region.

Influence	Site/s affected
Ivanhoe	
depressions/small gilgais	3, 12
localised drainage depression	10
minor disturbance	4
Wanaaring-Louth	
Rises land unit	13, 17, 22, 24
sandy soil	13, 16, 17, 24
exposed slope between salt lakes	22
localised soil collapse	13
Cobar	
open grassland	34, 35
high tree cover	27

3.2 Micro-scale variation within each survey region

Attributes recorded near each vertebrate and or invertebrate pitfall trap include factors known to influence trap captures (section 2.1.3) and those related to woody shrub 'cover' close to each trap. Each of these attributes was assessed for each pitfall trap, as described in Appendix 1. Data for each of these predictor variables are summarised for each region in Table A3.5.

Table A3.5 Summary of pitfall trap attributes by region. Mean and range values are provided for numeric attributes. For factor variables the number of sites within each category are listed.

Attribute	Ivanhoe	Wanaaring-Louth	Cobar
Invertebrate pitfall trap attributes			
Mean distance to closest woody shrub (m)	5.20 (0.36 - 53.0)	4.41 (0.18 - 69.0)	4.28 (0.13 - 44.0)
Trap location re shrub density (Within Clump, Open Area etc.)	WC:43; OA:77	WC:60; OA:60	WC:67; OA:43
Ground cover(%)	13.97 (0 - 95)	22.53 (1 - 70)	28.13 (0.5 - 95)
Leaf litter (%)	30.54 (0.5 - 100)	24.28 (0.5 - 90)	35.05 (0.5 - 100)
Mean distance to closest tree (m)	4.50 (0.15 - 13.8)	33.53 (1.3 - 83)	21.76 (0.39 - 84)
Mean distance to closest log (m)	3.08 (0.1 - 12.86)	5.29 (0 - 28); 1 n/a	7.56 (0.17 - 54)
Under canopy? (SC=shrub canopy (c.).; TC=tree c.; TSC=both; UC=under c. (not specified); NUC=not under c.)	NUC:64; SC:23; TC:30; TSC:1; UC:2	NUC:90; SC:27; TC:2; UC:1	NUC:89; SC:12; TC:5; UC:4
Vertebrate pitfall trap attributes			
Mean distance to closest woody shrub (m)	5.98 (0.52 - 61.0); 1 n/a	3.63 (0.2 - 23.5)	4.66 (0.15 - 46)
Trap location re shrub density (Within Clump, Open Area etc.)	WC:48; OA:60	WC:63; OA:45	WC:62; OA:37
Ground cover(%)	12.19 (0 - 95)	15.04 (0 - 85)	33.05 (0 - 95)
Leaf litter (%)	28.83 (0.5 - 100)	22.69 (0.5 - 95)	36.29 (0.5 - 100)

Appendix 4: Ant taxonomy

4.1 Ant morphospecies (as identified by staff from the Key Centre for Biodiversity and Bioresources, Macquarie University), corresponding species names (as identified by Dr Alan Andersen), and names used in this report. Species identifications for undescribed taxa (e.g. sp. A) are specific to this investigation and do not correlate with previous identifications of the same name. Morphospecies names were retained under two circumstances: (1) morphospecies 'not identified to species level' because images were not available (see section 2.1.5.5); (2) morphospecies for which images failed to present diagnostic characters (uncertainty of species identifications identified with "?"). *Monomorium* and *Tetramorium* species and morphospecies identifications could not be matched, and are listed separately in Appendix 4.2. *Melophorus* were not separated into morphospecies.

Morphospecies identification	Species identification	Name applied in this report
*Anochetus*0001	*Anochetus armstrongi*	*Anochetus armstrongi*
*Calomyrmex*0001	*Calomyrmex ?cyanea*	*Calomyrmex*0001
*Camponotus*0001	*Camponotus ephippium*	*Camponotus ephippium*
*Camponotus*0002	*Camponotus* sp. A (*nigroaeneus* gp)	*Camponotus* sp. A
*Camponotus*0003	*Camponotus* sp. A (*nigroaeneus* gp)	
*Camponotus*0004	*Camponotus nigriceps*	*Camponotus nigriceps*
*Camponotus*0005	*Camponotus* sp. B (*discors* gp)	*Camponotus* sp. B
*Camponotus*0006	*Camponotus* sp. C (*claripes* gp)	*Camponotus* sp. C
*Camponotus*0007	*Camponotus* sp. nr. *aurocinctus*	*Camponotus* sp. nr. *aurocinctus*
*Camponotus*0008	*Camponotus* sp. nr. *capito*	*Camponotus* sp. nr. *capito*
*Camponotus*0009	*Camponotus* sp. D (*evae* gp)	*Camponotus* sp. D
*Camponotus*0010	*Camponotus tricoloratus*	*Camponotus tricoloratus*
*Camponotus*0011	*Camponotus whitei*	*Camponotus whitei*
*Cardiocondyla*0001	*Cardiocondyla* sp. A (*nuda* gp)	*Cardiocondyla* sp. A
*Cardiocondyla*0002	*Cardiocondyla* sp. A?	*Cardiocondyla*0002
*Cerapachys*0001	*Cerapachys* sp. A (*brevis* gp)	*Cerapachys* sp. A
*Cerapachys*0002	*Cerapachys* sp. B (*fervidus* gp)	*Cerapachys* sp. B
*Cerapachys*0003	not identified to species level	*Cerapachys*0003
*Cerapachys*0004	*Cerapachys* sp. A?	*Cerapachys*0004
*Colobostruma*0001	*Colobostruma* sp. A	*Colobostruma* sp. A
*Crematogaster*0001	*Crematogaster* sp. A (*queenslandica* gp)	*Crematogaster* sp. A
*Crematogaster*0002	*Crematogaster* sp. B	*Crematogaster* sp. B
*Crematogaster*0004	*Crematogaster* sp. B	
*Crematogaster*0003	*Crematogaster* sp. C (*laeviceps* gp)	*Crematogaster* sp. C
*Dolichoderus*0001	*Dolichoderus* sp. A (*reflexus* gp)	*Dolichoderus* sp. A
*Epopostruma*0001	*Epopostruma* sp. A	*Epopostruma* sp. A
*Hypoponera*0001	*Hypoponera* sp. A	*Hypoponera* sp. A
*Iridomyrmex*0001	not identified to species level	*Iridomyrmex*0001
*Iridomyrmex*0002	not identified to species level	*Iridomyrmex*0002
*Iridomyrmex*0003	not identified to species level	*Iridomyrmex*0003

Morphospecies identification	Species identification	Name applied in this report
*Iridomyrmex*0004	not identified to species level	*Iridomyrmex*0004
*Iridomyrmex*0005	not identified to species level	*Iridomyrmex*0005
*Iridomyrmex*0006	not identified to species level	*Iridomyrmex*0006
*Iridomyrmex*0007	not identified to species level	*Iridomyrmex*0007
*Iridomyrmex*0008	not identified to species level	*Iridomyrmex*0008
*Iridomyrmex*0009	not identified to species level	*Iridomyrmex*0009
*Iridomyrmex*0010	not identified to species level	*Iridomyrmex*0010
*Iridomyrmex*0011	not identified to species level	*Iridomyrmex*0011
*Iridomyrmex*0012	not identified to species level	*Iridomyrmex*0012
*Iridomyrmex*0013	not identified to species level	*Iridomyrmex*0013
*Iridomyrmex*0014	not identified to species level	*Iridomyrmex*0014
*Iridomyrmex*0015	not identified to species level	*Iridomyrmex*0015
Melophorus	not fully identified	*Melophorus*
*Meranoplus*0001	*Meranoplus* sp. A (*excavatus* gp)	*Meranoplus* sp. A
*Meranoplus*0002	*Meranoplus* sp. B (*fenestratus* gp)	*Meranoplus* sp. B
*Meranoplus*0003	*Meranoplus* sp. C	*Meranoplus* sp. C
*Meranoplus*0004	*Meranoplus* sp. D	*Meranoplus* sp. D
*Meranoplus*0005	*Meranoplus* sp. E	*Meranoplus* sp. E
*Meranoplus*0006	*Meranoplus* sp. F	*Meranoplus* sp. F
*Meranoplus*0007	*Meranoplus* sp. G (*diversus* gp)	*Meranoplus* sp. G
*Meranoplus*0008	*Meranoplus* sp. H (*diversus* gp)	*Meranoplus* sp. H
*Meranoplus*0009	*Meranoplus* sp. I (*dimidiatus* gp)	*Meranoplus* sp. I
*Meranoplus*0010	*Meranoplus* sp. J? (or A?)	*Meranoplus*0010
*Meranoplus*0011	*Meranoplus* sp. K	*Meranoplus* sp. K
*Meranoplus*0012	not identified to species level	*Meranoplus*0012
*Myrmecia*0001	*Myrmecia* sp. A (*pilosula* gp)	*Myrmecia* sp. A
*Myrmecia*0002	*Myrmecia formosa*	*Myrmecia formosa*
*Myrmecia*0003	*Myrmecia* sp. B (*pilosula* gp)	*Myrmecia* sp. B
*Notoncus*0001	*Notoncus ?ectatommoides*	*Notoncus*0001
*Odontomachus*0001	*Odontomachus* sp. A (*ruficeps* gp)	*Odontomachus* sp. A
*Opisthopsis*0001	*Opisthopsis rufithorax*	*Opisthopsis rufithorax*
*Pachycondyla*0001	*Brachyponera lutea*	*Brachyponera lutea*
*Paratrechina*0001	*Paratrechina* sp. A (*obscura* gp)	*Paratrechina* sp. A
*Pheidole*0001	*Pheidole* sp. A (group D)	*Pheidole* sp. A
*Pheidole*0002	*Pheidole* sp. B (group ?D)	*Pheidole* sp. B
*Pheidole*0003	*Pheidole* sp. C (group ?C)	*Pheidole* sp. C
*Pheidole*0004	*Pheidole* sp. D (*mjobergi* gp)	*Pheidole* sp. D
*Pheidole*0005	*Pheidole* sp. E (*hartmeyeri* gp)	*Pheidole* sp. E
*Pheidole*0006	*Pheidole* sp. F (group ?D)	*Pheidole* sp. F
*Pheidole*0007	*Pheidole* sp. G (group D)	*Pheidole* sp. G
*Pheidole*0008	*Pheidole* sp. G (group D)	

Morphospecies identification	**Species identification**	**Name applied in this report**
*Pheidole*0009	*Pheidole* sp. H	*Pheidole* sp. H
*Pheidole*0010	*Pheidole* sp. B? (group D)	*Pheidole*0010
*Pheidole*0011	*Pheidole* sp. (group D)	*Pheidole* sp.
*Polyrhachis*0001	*Polyrhachis* sp. A (*schwiedlandi* gp)	*Polyrhachis* sp. A
*Probolomyrmex*0001	*Cerapachys ?edentatus*	*Cerapachys*0005
*Rhytidoponera*0001	*Rhytidoponera ?maniae*	*Rhytidoponera*0001
*Rhytidoponera*0002	*Rhytidoponera metallica*	*Rhytidoponera metallica*
*Rhytidoponera*0003	*Rhytidoponera maniae?*	*Rhytidoponera*0003
*Rhytidoponera*0004	*Rhytidoponera* sp. A (*mayri* gp)	*Rhytidoponera* sp. A
*Solenopsis*0001	*Solenopsis* sp. A	*Solenopsis* sp. A
*Solenopsis*0002	*Solenopsis* sp. A?	*Solenopsis*0002
*Stigmacros*0001	*Stigmacros elegans*?	*Stigmacros*0001
*Stigmacros*0002	*Stigmacros* sp. A (silvery species)	*Stigmacros* sp. A
*Stigmacros*0003	*Stigmacros ?aciculata*	*Stigmacros*0003
*Stigmacros*0004	*Stigmacros* sp. B (*punctatissimus* gp)	*Stigmacros* sp. B
*Stigmacros*0005	*Stigmacros aemula*	*Stigmacros aemula*
*Stigmacros*0006	*Stigmacros elegans*	*Stigmacros elegans*
*Stigmacros*0007	*Stigmacros* sp. C (*punctatissimus* gp)	*Stigmacros* sp. C
*Stigmacros*0008	*Stigmacros aciculata*	*Stigmacros aciculata*
*Stigmacros*0009	*Stigmacros pilosella*	*Stigmacros pilosella*
*Stigmacros*0010	*Melophorus* sp. A (*mjobergi* gp)	*Melophorus* sp. A
*Tapinoma*0001	*Tapinoma* sp. A	*Tapinoma* sp. A
*Tapinoma*0005	*Tapinoma* sp. A	
*Tapinoma*0003	*Doleromyrma* sp. A (*darwinianum* gp)	*Doleromyrma* sp. A
*Tapinoma*0004	*Tapinoma* sp. B	*Tapinoma* sp. B
UG(2)0001	*Monomorium* sp. M (*whitei* gp)	*Monomorium* sp. M
UG(2)0003	*Monomorium* sp. M (*whitei* gp)	
UG(2)0002	*Monomorium* sp. (*whitei* gp)	*Monomorium* sp.

4.2 *Monomorium* and *Tetramorium* morphospecies and corresponding species names as identified by Dr Alan Andersen to date.

Morphospecies identification	Species identification
*Monomorium*0001	*Monomorium* sp. K (*laeve gp*), sp. L (*laeve gp*) and sp. M (*laeve gp*)
*Monomorium*0002	*Monomorium* sp. A (*rothsteini* gp), sp. B (*sordidum* gp), sp. D (*sordidum* gp) and sp. E (*sordidum* gp)
*Monomorium*0003	*Monomorium* sp. B (*sordidum gp*), sp. E (*sordidum gp*) and sp. I (*nigrius* gp)
*Monomorium*0004	*Monomorium* sp. A (*rothsteini* gp), sp. C (*sordidum gp*), sp. D (*sordidum* gp), sp. E (*sordidum* gp) and sp. F (*eremophilum* gp)
*Monomorium*0005	*Monomorium* sp. G (*eremophilum* gp), sp. I (*nigrius* gp) and sp. K (*laeve* gp)
*Monomorium*0006	*Monomorium* sp. B (*sordidum* gp), sp. D (*sordidum* gp), sp. E (*sordidum* gp) and sp. F (*eremophilum* gp)
*Monomorium*0007	*Monomorium* sp. A (*rothsteini* gp), sp. E (*sordidum* gp) and sp. F (*eremophilum* gp)
*Monomorium*0008	*Monomorium* sp. G (*eremophilum* gp) and sp. J (*carinatum* gp)
*Monomorium*0009	*Monomorium* sp. B (*sordidum* gp), sp. D (*sordidum* gp), sp. E (*sordidum* gp), sp. F (*eremophilum* gp) and sp. J (*carinatum* gp)
*Monomorium*0010	*Monomorium* sp. D (*sordidum* gp) and sp. E (*sordidum* gp)
*Monomorium*0011	*Monomorium* sp. A (*rothsteini* gp)
*Monomorium*0012	*Monomorium* sp. A (*rothsteini* gp), sp. C (*sordidum* gp) and sp. F (*eremophilum* gp)
*Monomorium*0013	*Monomorium* sp. B (*sordidum* gp) and sp. E (*sordidum* gp)
*Monomorium*0014	*Monomorium* sp. H
*Monomorium*0015	*Monomorium* sp. (*sordidum* gp)
*Monomorium*0016	*Monomorium* sp. (*sordidum* gp)
*Tetramorium*0001	*Tetramorium* sp. A (*striolatum* gp), sp. C (*impressum* gp)
*Tetramorium*0002	*Tetramorium* sp. C (*impressum* gp)
*Tetramorium*0003	*Tetramorium* sp. C (*impressum* gp)
*Tetramorium*0004	*Tetramorium* sp. A (*striolatum* gp), sp. B (*impressum* gp) and sp. C (*impressum* gp)

Appendix 5: Presence of flora, vertebrate and invertebrate taxa at each study site

Flora are listed alphabetically within each life form grouping (nomenclature according to Harden, 1990 – 1994; some common names from Cunningham *et al.* 1992). Vertebrates are listed by Class, and arranged by Family or Order (nomenclature according to Stanger *et al.* 1998). Invertebrate 'Orders' and ants are listed alphabetically. Exotic taxa are marked by * beside the scientific name. Within each survey region the sites are arranged in order of increasing woody shrub cover. Correlation results (r and *p* values) relate to woody shrub cover and density (those for shrub density are subscripted with "$_D$"). Significant results are included separately for taxa present in each region and for species common to all three survey regions. Significant results based on the presence of one organism at one study site are indicated by * beside the *p*-value. Significant correlation results for those two site attributes (number of small logs – Lo; and amount of leaf litter – Li) highly correlated with woody shrub cover in the Cobar region are indicated by * (*p*<0.05) or ** (*p*<0.01); sign is indicated by "+" (positive) or "-" (negative). Those taxa for which the correlation with woody shrub cover is >–0.1 and <0.1 are marked with #.

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Trees																																								
Acacia sp.																									✓										✓				#	
Acacia acuminata subsp. *burkittii*																																								
Acacia aneura	Mulga					✓		✓															✓							✓								✓	r=0.633 *p*=0.036	#
Acacia cambagei	Gidgee																	✓	✓																					
Acacia colletioides	Spine Bush				✓							✓																												
Acacia excelsa	Ironwood																																							
Acacia homalophylla	Yarran																																							
Acacia loderi	Nelia									✓				#																										
Acacia oswaldii	Miljee																																							
Acacia tetragonophylla	Dead Finish																																							
Acacia victoriae	Prickly Wattle																																							
Alectryon oleifolius	Western Rosewood		✓	✓	✓	✓	✓	✓		✓	✓		✓											✓												✓			#	
Apophyllum anomalum	Warriorbush	✓	✓	✓	✓		✓		✓		✓	✓																	✓											
Atalaya hemiglauca	White Wood																															✓								
Brachychiton populneus	Kurrajong																																							

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Callitris glaucophylla	White Cypress Pine																																		✓	✓	✓	✓	r=0.79 *p* =0.004 r_D=0.763 p_D=0.006 Lo**+	
Capparis mitchellii	Wild Orange																																							
Casuarina cristata	Belah																																							
Casuarina pauper	Belah	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓																											
Eucalyptus intertexta	Red Box																																					✓	r=0.736 *p* =0.010*	
Eucalyptus populnea ssp. *bimbil*	Bimble Box																																							
Eucalyptus socialis	Pointed Mallee																																							
Flindersia maculosa	Leopardwood					✓		✓																					✓											
Geijera parviflora	Wilga	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	#														✓	✓	✓		✓					✓		Li*+	
Grevillea huegelii	Comb Spider Flower																																							
Grevillea striata	Beefwood																																							
Hakea tephrosperma	Hooked Needlewood																															✓								
Myoporum platycarpum	Sugarwood											✓		r=0.6 *p* =0.039*																										
Pittosporum phylliraeoides	Butterbush												✓	r=0.624 *p* =0.030* r_D=0.813 p_D=0.001*																										
Shrubs																																								
Dodonaea viscosa ssp. *angustissima*	Narrow-leaf Hopbush		✓				✓	✓				✓		#	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Lo*+	
Eremophila bowmanii ssp. *bowmanii*	Silver Turkey-bush																																					✓	r=0.736 *p* =0.010*	
Eremophila deserti	Ellangowan Poison Bush (Dogwood)		✓		✓						✓																	✓	✓									✓		
Eremophila duttonii	Harlequin Fuschia Bush															✓																								

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Eremophila glabra	Tar Bush																																							
Eremophila longifolia	Emu Bush																							✓							✓		✓		✓					
Eremophila mitchellii	Budda																											✓										✓	r=0.664 *p* =0.026	
Eremophila oppositifolia	Weeooka					✓																																		
Eremophila sturtii	Turpentine	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		r=0.41 *p* =0.009 r_D=0.263 p_D=0.042
Senna artemisioides nothosubsp. *artemisioides*	Silver Cassia																					✓					# r_D=0.610 p_D=0.035*													
Senna artemisioides ssp. *filifolia*	Punty Bush				✓			✓		✓	✓	✓	✓	r=0.689 *p* =0.004 r_D=0.844 p_D=0.000	✓		✓					✓													✓	✓		✓	r=0.742 *p* =0.009 r_D=0.593 p_D=0.050	r=0.538 *p* =0.001 r_D=0.596 p_D=0.041
Senna artemisioides ssp. *helmsii*	Blunt-leaf Cassia		✓	✓	✓					✓	✓	✓	✓	r=0.646 *p* =0.018																										
Chenopods																																								
Atriplex eardleyae	Small Saltbush															✓													✓											
Atriplex limbata	Spreading Saltbush															✓			✓	✓								✓	✓											
Atriplex stipitata	Bitter Saltbush	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		r_D=-0.396 p_D=0.040	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					✓		✓		✓		✓				
Atriplex suberecta	Lagoon Saltbush																											✓				✓		✓						
Chenopodium	a goosefoot																							✓																
Chenopodium cristatum	Crested Goosefoot	✓	✓	✓	✓	✓						✓	✓	#	✓	✓	✓	✓	✓	✓			✓		✓	✓														
Chenopodium desertorum	Desert Goosefoot		✓		✓	✓		✓		✓																														
Chenopodium desertorum ssp. *anidiophyllum*	Mallee Goosefoot	✓										✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓														

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Chenopodium desertorum ssp. *microphyllum*	a goosefoot														✓		✓	✓	✓	✓		✓	✓	✓	✓	✓								✓			✓	✓	r_D=0.413 p_D=0.039	
Chenopodium melanocarpum	Black Crumbweed				✓																								✓	✓		✓	✓	✓		✓	✓		#	
Dissocarpus paradoxus	Cannonball	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		#													
Einadia nutans ssp. *eremaea*	Climbing Saltbush							✓						#																										
Einadia nutans ssp. *nutans*	Climbing Saltbush	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓		✓	✓	✓	✓	✓		
Einadia nutans ssp. *oxycarpa*	Climbing Saltbush																	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓		✓				✓					
Enchylaena tomentosa	Ruby Saltbush	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		#	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓															
Maireana	a bluebush						✓																																	
Maireana enchylaenoides	Wingless Fissure-weed																											✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		
Maireana georgei	Satiny Bluebush																							✓																
Maireana humillima	a bluebush																													✓					✓					
Maireana lobiflora	Loned Bluebush																											✓				✓	✓	✓				✓		
Maireana sclerolaenoides	Woolly-fruit Copperburr	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓																											
Maireana trichoptera	bluebush				✓																								✓		✓		✓	✓		✓	✓		#	
Maireana triptera	Three-winged Bluebush			✓																																				
Rhagodia spinescens	Thorny Saltbush																		✓		✓			✓																
Salsola kali var. *kali*	Buckbush		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	✓		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	r_D=-0.509 p_D=0.030 Li**-	#
Sclerolaena bicornis	Goathead Burr																		✓																					
Sclerolaena birchii	Galvanised Burr																											✓	✓	✓	✓	✓	✓	✓		✓	✓		Lo*-	

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Sclerolaena convexula	Tall Copperburr														✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Sclerolaena diacantha	Grey Copperburr	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		#
Sclerolaena eriacantha	Silky Copperburr															✓																								
Sclerolaena lanicuspis	Woolly Copperburr						✓									✓																								
Sclerolaena longicuspis	a copperburr															✓	✓			✓				✓	✓															
Sclerolaena obliquicuspis	Limestone Copperburr	✓		✓	✓	✓	✓		✓		✓		✓							✓		✓					#													
Sclerolaena patenticuspis	Spear-fruit Copperburr	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓		✓	✓				✓	✓		✓	✓	✓	✓			✓											#
Sclerolaena spp.	a copperburr															✓																								
Sclerolaena tricuspis	Streaked Poverty-bush															✓							✓																	
Grasses																																								
Amphipogon caricinus var. *caricinus*	Long Greybeard Grass																													✓										
Aristida behriana	Brush Wiregrass																											✓												
Aristida contorta	Kerosene Grass														✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			r=-0.596 *p*=0.041	✓		✓	✓	✓	✓	✓	✓	✓	✓			
Aristida jerichoensis var. *jerichoensis*	No. 9 Wiregrass														✓		✓	✓									r=-0.576 *p*=0.05													
Aristida jerichoensis var. *subspinulifera*	No. 9 Wiregrass																											✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Austrodanthonia caespitosa	White-top																											✓												
Austrodanthonia setacea	Small-flowered Wallaby Grass		✓	✓	✓		✓					✓																✓	✓		✓	✓	✓	✓	✓	✓		✓		

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Austrostipa acrociliata	Graceful Speargrass																																✓						#	
Austrostipa nitida	a speargrass	✓	✓	✓	✓				✓		✓	✓	✓	#							✓						#						✓						#	#
Austrostipa nodosa	a speargrass																															✓					✓			
Austrostipa scabra	Rough Speargrass									✓				#																										
Austrostipa scabra subsp. *scabra*	Rough Speargrass	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	r=0.662 *p*=0.019 r_D=0.750 p_D=0.006	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Austrostipa tuckeri	Tucker's Speargrass																												✓			✓	✓	✓	✓					
Bothriochloa macra	Red-leg Grass																											✓	✓		✓				✓	✓				
Chloris pectinata	Comb Windmill Grass																																							
Chloris truncata	Windmill Grass																	✓										✓	✓			✓	✓	✓		✓				
Dactyloctenium radulans	Button Grass														✓	✓	✓		✓	✓							r=-0.608 *p*=0.036 r_D=-0.640 p_D=0.009		✓											
Dichanthium sericeum	Queensland Bluegrass																											✓					✓							
Digitaria brownii	Cotton Panic Grass																											✓	✓	✓	✓	✓		✓	✓				r_D=-0.525 p_D=0.024	
Digitaria hystrichoides	Curly Umbrella Grass																											✓		✓	✓		✓	✓	✓					
Elymus scaber	a wheatgrass																														✓									
Elymus scaber var. *scaber*	a wheatgrass																											✓							✓					
Enneapogon avenaceus	Common Bottlewashers														✓	✓	✓		✓		✓		✓	✓	✓	✓	#	✓	✓	✓	✓	✓	✓	✓		✓			r=-0.772 *p*=0.005 r_D=-0.672 p_D=0.008 Lo**-	
Enneapogon nigricans	Niggerheads																											✓	✓		✓		✓							
Enteropogon	a grass		✓	✓		✓		✓		✓																														

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	**2**	**4**	**5**	**11**	**7**	**10**	**3**	**12**	**6**	**8**	**9**	**corr.**	**23**	**22**	**15**	**21**	**18**	**19**	**17**	**14**	**20**	**24**	**13**	**16**	**corr.**	**35**	**34**	**33**	**32**	**25**	**31**	**26**	**28**	**30**	**29**	**27**	**corr.**	
Enteropogon acicularis	Curly Windmill Grass																✓		✓		✓	✓			✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	r_D=-0.450 p_D=0.045	
Eragrostis	a grass							✓						#																										
Eragrostis eriopoda	Woollybutt														✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓			✓					✓	✓	✓	Li**+	
Eragrostis lacunaria	Purple Lovegrass																✓	✓	✓			✓			✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#	
Erophila verna ssp. *verna**	Whitlow Grass		✓																																					
*Hordeum leporinum**	Barley Grass		✓						✓																															
Monachather paradoxa	Mulga Oats/Bandicoot Grass																												✓				✓	✓	✓	✓	✓	✓	Lo*+	
Panicum effusum	Hairy Panic																											✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	#	
Panicum queenslandicum var. *queenslandicum*	Yabila Grass																				✓				✓															
Panicum subxerophilum	Cane Panic																																				✓	✓	r=0.869 p=0.001 r_D=0.938 p_D=0.000 Lo*+; Li**+	
Paspalidium constrictum	Box Grass	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓					✓				✓		✓	✓		✓			✓			✓	✓	✓	✓	✓		✓	#	#
*Pentaschistis airoides**	False Hairgrass																																			✓			#	
*Schismus barbatus**	Arabian Grass	✓			✓			✓			✓		✓		✓	✓		✓				✓	✓			✓											✓	✓	r=0.698 p=0.017 r_D=0.871 p_D=0.000 Lo*+; Li**+	
Sporobolus caroli	Fairy Grass		✓																										✓											
Themeda australis	Kangaroo Grass																											✓		✓			✓							
Thyridolepis mitchelliana	Mulga Mitchell Grass																					✓					# r_D=0.610 p_D=0.035*	✓					✓		✓			✓	r=0.692 p=0.018	
Tragus australianus	Small Burr Grass														✓	✓	✓			✓						✓														

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Tripogon loliiformis	Five-minute Grass														✓	✓	✓		✓	✓		✓	✓	✓	✓			✓				✓	✓	✓	✓		✓			
Triraphis mollis	Purple Plume Grass																✓								✓															
Urochloa subquadripara	a grass																✓																							
Mistletoes																																								
Amyema	a misteltoe																																							
Amyema linophyllum ssp. *orientale*	a misteltoe		✓						✓				✓																											
Amyema lucasii	a misteltoe																																							
Amyema miquelii	a misteltoe																																							
Amyema miraculosum ssp. *boormanii*	Fleshy Mistletoe	✓	✓		✓	✓		✓				✓																									✓		r_D=0.669 p_D=0.024* Li**+	
Amyema quandang	a mistletoe																																					✓	r=0.736 p=0.010*	
Amyema quandang var. *quandang*	a misteltoe									✓				#																										
Lysiana exocarpi	Harlequin Mistletoe				✓					✓																														
Lysiana exocarpi ssp. *exocarpi*	Harlequin Mistletoe		✓																																					
Lysiana exocarpi ssp. *tenuis*	Harlequin Mistletoe				✓			✓																																
Lysiana murrayi	Mulga Mistletoe																																							
Lysiana subfalcata	Northern Mistletoe																																							
Forbs/herbs																																								
Abutilon																												✓		✓						✓				
Abutilon fraseri	Dwarf Lantern Flower	✓	✓							✓													✓																	
Abutilon otocarpum	Desert Chinese Lantern														✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Alternanthera species A	a joyweed														✓		✓								✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
*Alyssum linifolium**	Flaxleaf Alyssum	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓																											
*Araujia sericiflora**	a vine										✓																													
Astroloma	a small shrub									✓				#																										
Boerhavia dominii	Tar Vine														✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	r=-0.641 p=0.033 r_D=-0.763 p_D=0.001 Lo*-; Li**-	
Brachyachne ciliaris	Variable Daisy																				✓					✓														
Brachycome ciliaris var. *ciliaris*	Variable Daisy		✓		✓																																			
Brachyscome ciliaris	Variable Daisy																		✓		✓			✓	✓	✓	r=0.648 p=0.023													
Brachyscome lineariloba	Hard-headed Daisy				✓																																			
Bracteantha viscosa	Sticky Everlasting																																✓						#	
Brassica	a forb																																					✓	r=0.736 p=0.010*	
Bulbine alata	Native Leek														✓	✓	✓	✓	✓	✓	✓		✓			✓	r_D=-0.626 p_D=0.005													
Bulbine spp.					✓							✓																												
Calandrinia pumila	Tiny Purslane		✓	✓	✓	✓		✓			✓	✓		#						✓			✓																	
Calotis cuneifolia	Purple Burr-daisy																											✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Calotis hispidula	Bogan Flea	✓	✓		✓							✓	✓		✓	✓																✓								#
Calotis lappulacea	Yellow Burr-daisy																											✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
*Carrichtera annua**	Ward's Weed		✓			✓	✓	✓	✓		✓	✓																												
*Carthamus lanatus**	Saffron Thistle																											✓	✓	✓		✓	✓						r=-0.624 p=0.04 r_D=-0.616 p_D=0.035 Lo**-	

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Chamaesyce drummondii	Caustic Weed							✓						#	✓	✓	✓		✓				✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Cheilanthes sieberi ssp. *sieberi*	Mulga Fern						✓	✓					✓												✓			✓		✓					✓	✓	✓	✓		
*Citrullus colocynthis**	Colocynth																												✓											
Convolvulus erubescens	Australian Bindweed						✓	✓		✓						✓	✓		✓					✓	✓	✓					✓		✓			✓				
Convolvulus microsepalus	a forb														✓	✓	✓	✓							✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
*Cucumis myriocarpus**	Paddy Melon														✓	✓					✓					✓		✓												
Cullen tenax																												✓												
Cuphonotus andraeanus	Downy Mother-of-Misery																																					✓	r=0.736 *p* =0.010*	
Daucus glochidiatus	Australian Carrot															✓																								
Erodium crinitum	Blue Crowfoot		✓	✓	✓		✓	✓		✓			✓	#	✓	✓			✓	✓					✓				✓											
Fimbristylis dichotoma	Common Fringe Rush															✓	✓			✓								✓				✓		✓						
Glossogyne tannensis	a forb																															✓		✓		✓	✓			
Glycine	a vine																	✓																						
Glycine clandestina	Twining Glycine																																		✓			✓	Lo*+	
Gnephosis arachnoidea	a forb		✓	✓	✓		✓	✓																																
Goodenia	a forb															✓																								
Goodenia cycloptera	Serrated Goodenia														✓	✓	✓		✓	✓	✓		✓	✓			r=-0.599 *p* =0.04 r_D=-0.602 p_D=0.020			✓		✓	✓	✓	✓	✓	✓	✓	Lo*+	
Goodenia fascicularis	Silky Goodenia			✓																								✓		✓	✓	✓	✓	✓		✓			Lo*-	
Goodenia havilandii	Hill Goodenia																																✓						#	
Gypsophila tubulosa	a forb																													✓	✓	✓	✓	✓		✓				

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	**2**	**4**	**5**	**11**	**7**	**10**	**3**	**12**	**6**	**8**	**9**	**corr.**	**23**	**22**	**15**	**21**	**18**	**19**	**17**	**14**	**20**	**24**	**13**	**16**	**corr.**	**35**	**34**	**33**	**32**	**25**	**31**	**26**	**28**	**30**	**29**	**27**	**corr.**	
*Harmsiodoxa blennodioides**	Hairy-pod Cress				✓										✓	✓	✓			✓			✓				r_D=-0.552 p_D=0.031													
Heliotropium species A	a heliotrope																✓																							
Hibiscus sturtii var. grandiflorus	Hill Hibiscus														✓																									
Jasminum lineare	Native Jasmine									✓				#															✓											
Lepidium papillosum	Warty Peppercress				✓																																			
Lepidium phlebopetalum	Veined Peppercress																	✓	✓	✓			✓				#													
Lepidium pseudohyssopifolium	a peppercress				✓																																			
Leptorhynchos baileyi	a button daisy																													✓	✓	✓	✓	✓	✓	✓	✓	✓		
Leptorhynchos tetrachaetus	Beauty Buttons																											✓			✓	✓		✓						
Linum marginale	Wild Flax																											✓					✓			✓				
Marsdenia australis	Doubah			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓									✓			✓		r_D=0.726 p_D=0.008									✓			#	
*Medicago laciniata**	Cut-leaf Medic	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓																			✓								
Millotia greevesii var. *greevesii*	Creeping Millotia																																							
Minuria leptophylla	Minnie Daisy																											✓		✓		✓	✓			✓				
Nicotiana goodspeedii	Small Flower Tobacco	✓		✓	✓																																			
Olearia calcarea	a daisy-bush					✓																																		
Olearia pimeleoides	Showy Daisy-bush				✓	✓				✓									✓		✓		✓	✓		✓														
*Oxalis corniculata**	Yellow Wood-sorrel	✓	✓		✓		✓	✓		✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓		✓	✓	✓		✓	✓			✓	✓		✓	✓	✓	✓	#	
Parsonsia eucalyptophylla	Gargaloo										✓																										✓		r_D=0.669 p_D=0.024* Li**+	
Phyllanthus lacunellus	a spurge																																					✓	r=0.736 p=0.010*	

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		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Pimelea microcephala ssp. *microcephala*	Shrubby Rice-flower																											✓	✓											
Pimelea trichostachya	Spiked Rice-flower														✓	✓	✓		✓								r=-0.663 *p* =0.019 r_D=-0.592 p_D=0.032			✓	✓		✓		✓	✓	✓		#	
Plantago turrifera	Small Sagoweed														✓			✓	✓																					
Podolepis capillaris	Invisible Plant														✓								✓																	
Portulaca intraterranea	Large Pigweed														✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	r=-0.622 *p* =0.031	✓	✓	✓		✓	✓	✓	✓	✓	✓			
Ptilotus atriplicifolius var. *atriplicifolius*	Crimson Foxtail					✓		✓	✓						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		#
Ptilotus exaltatus var. *exaltatus*	Showy Foxtail			✓					✓	✓																														
Ptilotus gaudichaudii	Paper Foxtail																																			✓			#	
Ptilotus gaudichaudii var. *gaudichaudii*	Paper Foxtail			✓	✓	✓				✓							✓	✓					✓		✓		#	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Ptilotus gaudichaudii var. *parviflorus*	Shrubby Foxtail		✓					✓			✓			#																										
Ptilotus obovatus	Silver-tails				✓					✓				#						✓						✓														
Ptilotus obovatus var. *obovatus*	Silver-tails						✓	✓																																
Rhodanthe floribunda	Common White Sunray Daisy	✓													✓	✓				✓			✓							✓	✓	✓	✓	✓	✓	✓	✓	✓	#	#
Rhyncharrhena linearis	a vine	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	#			✓																	✓				✓		#
*Rostraria pumila**	Roughtail		✓																																					
Rumex brownii	Slender Dock																															✓								
*Salvia verbenaca**	Wild Sage																											✓	✓	✓	✓	✓		✓	✓				r=-0.639 *p* =0.034 r_D=-0.638 p_D=0.014 Lo*-	

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	**2**	**4**	**5**	**11**	**7**	**10**	**3**	**12**	**6**	**8**	**9**	**corr.**	**23**	**22**	**15**	**21**	**18**	**19**	**17**	**14**	**20**	**24**	**13**	**16**	**corr.**	**35**	**34**	**33**	**32**	**25**	**31**	**26**	**28**	**30**	**29**	**27**	**corr.**	
Sauropus trachyspermus																	✓				✓			✓	✓			✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		
Scaevola spinescens	Spiny Fan-flower							✓						#																										
Sida							✓	✓																					✓											
Sida ammophila	Sand Sida														✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓															
Sida corrugata	Corrugated Sida		✓														✓					✓	✓			✓		✓	✓		✓	✓	✓		✓					
Sida cunninghamii	Ridge Sida																											✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Sida fibulifera	Pin Sida							✓		✓				#	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		r=-0.806 *p* =0.003 r_D=-0.738 p_D=0.006 Lo*-	r=-0.357 *p* =0.044 r_D=-0.261 p_D=0.000
Sida intricata	Twiggy Sida																											✓	✓			✓								
Sida trichopoda	High Sida														✓	✓	✓			✓		✓				✓														
*Silene nocturna**	Mediterranean Catchfly				✓						✓			#																										
Sisymbrium erysimoides	Smooth Mustard	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓																											
*Sisymbrium orientale**	Hedge Mustard		✓																																					
Solanum cleistogamum	Shy Nightshade														✓		✓			✓	✓	✓	✓	✓	✓	✓	#			✓	✓		✓	✓		✓	✓	✓	#	
Solanum esuriale	Quena																✓				✓							✓	✓	✓	✓	✓	✓	✓		✓	✓		Lo*-	
Solanum ferocissimum	Spiny Potato-bush							✓						#														✓	✓								✓	✓		
*Sonchus oleraceus**	Common Sowthistle		✓																																					
Spartothamnella puberula	Red-berried Stick-plant																																					✓	r=0.736 *p* =0.010*	
*Spergularia marina**	Sandspurry																																							
Swainsona	a pea																✓																							
Swainsona affinis	Poison Pea																																					✓	r=0.736 *p* =0.010*	
Templetonia egena	Desert Broombush							✓						#																										
Templetonia sulcata	Flat Mallee-pea									✓				#																										

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Tetragonia tetragonoides	New Zealand Spinach	✓				✓	✓					✓		#	✓																									
Teucrium racemosum	Grey Germander																													✓		✓								
Tribulus terrestris	Cat-head		✓					✓	✓						✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓			✓			✓	✓				
Velleia paradoxa	Spur Velleia																													✓								✓		
Vittadinia condyloides	a forb																						✓																	
Vittadinia cuneata	Fuzzweed																												✓	✓	✓									
Vittadinia cuneata var. *cuneata*	Fuzzweed																✓		✓		✓	✓	✓	✓	✓	✓					✓	✓	✓	✓	✓	✓	✓	✓		
Vittadinia cuneata var. *hirsuta*	Fuzzweed	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓																												
Vittadinia pustulata	a forb																											✓		✓		✓			✓	✓		✓		
*Vulpia myuros**	Rat's-tail Fescue																														✓				✓	✓	✓			
Wahlenbergia	bluebells								✓					#																										
Wahlenbergia communis	Tufted Bluebells		✓					✓				✓	✓				✓								✓															
Wahlenbergia luteola	bluebells																											✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Zygophyllum ammophilum	Sand Twinleaf	✓	✓	✓	✓	✓	✓	✓			✓	✓																												
Zygophyllum eremaeum	Climbing Twinleaf			✓	✓	✓				✓	✓	✓	✓																											
Zygophyllum glaucum	Pale Twinleaf												✓	r=0.624 p=0.030* r_D=0.813 p_D=0.001*																										
Zygophyllum iodocarpum	Violet Twinleaf		✓		✓	✓	✓		✓	✓		✓	✓																											
Zygophyllum ovatum	Dwarf Twinleaf	✓	✓		✓				✓		✓		✓																											
Birds																																								

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Dromaius novaehollandiae	Emu	✓	✓		✓		✓			✓	✓				✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#			✓				✓	✓		✓	✓	r=0.567 *p*=0.045 Lo*+	
Coturnix pectoralis	Stubble Quail																													✓				✓						
Aquila audax	Wedge-tailed Eagle																												✓											
Accipiter fasciatus	Brown Goshawk									✓				#																										
Falco peregrinus	Peregrine Falcon																												✓											
Falco cenchroides	Australian Kestrel																				✓						#				✓									
Turnix velox	Little Button-quail																											✓		✓						✓				
Turnix varia	Painted Button-quail																																				✓		r_D=0.669 p_D=0.024* Li**+	
Phaps chalcoptera	Common Bronzewing	✓			✓		✓	✓			✓	✓			✓				✓		✓	✓	✓												✓		✓		Lo*+	#
Ocyphaps lophotes	Crested Pigeon	✓			✓											✓	✓	✓						✓				✓	✓	✓		✓			✓					r=-0.313 *p*=0.022 r_D=-0.269 p_D=0.043
Cacatua leadbeateri	Pink Cockatoo		✓	✓	✓	✓									✓														✓				✓		✓					r=-0.31 *p*=0.029
Cacatua roseicapilla	Galah		✓			✓			✓								✓	✓	✓				✓	✓		✓		✓	✓											
Nymphicus hollandicus	Cockatiel																													✓								✓	#	
Aprosmictus erythropterus	Red-winged Parrot																																✓	✓					#	
Psephotus haematonotus	Red-rumped Parrot																				✓			✓				✓	✓			✓								
Psephotus varius	Mulga Parrot	✓	✓	✓	✓	✓					✓					✓	✓		✓			✓		✓								✓		✓	✓		✓	✓	r=0.753 *p*=0.008 r_D=0.634 p_D=0.035 Lo*+	
Barnardius barnardi	Mallee Ringneck	✓	✓	✓	✓	✓	✓	✓				✓	✓				✓		✓					✓		✓		✓	✓	✓		✓	✓			✓	✓	✓		
Northiella haematogaster	Blue Bonnet		✓												✓	✓	✓		✓			✓		✓				✓	✓	✓	✓		✓						r=-0.566 *p*=0.024 Lo*-	r=-0.325 *p*=0.015

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Melopsittacus undulatus	Budgerigar																															✓								
Cuculus pallidus	Pallid Cuckoo		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓			✓																				
Chrysococcyx osculans	Black-eared Cuckoo	✓		✓																																				
Chrysococcyx basalis	Horsfield's Bronze-Cuckoo							✓						#							✓						#			✓										
Tyto alba	Barn Owl																															✓								
Podargus strigoides	Tawny Frogmouth																													✓				✓						
Aegotheles cristatus	Australian Owlet-nightjar		✓	✓		✓	✓	✓		✓	✓		✓	#	✓		✓		✓	✓	✓		✓	✓		✓	#			✓		✓	✓	✓	✓	✓	✓	✓		
Halcyon pyrrhopygia	Red-backed Kingfisher															✓	✓																							
Merops ornatus	Rainbow Bee-eater		✓		✓								✓		✓	✓	✓			✓		✓	✓				r=-0.603 p=0.038										✓	✓	r=0.779 p=0.001 r_D=0.653 p_D=0.005	#
Climacteris picumnus	Brown Treecreeper		✓	✓	✓	✓	✓			✓	✓																													
Climacteris affinis	White-browed Treecreeper		✓		✓	✓		✓																																
Malurus cyaneus	Superb Blue Wren																																			✓			#	
Malurus splendens	Splendid Wren																	✓		✓		✓	✓	✓	✓	✓	r=0.727 p=0.007					✓		✓	✓	✓	✓	✓		
Malurus lamberti	Variegated Wren																									✓		✓		✓		✓								
Pardalotus striatus	Striated Pardalote																												✓								✓	✓	r=0.675 p=0.036 r_D=0.598 p_D=0.04	
Gerygone fusca	Western Gerygone		✓			✓																																		
Smicrornis brevirostris	Weebill								✓				✓	r_D=0.718 p_D=0.023			✓													✓				✓			✓	✓	r=0.833 p=0.003 r_D=0.752 p_D=0.004	r=0.457 p=0.016 r_D=0.571 p_D=0.000

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Acanthiza nana	Yellow Thornbill				✓																											✓		✓			✓	✓	r=0.886 *p*=0.001 r_D=0.906 p_D=0.001 Li*+	
Acanthiza apicalis	Inland Thornbill		✓	✓				✓	✓		✓		✓	#	✓		✓		✓			✓		✓	✓		#					✓	✓				✓	✓	r=0.778 *p*=0.018 r_D=0.804 p_D=0.016	
Acanthiza uropygialis	Chestnut-rumped Thornbill		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	#	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓					✓	✓	✓	✓	✓	✓	✓	✓		r=0.283 *p*=0.025
Acanthiza reguloides	Buff-rumped Thornbill		✓			✓		✓	✓	✓		✓												✓																
Acanthiza chrysorrhoa	Yellow-rumped Thornbill	✓	✓							✓		✓							✓	✓		✓		✓			#					✓	✓	✓	✓	✓	✓	✓		#
Aphelocephala leucopsis	Southern Whiteface														✓	✓	✓	✓	✓			✓	✓			✓	r=-0.65 *p*=0.022			✓		✓	✓	✓	✓	✓				
Melithreptus brevirostris	Brown-headed Honeyeater																																				✓		r_D=0.669 p_D=0.024* Li**+	
Plectorhyncha lanceolata	Striped Honeyeater	✓		✓			✓					✓	✓											✓								✓	✓	✓						
Phylidonyris albifrons	White-fronted Honeyeater																																	✓	✓				#	
Lichenostomus virescens	Singing Honeyeater			✓		✓	✓	✓	✓	✓	✓		✓	#		✓	✓		✓	✓	✓	✓	✓	✓		✓	#		✓	✓	✓	✓	✓	✓	✓	✓	✓			#
Manorina flavigula	Yellow-throated Miner	✓						✓		✓			✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		
Acanthagenys rufogularis	Spiny-cheeked Honeyeater		✓	✓	✓	✓	✓	✓	✓	✓			✓				✓				✓	✓	✓	✓	✓	✓	r=0.795 *p*=0.002 r_D=0.861 p_D=0.0	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		r=0.444 *p*=0.027 r_D=0.405 p_D=0.031
Philemon citreogularis	Little Friarbird					✓																																		
Ephthianura aurifrons	Orange Chat									✓				#																										
Ephthianura tricolor	Crimson Chat		✓	✓												✓	✓			✓																				

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Petroica goodenovii	Red-capped Robin	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#	✓			✓	✓	✓		✓	✓	✓	✓	✓	r=0.693 p=0.012 r_D=0.711 p_D=0.03			✓		✓	✓	✓	✓	✓	✓	✓		
Melanodryas cucullata	Hooded Robin					✓																											✓	✓					#	
Pomatostomus temporalis	Grey-crowned Babbler	✓																											✓	✓			✓		✓		✓	✓	#	
Pomatostomus superciliosus	White-browed Babbler			✓	✓					✓		✓																												
Pomatostomus ruficeps	Chestnut-crowned Babbler																			✓							#	✓	✓		✓	✓						✓	#	
Pomatostomus halli	Hall's Babbler																									✓														
Daphoenositta chrysoptera	Varied Sitella			✓				✓											✓																					
Oreoica gutturalis	Crested Bellbird		✓	✓	✓			✓	✓		✓	✓		#	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	#					✓	✓	✓	✓	✓	✓			
Pachycephala rufiventris	Rufous Whistler	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	#			✓		✓	✓	✓	✓	✓		✓	✓	r=0.71 p=0.02					✓		✓	✓	✓	✓	✓	Lo*+	
Colluricincla harmonica	Grey Shrike-thrush	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					✓				✓	✓	✓								✓		✓	✓	✓	✓	✓	r=0.619 p=0.016 r_D=0.612 p_D=0.03 Lo*+	#
Myiagra inquieta	Restless Flycatcher									✓				#																										
Grallina cyanoleuca	Australian Magpie Lark			✓									✓			✓	✓		✓		✓		✓		✓		#	✓	✓	✓	✓	✓	✓		✓			✓		
Rhipidura leucophrys	Willie Wagtail	✓	✓		✓		✓								✓		✓		✓	✓	✓	✓	✓	✓		✓		✓	✓		✓	✓	✓	✓	✓	✓				
Coracina maxima	Ground Cuckoo-shrike																✓																							
Coracina novaehollandiae	Black-faced Cuckoo-shrike														✓		✓	✓			✓				✓	✓				✓				✓	✓			✓	r=0.723 p=0.038	
Lalage sueurii	White-winged Triller				✓								✓		✓		✓																							
Artamus personatus	White-breasted Woodswallow																				✓						#						✓						#	

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Artamus superciliosus	White-browed Woodswallow				✓								✓															✓			✓	✓		✓						
Artamus cinereus	Black-faced Woodswallow															✓	✓		✓																					
Cracticus nigrogularis	Pied Butcherbird						✓		✓					#			✓											✓	✓	✓		✓			✓			✓		
Cracticus torquatus	Grey Butcherbird	✓		✓	✓				✓			✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#	✓		✓	✓	✓	✓	✓	✓		✓	✓		
Gymnorhina tibicen	Australian Magpie	✓	✓	✓	✓		✓					✓			✓	✓	✓	✓	✓		✓	✓	✓	✓		✓		✓	✓	✓		✓	✓	✓		✓	✓	✓		
Corvus bennetti	Little Crow																					✓			✓		r_D=0.715 p_D=0.006		✓											
Corvus coronoides	Australian Raven		✓		✓					✓		✓								✓						✓				✓		✓			✓					
Corcorax melanorhamphos	White-winged Chough		✓		✓		✓	✓					✓	#			✓													✓			✓		✓			✓	#	#
Struthidea cinerea	Apostelbird	✓															✓	✓	✓									✓	✓		✓	✓	✓		✓		✓	✓		
Chlamydera maculata	Spotted Bowerbird											✓		r=0.6 p=0.039*			✓							✓					✓	✓					✓	✓	✓			
Anthus novaeseelandiae	Richard's Pipit															✓												✓												
Poephila bichenovii	Double-barred Finch																															✓								
Poephila guttata	Zebra Finch																																✓			✓			#	
Dicaeum hirundinaceum	Mistletoebird		✓		✓	✓	✓	✓	✓	✓	✓																			✓		✓	✓	✓	✓	✓		✓		
Cinclorhamphus mathewsi	Rufous Songlark																											✓												
Reptiles																																								
Diplodactylus ciliaris	Spiny-tailed Gecko																✓							✓	✓		#													
Diplodactylus intermedius	Eastern Spiny-tailed Gecko																													✓										

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Diplodactylus steindachneri	Steindachner's Gecko	✓			✓							✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	r=-0.602 *p*=0.038 r_D=-0.688 p_D=0.028	✓	✓	✓	✓	✓	✓	✓	✓	✓			r=-0.52 *p*=0.017 r_D=-0.504 p_D=0.015 Lo*-; Li**-	
Diplodactylus vittatus	Wood (Stone) Gecko	✓		✓	✓			✓																																
Gehyra variegata	Tree Dtella	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓		✓	✓	✓		✓		✓	✓		
Heteronotia binoei	Bynoe's Gecko (Prickly Gecko)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓					✓		✓	✓			#		✓							✓				
Nephrurus levis	Smooth Knob-tailed Gecko															✓	✓				✓	✓			✓	✓														
Oedura marmorata	Marbled Velvet Gecko					✓	✓	✓																																
Rhynchoedura ornata	Beaked Gecko	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#	#
Pygopus nigriceps	Hooded Scaly-foot		✓								✓			#														✓				✓			✓			✓		
Ctenophorus nuchalis	Central Netted Dragon																					✓					# r_D=0.61 p_D=0.035*			✓		✓	✓	✓	✓	✓	✓			
Ctenophorus pictus	Painted Dragon																																	✓					#	
Pogona vitticeps	Central Bearded Dragon			✓													✓									✓			✓		✓			✓	✓		✓			#
Varanus gouldii	Gould's Goanna (Sand Goanna)	✓									✓	✓	✓	r=0.649 *p*=0.022 r_D=0.661 p_D=0.019					✓											✓								✓		
Varanus varius	Lace Monitor						✓																																	
Cryptoblepharus carnabyi	Carnaby's Wall Skink	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓	✓					✓	✓																
Ctenotus allotropis	striped skink																											✓		✓	✓	✓	✓	✓	✓	✓				
Ctenotus leonhardii	striped skink															✓			✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓			
Ctenotus regius	Regal (Royal) Striped Skink															✓			✓	✓	✓	✓		✓	✓		#													
Ctenotus schomburgkii	striped skink				✓	✓									✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	r=0.594 *p*=0.042								✓	✓				
Ctenotus sp.	striped skink															✓								✓					✓			✓	✓							

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Egernia inornata	Desert Skink																	✓	✓	✓	✓	✓	✓	✓	✓	✓	r=0.708 p=0.01 r_D=0.783 p_D=0.002													
Egernia striolata	Tree Skink	✓		✓	✓		✓	✓			✓		✓																											
Eremiascincus richardsonii	Broad-banded Sand Swimmer															✓	✓		✓					✓	✓															
Lerista labialis	burrowing skink															✓	✓	✓		✓	✓	✓		✓	✓		#													
Lerista muelleri	Mueller's Skink			✓	✓		✓		✓	✓		✓			✓									✓	✓	✓	#				✓				✓		✓	✓	r=0.657 p=0.028 r_D=0.721 p_D=0.018 Lo**+	
Lerista punctatovittata	Spotted Burrowing Skink	✓															✓																			✓			#	
Menetia greyii	Grey's Skink	✓	✓			✓	✓	✓	✓			✓				✓					✓							✓												
Morethia boulengeri	Boulenger's Skink	✓	✓	✓		✓	✓	✓	✓		✓		✓		✓			✓		✓			✓	✓	✓	✓						✓	✓		✓			✓		
Tiliqua occipitalis	Western Blue-tongued Lizard										✓																													
Trachydosaurus rugosus	Shingle-back Lizard (Bogeye)	✓	✓	✓	✓		✓	✓	✓	✓				r=-0.545 p=0.02 r_D=-0.561 p_D=0.021		✓	✓			✓	✓	✓				✓		✓	✓	✓	✓	✓	✓			✓			r=-0.462 p=0.024 r_D=-0.411 p_D=0.044 Lo**-	r=-0.365 p=0.001 r_D=-0.303 p_D=0.007
Ramphotyphlops bituberculatus	blind snake																							✓	✓										✓		✓	✓	r=0.799 p=0.003 r_D=0.767 p_D=0.006 Lo**+	
Ramphotyphlops sp.	blind snake																								✓															
Pseudonaja nuchalis	Western Brown Snake										✓																		✓											
Suta suta	Curl (Myall) Snake									✓				#																										
Frogs																																								

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Limnodynastes fletcheri	Barking Marsh Frog																																		✓				#	
Neobatrachus sudelli	Common Spadefoot Toad												✓	r=0.624 p=0.030* r_D=0.813 p_D=0.001*	✓																									
Uperoleia rugosa	Wrinkled Toadlet																	✓																						
Mammals																																								
Tachyglossus aculeatus	Short-beaked Echidna	✓		✓			✓	✓				✓		#							✓	✓					#			✓	✓			✓						#
Antechinomys laniger	Kultarr																																✓						#	
Sminthopsis murina	Common Dunnart						✓	✓	✓	✓	✓	✓																									✓		r_D=0.669 p_D=0.024* Li**+	
Macropus fuliginosus	Western Grey Kangaroo			✓		✓									✓		✓		✓									✓						✓			✓		# Li*+	
Macropus giganteus	Eastern Grey Kangaroo		✓												✓					✓									✓			✓								
Macropus rufus	Red Kangaroo	✓		✓				✓		✓			✓		✓		✓	✓	✓									✓	✓											r=-0.345 p=0.024
Macropus sp.	kangaroo																												✓							✓				
Tadarida australis	Yellow-bellied Sheathtail-bat					✓																																		
*Mus musculus**	House Mouse				✓			✓																	✓															
Pseudomys hermannsburgensis	Sandy Inland Mouse														✓																									
*Capra hircus**	Goat (feral)					✓		✓		✓	✓			#					✓					✓	✓	✓												✓	r=0.736 p=0.010*	
*Lepus capensis**	Brown Hare																															✓								
*Oryctolagus cuniculus**	Rabbit		✓	✓		✓																							✓	✓	✓		✓		✓	✓	✓			
*Sus scrofa**	Pig (feral)																											✓				✓			✓					
*Canis familiaris**	Dog (feral)															✓					✓					✓														

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
*Felis catus**	Cat (feral)																																				✓		r_D=0.669 p_D=0.024* Li**+	
*Vulpes vulpes**	Fox				✓				✓		✓			#	✓		✓		✓			✓				✓				✓	✓					✓				
Invertebrate 'Orders'																																								
Acarina	Mites & Ticks	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	r=-0.627 p=0.031 r_D=-0.623 p_D=0.03 Lo*-	
Araneae	Spiders	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	r_D=0.594 p_D=0.046	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		#
Arthropoda	Arthropods																														✓									
Blattodea	Cockroaches			✓	✓			✓											✓	✓			✓		✓	✓							✓	✓	✓		✓	✓	r=0.677 p=0.015 r_D=0.586 p_D=0.039 Lo**+	
Coleoptera	Beetles	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		#
Collembola	Springtails	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	r=0.56 p=0.045 r_D=0.627 p_D=0.019	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Diplopoda	Millipedes																					✓					# r_D=0.61 p_D=0.035*													
Diptera	Flies	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#	#
Formicidae	Ants	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		#
Geophilida	Earth Centipedes									✓				#																										
Hemiptera	Bugs	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Hymenoptera	Bees & Wasps (but not Ants)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	r_D=0.637 p_D=0.022	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#	#
Isopoda	Slaters		✓		✓	✓							✓							✓				✓				✓	✓		✓				✓	✓	✓	✓		

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Isoptera	Termites	✓		✓	✓		✓	✓		✓	✓	✓	✓		✓	✓	✓	✓		✓	✓		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Larvae	Larvae	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Lepidoptera	Butterflies & Moths			✓	✓	✓		✓	✓		✓	✓	✓			✓	✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		✓	✓	✓		r_D=0.342 p_D=0.044
Lithobiida	Lithobiid Centipedes																																		✓				#	
Mantodea	Mantids						✓								✓	✓		✓	✓	✓		✓			✓	✓	#	✓		✓	✓				✓					
Neuroptera	Lacewings											✓		r=0.6 *p*=0.039*																										
Orthoptera	Grasshoppers & Crickets	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	r=0.785 *p*=0.008	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Phasmatodea	Stick Insects																									✓														
Polyxenida	Pin Cushion Millipedes			✓				✓																																
Pseudoscorpionida	Pseudoscorpions	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		#
Psocoptera	Book Lice		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓		✓	✓		
Scolopendrida	Scolopendrid Centipedes											✓		r=0.6 *p*=0.039*								✓		✓	✓		r_D=0.708 p_D=0.007	✓	✓		✓							✓	#	
Scorpionida	Scorpions															✓	✓									✓											✓	✓	r=0.869 *p*=0.001 r_D=0.938 p_D=0.00 Lo*+; Li**+	
Scutigerida	House Centipedes																	✓	✓												✓									
Symphyla	Soft-bodied Myriapods																														✓									
Thysanoptera	Thrips	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	r=0.647 *p*=0.022	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Thysanura	Silverfish	✓			✓						✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓		✓	✓					✓		✓		#
Ants																																								
Anochetus armstrongi			✓	✓	✓				✓				✓		✓	✓	✓	✓	✓	✓		✓	✓				r=-0.436 *p*=0.032	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		
Brachyponera lutea																																						✓	r=0.736 *p*=0.01	
Calomyrmex 0001						✓												✓			✓			✓	✓															

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Camponotus ephippium			✓	✓	✓		✓	✓	✓		✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	r=0.678 p=0.03 r_D=0.729 p_D=0.028 Lo*+	r_D=0.346 p_D=0.042
Camponotus sp. A		✓		✓	✓	✓	✓	✓	✓			✓	✓									✓		✓	✓		r_D=0.738 p_D=0.006		✓			✓		✓			✓	✓		
Camponotus nigriceps				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#			✓	✓				✓	✓	✓		✓				✓	✓	✓		✓	✓	✓	✓	✓	r=0.594 p=0.033 Lo**+	
Camponotus sp. B		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓	✓		✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Camponotus sp. C		✓	✓	✓			✓	✓			✓																	✓	✓	✓		✓			✓			✓		
Camponotus sp. nr. *aurocinctus*																			✓	✓	✓			✓	✓	✓	r=0.772 p=0.009			✓					✓		✓		#	
Camponotus sp. nr. *capito*																✓		✓	✓	✓	✓	✓		✓	✓	✓														
Camponotus sp. D																			✓	✓																		✓	r=0.736 p=0.01*	
Camponotus tricoloratus																		✓	✓										✓					✓						
Camponotus whitei			✓																																					
Cardiocondyla sp. A																	✓															✓								
Cardiocondyla 0002																															✓									
Cerapachys sp. A							✓												✓						✓						✓									#
Cerapachys sp. B																✓				✓																				
Cerapachys 0003																					✓						#													
Cerapachys 0004																								✓							✓			✓						
Cerapachys 0005			✓																																					
Colobostruma sp. A			✓																																					
Crematogaster 0001		✓	✓	✓	✓	✓	✓			✓	✓	✓	✓									✓					# r_D=0.61 p_D=0.035					✓								
Crematogaster sp. B		✓			✓		✓		✓																															

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Crematogaster sp. C			✓	✓	✓	✓					✓		✓																											
Doleromyrma sp. A															✓		✓																							
Dolichoderus sp. A					✓																																			
Epopostruma sp. A				✓	✓																																			
Hypoponera sp. A											✓																													
Iridomyrmex 0001		✓	✓	✓	✓		✓	✓			✓	✓		#			✓		✓	✓	✓	✓		✓	✓	✓	#	✓	✓				✓				✓	✓		#
Iridomyrmex 0002							✓				✓			#						✓							#													
Iridomyrmex 0003		✓			✓				✓				✓	#									✓	✓										✓					#	#
Iridomyrmex 0004				✓		✓			✓		✓			#	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓					✓	✓	✓			✓	✓	✓	r=0.705 p=0.041 r_D=0.756 p_D=0.026	r=0.342 p=0.045
Iridomyrmex 0005		✓	✓		✓	✓			✓	✓	✓		✓		✓	✓	✓	✓	✓	✓			✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#	#
Iridomyrmex 0006															✓	✓	✓	✓		✓			✓	✓	✓	✓		✓		✓								✓		
Iridomyrmex 0007		✓							✓	✓			✓			✓	✓							✓						✓		✓								#
Iridomyrmex 0008			✓		✓	✓			✓			✓	✓		✓	✓	✓	✓	✓	✓			✓			✓	r_D=-0.585 p_D=0.012	✓	✓	✓	✓	✓		✓	✓	✓	✓		#	#
Iridomyrmex 0009		✓	✓						✓				✓			✓				✓			✓		✓					✓		✓	✓	✓	✓	✓	✓	✓	#	#
Iridomyrmex 0010				✓		✓						✓		#		✓	✓	✓					✓			✓		✓		✓		✓				✓	✓	✓	r=0.615 p=0.044 r_D=0.577 p_D=0.045	r_D=0.339 p_D=0.046
Iridomyrmex 0011			✓												✓		✓									✓		✓					✓					✓		
Iridomyrmex 0012		✓																✓	✓	✓				✓				✓		✓		✓	✓							#
Iridomyrmex 0013																		✓		✓				✓	✓							✓					✓	✓	r=0.746 p=0.01 r_D=0.616 p_D=0.03	
Iridomyrmex 0014																							✓															✓	r=0.736 p=0.01	
Iridomyrmex 0015																														✓			✓		✓			✓		
Melophorus		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	r=-0.654 p=0.025 Lo*-	

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	2	4	5	11	7	10	3	12	6	8	9	corr.	23	22	15	21	18	19	17	14	20	24	13	16	corr.	35	34	33	32	25	31	26	28	30	29	27	corr.	
Melophorus sp. A																															✓									
Meranoplus sp. A		✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	#		✓	✓		✓	✓	✓	✓	✓		✓	✓		✓	✓		✓	✓	✓	✓			✓	✓		#
Meranoplus sp. B		✓	✓	✓	✓	✓		✓					✓									✓					# r_D=0.61 p_D=0.035*													
Meranoplus sp. C		✓	✓		✓			✓			✓	✓			✓			✓	✓		✓	✓		✓			#			✓	✓	✓								#
Meranoplus sp. D																					✓	✓			✓	✓	r=0.506 *p* =0.042 r_D=0.858 p_D=0.00											✓	r=0.736 *p* =0.01*	
Meranoplus sp. E							✓	✓	✓																	✓		✓	✓	✓	✓	✓		✓	✓		✓	✓	#	#
Meranoplus sp. F											✓																						✓						#	
Meranoplus sp. G											✓																		✓	✓			✓		✓	✓				
Meranoplus sp. H																	✓												✓	✓	✓		✓	✓	✓	✓	✓			
Meranoplus sp. I																									✓															
Meranoplus sp.																✓																				✓			#	
Meranoplus sp. K												✓		r=0.6 *p* =0.039*																	✓			✓						
Meranoplus 0012			✓																																					
Monomorium sp. M			✓																																	✓			#	
Monomorium sp.																																				✓			#	
Myrmecia sp. A					✓																											✓	✓				✓		#	
Myrmecia formosa																																✓	✓			✓			#	
Myrmecia sp. B																✓		✓	✓	✓																				
Notoncus 0001																								✓	✓															
Odontomachus sp. A																																			✓		✓		Lo**+	
Opisthopsis rufithorax							✓																	✓																
Paratrechina sp. A																												✓				✓			✓	✓		✓	#	
Pheidole sp. A		✓	✓	✓	✓	✓			✓	✓	✓		✓	#	✓	✓	✓		✓						✓		r=-0.629 *p* =0.034	✓		✓			✓	✓				✓	#	

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	**2**	**4**	**5**	**11**	**7**	**10**	**3**	**12**	**6**	**8**	**9**	**corr.**	**23**	**22**	**15**	**21**	**18**	**19**	**17**	**14**	**20**	**24**	**13**	**16**	**corr.**	**35**	**34**	**33**	**32**	**25**	**31**	**26**	**28**	**30**	**29**	**27**	**corr.**	
Pheidole sp. B		✓	✓		✓		✓		✓			✓	✓					✓					✓		✓			✓					✓	✓		✓	✓	✓	r=0.745 p=0.011 r_D=0.874 p_D=0.002 Li**+	r=0.362 p=0.033 r_D=0.593 p_D=0.000
Pheidole sp. C				✓	✓	✓				✓		✓						✓	✓		✓					✓												✓	r=0.736 p=0.01	
Pheidole sp. D																													✓				✓			✓				
Pheidole sp. E															✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#	✓	✓	✓		✓	✓		✓	✓	✓	✓		
Pheidole sp. F		✓	✓	✓	✓				✓	✓	✓		✓	#	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	#		✓			✓		✓	✓	✓	✓	✓		#
Pheidole sp. G			✓		✓					✓	✓	✓				✓		✓	✓	✓	✓	✓	✓		✓		#		✓	✓	✓	✓		✓	✓		✓	✓		#
Pheidole sp. H		✓		✓	✓	✓	✓				✓		✓		✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	r=0.86 p=0.001 r_D=0.665 p_D=0.009	✓		✓				✓	✓	✓	✓	✓	r=0.705 p=0.009 r_D=0.68 p_D=0.01 Li*+	r=0.653 p=0.000 r_D=0.582 p_D=0.000
Pheidole 0010																✓						✓										✓					✓			
Pheidole sp.																✓	✓	✓				✓		✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	#	
Polyrhachis sp. A																			✓				✓		✓	✓	r=0.616 p=0.014		✓			✓					✓			
Rhytidoponera 0001			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					✓						✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	r=-0.687 p=0.014 r_D=-0.657 p_D=0.017 Lo**-	
Rhytidoponera metallica			✓	✓	✓	✓	✓		✓	✓		✓	✓		✓	✓	✓		✓	✓			✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	Lo*+; Li*+	#
Rhytidoponera 0003						✓	✓			✓	✓			#			✓			✓			✓												✓				#	#
Rhytidoponera sp. A				✓											✓			✓	✓	✓						✓	#		✓	✓		✓		✓	✓		✓			
Solenopsis sp. A		✓				✓					✓			#								✓					# r_D=0.61 p_D=0.035*													
Solenopsis 0002			✓						✓												✓						#													
Stigmacros 0001				✓	✓	✓		✓	✓	✓		✓	✓											✓	✓					✓	✓		✓		✓			✓		
Stigmacros sp. A				✓																	✓						#		✓						✓					

Scientific Name	Common Name	Ivanhoe													Wanaaring-Louth													Cobar												Common taxa
		1	**2**	**4**	**5**	**11**	**7**	**10**	**3**	**12**	**6**	**8**	**9**	**corr.**	**23**	**22**	**15**	**21**	**18**	**19**	**17**	**14**	**20**	**24**	**13**	**16**	**corr.**	**35**	**34**	**33**	**32**	**25**	**31**	**26**	**28**	**30**	**29**	**27**	**corr.**	
Stigmacros 0003				✓	✓		✓			✓																														
Stigmacros sp. B				✓									✓																					✓					#	
Stigmacros aemula			✓	✓	✓								✓	#																										
Stigmacros elegans							✓		✓																															
Stigmacros sp. C													✓	r=0.624 *p* =0.03* r_D=0.813 p_D=0.001*																					✓	✓	✓	✓	r=0.768 *p* =0.003 r_D=0.854 p_D=0.002 Lo**+; Li*+	
Stigmacros aciculata					✓																																			
Stigmacros pilosella																						✓					# r_D=0.61 p_D=0.035*													
Tapinoma sp. A		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	#	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		
Tapinoma sp. B			✓																												✓	✓								

Appendix 6 Taxa diversity and abundance

6.1 Total numbers of taxa (both native and exotic) at each study site, with the number of exotic flora and vertebrate fauna species shown in square brackets. Ant numbers in parentheses are the number of *Monomorium* and *Tetramorium* morphospecies excluded from the totals. The total number of taxa recorded per region, and average per site, are summarised for each taxonomic group in Table 4.1.

Survey region	Site no.	No. flora taxa	No. vertebrate species	No. invertebrate 'Orders'	No. ant taxa	Total no. taxa
Ivanhoe	1	32 [4]	31 [0]	14	21 (5)	98
	2	52 [9]	37 [1]	14	29 (6)	132
	3	27 [4]	25 [1]	14	24 (5)	90
	4	36 [2]	35 [1]	17	26 (4)	115
	5	54 [6]	38 [2]	18	31 (8)	141
	6	36 [7]	27 [2]	16	24 (4)	103
	7	35 [4]	31 [0]	15	22 (2)	103
	8	39 [4]	26 [0]	18	19 (3)	102
	9	33 [4]	29 [0]	16	25 (6)	103
	10	48 [4]	34 [2]	15	14 (6)	111
	11	37 [3]	30 [2]	15	22 (6)	104
	12	42 [3]	29 [1]	15	17 (4)	103
Wanaaring-Louth	13	45 [1]	29 [2]	18	28 (10)	120
	14	35 [2]	34 [1]	18	23 (6)	110
	15	55 [2]	47 [1]	17	24 (11)	143
	16	37 [3]	34 [3]	20	26 (7)	118
	17	38 [2]	30 [1]	16	19 (6)	103
	18	43 [1]	36 [2]	18	26 (8)	123
	19	42 [2]	28 [0]	19	26 (8)	115
	20	43 [2]	27 [0]	17	21 (8)	108
	21	31 [1]	24 [0]	17	26 (8)	98
	22	49 [4]	26 [1]	18	24 (10)	117
	23	48 [4]	31 [1]	15	18 (11)	112
	24	37 [1]	41 [1]	17	26 (7)	121
Cobar	25	64 [4]	47 [2]	15	35 (10)	161
	26	56 [1]	37 [0]	15	27 (8)	135
	27	58 [2]	36 [1]	20	36 (9)	150
	28	56 [3]	43 [2]	18	29 (9)	146
	29	50 [3]	38 [2]	18	32 (10)	138
	30	63 [3]	31 [2]	16	28 (6)	138
	31	62 [2]	37 [1]	15	26 (8)	140
	32	50 [2]	22 [2]	22	25 (9)	119
	33	55 [2]	38 [2]	17	30 (11)	140
	34	60 [4]	34 [1]	17	22 (10)	133
	35	67 [4]	30 [1]	18	24 (9)	139

6.2 Total numbers of individual animals (both native and exotic) at each study site, with the number of exotic individuals shown in square brackets. Plants were recorded using cover abundance scores and are therefore not included. Ant numbers in parentheses are the number of *Monomorium* and *Tetramorium* individuals excluded from the totals for ants and invertebrates at each site.

Survey region	Site no.	Vertebrates	Ants	Total invertebrates
Ivanhoe	1	144 [0]	379 (15)	2,222
	2	173 [1]	335 (41)	3,477
	3	72 [1]	263 (86)	3,158
	4	111 [1]	2,217 (21)	6,058
	5	128 [2]	409 (46)	30,868
	6	91 [12]	5,146 (14)	10,367
	7	103 [0]	5,529 (9)	13,089
	8	82 [0]	1,043 (33)	3,118
	9	69 [0]	252 (47)	2,814
	10	146 [2]	24,538 (11)	26,663
	11	115 [19]	250 (123)	2,466
	12	127 [1]	160 (127)	3,792
Wanaaring-Louth	13	114 [3]	869 (148)	3,293
	14	139 [1]	8,852 (347)	11,152
	15	272 [2]	243 (126)	950
	16	132 [4]	1,207 (102)	2,669
	17	99 [1]	45,056 (228)	46,914
	18	177 [3]	7,195 (116)	8,336
	19	123 [0]	1,445 (199)	3,131
	20	91 [0]	217 (63)	568
	21	106 [0]	567 (217)	1,263
	22	88 [1]	618 (325)	1,512
	23	156 [1]	971 (66)	1,289
	24	178 [37]	1,798 (70)	5,422
Cobar	25	213 [2]	952 (253)	4,693
	26	140 [0]	954 (3,017)	5,130
	27	143 [1]	1,605 (232)	3,432
	28	161 [3]	898 (195)	2,880
	29	117 [3]	861 (238)	2,385
	30	114 [2]	1,208 (33)	2,234
	31	168 [2]	3,307 (223)	4,245
	32	119 [3]	644 (166)	2,822
	33	130 [4]	872 (98)	2,969
	34	156 [4]	21,038 (74)	24,820
	35	137 [1]	886 (215)	3,401

Appendix 7: Significant guild and taxa association results

7.1 Guilds and taxa associations for which a significant negative response to woody shrub cover or density was recorded in each region or across the three regions collectively. Statistical results are for single variable linear models. n.s. = not significant at the *p*=0.05 level.

Guild	Woody Shrub Cover		Woody Shrub Density	
	r^2	*p*	r^2	*p*
Ivanhoe				
Ground-feeding Granivorous Birds	0.402	0.027		n.s.
Non-passerine Granivorous Birds	0.408	0.025		n.s.
Ground Pursuers bird guild	0.359	0.039		n.s.
Omnivorous and Herbivorous Birds	0.410	0.025		n.s.
Wanaaring-Louth				
Drought Avoiders plant guild	0.348	0.043	0.511	0.009
Groundcover plant guild		n.s.	0.422	0.022
Ground-feeding Granivorous Birds	0.370	0.036		n.s.
Passerine Granivorous Birds	0.378	0.033		n.s.
Ground Pursuers bird guild	0.462	0.015		n.s.
Ground Gleaners bird guild	0.437	0.019	0.396	0.028
Macropods	0.377	0.034	0.385	0.031
Cobar				
Drought Avoiders plant guild	0.526	0.012	0.460	0.022
Drought Endurers plant guild	0.661	0.002	0.533	0.011
Groundcover plant guild	0.463	0.021	0.386	0.041
Ground-feeding Granivorous Birds	0.384	0.042		n.s.
Cobar Plant Association B	0.498	0.015		n.s.
Hot Climate Specialists ant guild	0.688	0.002	0.648	0.003
Three-regions				
Ground-feeding Granivorous Birds	0.304	0.001	0.173	0.013
Non-passerine Granivorous Birds	0.245	0.003	0.140	0.027
Ground Pursuers	0.209	0.006	0.152	0.021
Ground Gleaners	0.119	0.042		n.s.
Macropods	0.202	0.007	0.118	0.043

7.2 Guilds and taxa associations for which a significant positive response to woody shrub cover or density was recorded in each region or across the three regions collectively. Statistical results are for single variable linear models. n.s. = not significant at the *p*=0.05 level.

Guild	**Woody Shrub Cover**		**Woody Shrub Density**	
	r^2	***p***	**r^2**	***p***
Ivanhoe				
none				
Wanaaring-Louth				
Scavenging Birds		n.s.	0.495	0.011
Burrowing Reptiles	0.333	0.050	0.420	0.023
Terrestrial Skinks	0.412	0.025		n.s.
Subordinate Camponotini ant guild	0.612	0.003		n.s.
Cold Climate Specialists ant guild		n.s.	0.421	0.022
Cobar				
Tree and Shrub Canopy-feeding Insectivorous Birds (bark)	0.611	0.004	0.453	0.023
Burrowing Reptiles	0.422	0.030	0.479	0.018
Subordinate Camponotini ant guild	0.470	0.020	0.402	0.036
Cryptic Species ant guild	0.541	0.010		n.s.
Cobar Ant Association A	0.373	0.046		n.s.
Three-regions				
none				

Appendix 8: Flora and fauna model results

8.1 Model results for flora and fauna taxa and guilds of the Ivanhoe region. Results are restricted to those taxa and guilds for which woody shrub cover (WSC) or density (WSD) was included in the two-variable stepwise linear regression model. All significant results included, regardless of taxon abundance. P/A indicates presence/absence data.

Taxa, guild or taxa association	Best predictor	r^2 (best predictor)	Second predictor	r^2(model)	p (best predictor)	p (second predictor)	sign (best predictor)	sign (second predictor)
Flora								
Atriplex stipitata	distance from water (km)	0.426	WSD	0.641	0.010	0.046	pos.	neg.
Myoporum platycarpum	WSC	0.360	nutrient cycling status	0.592	0.020	0.050	pos.	pos.
Pittosporum phylliraeoides	WSD	0.661	WSC	0.928	0.000	0.000	pos.	neg.
Senna artemisioides ssp. *filifolia*	WSD	0.724	n/a	0.724	0.000	n.s.	pos.	
Zygophyllum glaucum	WSD	0.661	WSC	0.928	0.000	0.000	pos.	neg.
Vertebrates								
Diplodactylus steindachneri	altitude	0.511	WSD	0.875	0.000	0.001	pos.	pos.
Neobatrachus sudelli	WSD	0.661	WSC	0.928	0.000	0.000	pos.	neg.
Pygopus nigriceps	mistletoe (P/A)	0.400	WSD	0.865	0.001	0.000	neg.	neg.
Smicrornis brevirostris	WSD	0.417	shedding bark on tree (P/A)	0.666	0.008	0.029	pos.	pos.
Varanus gouldii	WSD	0.437	solid litter cover (%)	0.725	0.004	0.013	pos.	pos.
Non-passerine Granivorous Birds	WSC	0.408	no. of logs on ground 15-25 cm	0.674	0.008	0.024	neg.	neg.
Omnivorous and Herbivorous Birds	cryptogamic cover (%)	0.631	WSC	0.803	0.000	0.021	neg.	neg.
Invertebrates								
Stigmacros sp. C	WSD	0.661	WSC	0.928	0.000	0.000	pos.	neg.

8.2 Model results for flora and fauna taxa and guilds of the Wanaaring-Louth region. Results are restricted to those taxa and guilds for which woody shrub cover (WSC) or density (WSD) was included in the two-variable stepwise linear regression model. All significant results included, regardless of taxon abundance. P/A indicates presence/absence data.

Taxa, guild or taxa association	Best predictor	r^2 (best predictor)	Second predictor	r^2 (model)	*p* (best predictor)	*p* (second predictor)	sign (best predictor)	sign (second predictor)
Flora								
Aristida contorta	WSC	0.521	morpho terrain	0.866	0.001	0.024	neg.	
Austrostipa scabra subsp. *scabra*	WSD	0.541	% surface rock	0.727	0.002	0.035	pos.	pos.
Bulbine alata	WSD	0.555	n/a	0.555	0.005	n.s.	neg.	
Dactyloctenium radulans	WSD	0.513	n/a	0.513	0.009	n.s.	neg.	
Eremophila sturtii	rabbit disturbance	0.355	WSC	0.775	0.004	0.003	neg.	pos.
Goodenia cycloptera	WSD	0.435	soil stability	0.823	0.001	0.002	neg.	pos.
Harmsiodoxa blennodioides	WSD	0.387	n/a	0.387	0.031	n.s.	neg.	
Marsdenia australis	WSD	0.527	n/a	0.527	0.008	n.s.	pos.	
Senna artemisioides nothosubsp. *artemisioides*	WSD	0.372	WSC	0.880	0.001	0.000	pos.	neg.
Sida corrugata	rabbit disturbance	0.338	WSD	0.787	0.004	0.002	neg.	pos.
Thyridolepis mitchelliana	WSD	0.372	WSC	0.880	0.001	0.000	pos.	neg.
Tribulus terrestris	tree crown separation	0.506	WSD	0.758	0.002	0.013	neg.	neg.
Drought Avoiders plant guild	WSD	0.511	n/a	0.511	0.009	n.s.	neg.	
Groundcover plant guild	WSD	0.422	% WW branches dead	0.844	0.001	0.001	neg.	pos.
Vertebrates								
Acanthagenys rufogularis	WSD	0.776	soil texture	0.917	0.000	0.004	pos.	neg.
Corvus bennetti	WSD	0.551	WSC	0.754	0.002	0.023	pos.	neg.
Ctenophorus nuchalis	WSD	0.372	WSC	0.880	0.001	0.000	pos.	neg.
Diplodactylus steindachneri	% surface rock	0.546	WSD	0.799	0.001	0.008	neg.	neg.

Taxa, guild or taxa association	Best predictor	r^2 (best predictor)	Second predictor	r^2 (model)	*p* (best predictor)	*p* (second predictor)	sign (best predictor)	sign (second predictor)
Vertebrates (cont'd)								
Egernia inornata	WSD	0.636	no. of logs on ground >25cm	0.774	0.001	0.043	pos.	neg.
Malurus lamberti	% WW branches dead	0.690	WSD	0.841	0.000	0.017	pos.	neg.
Malurus splendens	WSC	0.573	rabbit disturbance	0.785	0.001	0.016	pos.	neg.
Petroica goodenovii	WSC	0.425	altitude	0.690	0.007	0.022	pos.	neg.
Pomatostomus halli	% WW branches dead	0.690	WSD	0.841	0.000	0.017	pos.	neg.
Ground Pursuers	WSC	0.462	no. tree cracks	0.899	0.000	0.000	neg.	neg.
Scavenging Birds	WSD	0.495	no. of logs on ground 5-15cm	0.733	0.003	0.020	pos.	neg.
Invertebrates								
Diplopoda	WSD	0.372	WSC	0.880	0.001	0.000	pos.	neg.
Phasmatodea	% WW branches dead	0.690	WSD	0.841	0.000	0.017	pos.	neg.
Scolopendrida	WSD	0.533	n/a	0.533	0.007	n.s.	pos.	
Thysanoptera	WSC	0.424	altitude	0.849	0.001	0.001	pos.	neg.
Camponotus sp. A	solid litter cover (%)	0.602	WSD	0.795	0.001	0.017	pos.	pos.
Crematogaster sp. A	WSD	0.372	WSC	0.880	0.001	0.000	pos.	neg.
Meranoplus sp. B	WSD	0.372	WSC	0.880	0.001	0.000	pos.	neg.
Meranoplus sp. D	WSD	0.720	n/a	0.720	0.000	n.s.	pos.	
Meranoplus sp. E	% WW branches dead	0.690	WSD	0.841	0.000	0.017	pos.	neg.
Polyrhachis sp. A	WSC	0.473	n/a	0.473	0.014	n.s.	pos.	
Solenopsis sp. A	WSD	0.372	WSC	0.880	0.001	0.000	pos.	neg.
Stigmacros pilosella	WSD	0.372	WSC	0.880	0.001	0.000	pos.	neg.
Subordinate Camponotini ant guild	WSC	0.612	% surface rock	0.754	0.001	0.049	pos.	neg.
Wanaaring Ant Association B	soil stability	0.377	WSC	0.653	0.012	0.025	neg.	pos.

8.3 Model results for flora and fauna taxa and guilds of the Cobar region. Results are restricted to those taxa and guilds for which woody shrub cover (WSC) or density (WSD) was included in the two-variable stepwise linear regression model. All significant results included, regardless of taxon abundance. P/A indicates presence/absence data.

Taxa, guild or taxa association	Best predictor	r^2 (best predictor)	Second predictor	r^2 (model)	p (best predictor)	p (second predictor)	sign (best predictor)	sign (second predictor)
Flora								
Boerhavia dominii	WSD	0.713	WSC	0.851	0.000	0.026	neg.	pos.
Callitris glaucophylla	no. sm logs	0.830	n/a	0.830	0.000	n.s.	pos.	
Carthamus lanatus	no. sm logs	0.568	% WW branches dead	0.848	0.001	0.005	neg.	neg.
Chenopodium desertorum ssp. *microphyllum*	WSD	0.393	n/a	0.393	0.039	n.s.	pos.	
Einadia nutans ssp. nutans	no. of logs on ground >25 cm	0.478	WSC	0.788	0.003	0.009	neg.	pos.
Enneapogon avenaceus	no. sm logs	0.758	soil texture	0.873	0.000	0.027	neg.	neg.
Geijera parviflora	surface texture	0.802	no. sm logs	0.914	0.000	0.012	pos.	neg.
Goodenia fascicularis	no. sm logs	0.471	distance from water (km)	0.799	0.003	0.007	neg.	pos.
Monachather paradoxa	no. sm logs	0.439	no. of logs on ground >25cm	0.774	0.004	0.009	pos.	pos.
Panicum subxerophilum	WSD	0.880	distance from water (km)	0.937	0.000	0.027	pos.	neg.
Salsola kali var. kali	solid litter cover (%)	0.639	soil texture	0.794	0.001	0.039	neg.	neg.
Salvia verbenaca	WSD	0.505	soil depth	0.854	0.001	0.002	neg.	
Schismus barbatus	WSD	0.853	surface texture	0.934	0.000	0.014	**pos.**	pos.
Sclerolaena birchii	No. sm logs	0.477	n/a	0.477	0.019	n.s.	neg.	
Senna artemisioides ssp. *filifolia*	no. of logs on ground 15-25cm	0.730	WSC	0.840	0.000	0.047	pos.	pos.
Sida fibulifera	WSC	0.754	distance from water (km)	0.923	0.000	0.003	neg.	pos.
Solanum esuriale	no. sm logs	0.481	n/a	0.481	0.018	n.s.	neg.	
Drought Avoiders plant guild	no. sm logs	0.571	n/a	0.571	0.007	n.s.	neg.	
Drought Endurers plant guild	WSC	0.661	infiltration	0.849	0.000	0.013	neg.	pos.
Groundcover plant guild	WSC	0.462	% surface rock	0.769	0.004	0.012	neg.	neg.

Taxa, guild or taxa association	Best predictor	r^2 (best predictor)	Second predictor	r^2 (model)	*p* (best predictor)	*p* (second predictor)	sign (best predictor)	sign (second predictor)
Vertebrates								
Acanthiza apicalis	WSD	0.492	grazing severity	0.706	0.006	0.042	pos.	pos.
Acanthiza chrysorrhoa	mistletoe (P/A)	0.820	WSC	0.953	0.000	0.001	pos.	neg.
Acanthiza nana	WSD	0.713	grazing severity	0.873	0.000	0.013	pos.	pos.
Diplodactylus steindachneri	solid litter cover (%)	0.557	fire severity	0.813	0.001	0.011	neg.	neg.
Dromaius novaehollandiae	no. sm logs	0.422	n/a	0.422	0.031	n.s.	pos.	
Lerista muelleri	no. sm logs	0.704	stags (P/A)	0.881	0.000	0.009	pos.	neg.
Macropus fuliginosus	solid litter cover (%)	0.388	WSD	0.670	0.015	0.031	pos.	neg.
Merops ornatus	WSC	0.727	mistletoe (P/A)	0.876	0.000	0.014	pos.	neg.
Oreoica gutturalis	mistletoe (P/A)	0.659	WSC	0.905	0.000	0.002	pos.	neg.
Pardalotus striatus	nutrient cycling status	0.423	solid litter cover (%)	0.703	0.010	0.025	neg.	pos.
Ramphotyphlops bituberculatus	no. sm logs	0.790	distance from water (km)	0.906	0.000	0.014	pos.	neg.
Smicrornis brevirostris	WSC	0.648	no. sm logs	0.803	0.001	0.036	pos.	neg.
Trachydosaurus rugosus	no. tree cracks	0.654	no. sm logs	0.877	0.000	0.005	pos.	neg.
Tree and Shrub Canopy-feeding Insectivorous Birds (bark)	WSC	0.611	soil texture	0.849	0.000	0.007	pos.	pos.
Terrestrial Geckoes	no. tree holes	0.413	WSC	0.747	0.007	0.012	neg.	neg.
Burrowing Reptiles	shedding bark on ground (P/A)	0.792	no. sm logs	0.941	0.000	0.002	pos.	pos.
Small Terrestrial Skinks	soil depth	0.417	WSC	0.718	0.009	0.019		neg.
Invertebrates								
Blattodea	no. sm logs	0.600	distance from water (km)	0.769	0.002	0.042	pos.	neg.
Psocoptera	mistletoe (P/A)	0.438	solid litter cover (%)	0.675	0.011	0.042	neg.	pos.
Scorpionida	WSD	0.880	distance from water (km)	0.937	0.000	0.027	pos.	neg.

Taxa, guild or taxa association	Best predictor	r^2 (best predictor)	Second predictor	r^2 (model)	*p* (best predictor)	*p* (second predictor)	sign (best predictor)	sign (second predictor)
Invertebrates (cont'd)								
Camponotus ephippium	no. sm logs	0.475	n/a	0.475	0.019	n.s.	pos.	
Camponotus nigriceps	no. sm logs	0.566		0.566	0.008	n.s.	pos.	
*Iridomyrmex*0004	WSD	0.439	grazing severity	0.692	0.010	0.033	pos.	pos.
*Iridomyrmex*0013	WSC	0.539	grazing severity	0.813	0.001	0.009	pos.	pos.
Pheidole sp. B	solid litter cover (%)	0.799	n/a	0.799	0.000	n.s.	pos.	
Pheidole sp. H	WSC	0.548		0.548	0.009	n.s.	pos.	
*Rhytidoponera*0001	no. sm logs	0.586	n/a	0.586	0.006	n.s.	neg.	
Stigmacros sp. C	no. sm logs	0.868	n/a	0.868	0.000	n.s.	pos.	
Subordinate Camponotini ant guild	no. sm logs	0.533	soil depth	0.821	0.001	0.007	pos.	
Hot Climate Specialists ant guild	WSC	0.688	nutrient cycling status	0.821	0.001	0.041	neg.	neg.

8.4 Model results for flora and fauna taxa recorded in the three survey regions, guilds and taxa associations analysed across the three survey regions collectively. Results are restricted to those taxa and guilds for which woody shrub cover (WSC) or density (WSD) was included in the two-variable stepwise linear regression model, regardless of whether or not the response to region was significant. Results are included for the design model (region) as well as the cumulative r^2 values following fitting of the best and second predictors. All significant results included, regardless of taxon abundance. P/A indicates presence/absence data.

Taxa, guild or taxa association	**r^2 (region)**	***p* (region only)**	**best predictor**	**r^2 (best predictor)**	**second predictor**	**r^2 (model)**	***p* (region)**	***p*(best predictor)**	***p* (second predictor)**	**sign (best predictor)**	**sign (second predictor)**
Flora											
Eremophila sturtii	0.202	0.027	WSC	0.365	soil texture	0.561	0.003	0.002	0.001	pos.	pos.
Senna artemisioides ssp. *filifolia*	0.048	0.456	WSD	0.425	surface texture	0.608	0.177	0.000	0.001	pos.	
Sida fibulifera	0.628	0.000	WSD	0.737	n/a	0.737	0.000	0.001	n.s.	neg.	
Drought Endurers plant guild	0.692	0.000	distance from water (km)	0.739	WSC	0.773	0.000	0.019	0.042	neg.	neg.
Vertebrates											
Cacatua leadbeateri	0.030	0.617	cryptogamic cover (%)	0.213	WSC	0.335	0.519	0.007	0.026	pos.	neg.
Smicrornis brevirostris	0.108	0.161	WSD	0.404	stability	0.624	0.023	0.000	0.000	pos.	neg.
Varanus gouldii	0.068	0.325	% surface rock	0.213	WSC	0.367	0.217	0.014	0.011	pos.	pos.
Tree and Shrub Canopy-feeding Insectivorous Birds (bark)	0.351	0.001	shedding bark on tree (P/A)	0.434	WSC	0.520	0.000	0.030	0.028	pos.	pos.
Ground-feeding Insectivorous Birds	0.149	0.076	fire severity	0.282	WSD	0.400	0.036	0.015	0.021	pos.	neg.
Ground Gleaners	0.315	0.002	WSD	0.434	fire severity	0.556	0.000	0.008	0.007	neg.	neg.
Non-passerine Granivorous Birds	0.078	0.274	WSC	0.322	element	0.450	0.157	0.000	0.114	neg.	

Taxa, guild or taxa association	r^2 (region)	*p* (region only)	best predictor	r^2 (best predictor)	second predictor	r^2 (model)	*p* (region)	*p*(best predictor)	*p* (second predictor)	sign (best predictor)	sign (second predictor)
Invertebrates											
Pheidole sp. B	0.157	0.065	WSD	0.411	shedding bark on ground (P/A)	0.504	0.016	0.000	0.024	pos.	pos.
Hot Climate Specialists ant guild	0.798	0.000	WSC	0.835	mistletoe (P/A)	0.887	0.000	0.004	0.001	neg.	neg.
Three regions ant guild association A	0.295	0.004	WSC	0.421	grazing severity	0.608	0.000	0.004	0.001	pos.	pos.

8.5 Pitfall trap microhabitat model results for vertebrate and invertebrate taxa within each survey region. Results are separated on the basis of whether woody shrub cover (WSC) and density (WSD), as determined for each study site, were included in the list of microhabitat variables analysed. Significant results only are presented. For the factor variable 'Trap location', the category for which taxon abundance was greatest is listed under the sign for that predictor (categories are Open Area, and Within Clump). For the factor variable 'Canopy', the categories are arranged from highest to lowest average trap counts (categories are U under canopy; N not under canopy; S under shrub canopy; T under tree canopy). Canopy categories with zero counts are excluded.

Taxon or taxa grouping	best predictor	r^2 (best predictor)	second predictor	r^2 (second predictor or model)	third predictor	r^2 (model)	*p* (best predictor)	*p* (second predictor)	*p* (third predictor)	sign (best predictor)	sign (second predictor)	sign (third predictor)
Ivanhoe models without shrub cover and density												
Diplodactylus steindachneri	Distance to closest woody shrub	.075					<.01			pos.		
Hemiptera	Distance to closest woody shrub	.065					0.01			pos.		
Crematogaster sp. C	Canopy	.152					<.01			UNS		
Camponotus ephippium	Trap location	.08					0			WC		
Camponotus sp. C	Leaf litter	.078	Distance to closest woody shrub	.161			0	0		pos.	pos.	
Rhytidoponera metallica	Leaf litter	.095	Trap location	.189			<.01	<.01		pos.	OA	
Stigmacros sp. A	Canopy	.243					<.01			U		
*Stigmacros*0003	Distance to closest woody shrub	.086					<.01			pos.		
Stigmacros sp. B	Canopy	.115					0.01			UN		
Ivanhoe models with shrub cover and density												
Diplodactylus steindachneri	Distance to closest woody shrub	.075	WSC	.14			<.01	0.01		pos.	pos.	

Taxon or taxa grouping	best predictor	r^2 (best predictor)	second predictor	r^2 (second predictor or model)	third predictor	r^2 (model)	*p* (best predictor)	*p* (second predictor)	*p* (third predictor)	sign (best predictor)	sign (second predictor)	sign (third predictor)
Ivanhoe models with shrub cover and density (cont'd)												
Diplodactylus steindachneri	Distance to closest woody shrub	.075	WSD	.135			<.01	0.01		pos.	pos.	
Wanaaring models without shrub cover and density												
Pseudomys hermannsburgensis	Distance to closest woody shrub	.167					<.01			pos.		
Acarina	Trap location	.201	Canopy	.302			<.01	<.01		WC	UTSN	
Araneae	Canopy	.133					<.01			STNU		
Collembola	Leaf litter	.196	Trap location	.292			<.01	<.01		pos.	WC	
Hemiptera	Distance to closest woody shrub	.168	Trap location	.232			<.01	<.01		pos.	WC	
Hymenoptera	Canopy	.217	Trap location	.29			<.01	<.01		TUSN	WC	
Isopoda	Canopy	.333					<.01			USN		
Mantodea	Distance to closest woody shrub	.077					<.01			pos.		
Pseudoscorpionida	Distance to closest woody shrub	.086					<.01			pos.		
Psocoptera	Trap location	.077					<.01			WC		
Thysanoptera	Canopy	.192	Ground cover	.24			<.01	0.01		TSUN	neg.	
Thysanura	Trap location	.058					0.01			WC		
Camponotus sp. D	Canopy	.256					<.01			TS		

Taxon or taxa grouping	best predictor	r^2 (best predictor)	second predictor	r^2 (second predictor or model)	third predictor	r^2 (model)	*p* (best predictor)	*p* (second predictor)	*p* (third predictor)	sign (best predictor)	sign (second predictor)	sign (third predictor)
Wanaaring models without shrub cover and density (cont'd)												
Cerapachys sp. A	Distance to closest woody shrub	.311					<.01			pos.		
Crematogaster sp. A	Canopy	.496					<.01			S		
*Iridomyrmex*0013	Trap location	.06					0.01			WC		
*Notoncus*0001	Distance to closest woody shrub	.129	Trap location	.196			<.01	<.01		pos.	WC	
Pheidole sp. H	Canopy	.199					<.01			SUN		
Wanaaring models with shrub cover and density												
Diplodactylus steindachneri	WSD	.092					<.01			neg.		
Egernia inornata	WSD	.077					<.01			pos.		
Collembola	Leaf litter	.196	WSC	.301			<.01	<.01		pos.	pos.	
Anochetus armstrongi	WSC	.086					<.01			neg.		
Cerapachys sp. A	Distance to closest woody shrub	.311	WSC	.357			<.01	0.01		pos.	pos.	
*Iridomyrmex*0004	WSC	.096					<.01			pos.		
*Iridomyrmex*0013	WSC	.177	Distance to closest woody shrub	.228			<.01	0.01		pos.	pos.	
*Notoncus*0001	Distance to closest woody shrub	.129	WSC	.222			<.01	<.01		pos.	pos.	

Taxon or taxa grouping	best predictor	r^2 (best predictor)	second predictor	r^2 (second predictor or model)	third predictor	r^2 (model)	*p* (best predictor)	*p* (second predictor)	*p* (third predictor)	sign (best predictor)	sign (second predictor)	sign (third predictor)
Cobar models without shrub cover and density												
Rhynchoedura ornata	Trap location	.097	Leaf litter	.169			<.01	0.02		WC	neg.	
Acarina	Ground cover	.12	Trap location	.176			<.01	0.01		pos.	OA	
Blattodea	Canopy	.119					<.01			USTN		
Coleoptera	Canopy	.162					<.01			TUSN		
Hymenoptera	Canopy	.215	Ground cover	.314			<.01	<.01		TSUN	pos.	
Larvae	Distance to closest woody shrub	.128					<.01			pos.		
Lithobiida	Canopy	.243					<.01			U		
Psocoptera	Distance to closest woody shrub	.242					<.01			pos.		
Scolopendrida	Distance to closest woody shrub	.055	Canopy	.258			0.01	<.01		pos.	TN	
number of invertebrate 'Orders'	Distance to closest woody shrub	.079					<.01			pos.		
Anochetus armstrongi	Distance to closest woody shrub	.081					<.01			pos.		
Camponotus ephippium	Distance to closest woody shrub	.094	Ground cover	.148			<.01	0.01		neg.	neg.	
Camponotus sp. D	Canopy	.193					<.01			T		
Crematogaster sp. A	Canopy	.193					<.01			T		
Meranoplus sp. H	Canopy	.271					<.01			UNTS		

Taxon or taxa grouping	best predictor	r^2 (best predictor)	second predictor	r^2 (second predictor or model)	third predictor	r^2 (model)	*p* (best predictor)	*p* (second predictor)	*p* (third predictor)	sign (best predictor)	sign (second predictor)	sign (third predictor)
Cobar models without shrub cover and density (cont'd)												
Pheidole sp. G	Canopy	.221					<.01			UN		
*Rhytidoponera*0001	Trap location	.075					<.01			OA		
Rhytidoponera metallica	Canopy	.167					<.01			USTN		
Stigmacros sp. B	Canopy	.243					<.01			U		
Cobar models with shrub cover and density												
Ctenotus allotropis	WSD	.064	Trap location	.178			0.01	0		neg.	WC	
Pomatostomus ruficeps	WSC	.055					0.02			pos.	pos.	
Rhynchoedura ornata	Trap location	.097	Leaf litter	.169	WSC	23	<.01	0.02	0.01	WC	neg.	neg.
Acarina	WSC	.18					<.01			neg.		
Hemiptera	WSC	.121					<.01			neg.		
Scorpionida	WSC	.063					0.01			pos.		
Camponotus nigriceps	WSC	.072					0.01			pos.		
*Iridomyrmex*0004	WSC	.076					<.01			pos.		
Brachyponera lutea	WSC	.10					<.01			pos.		
Pheidole sp. C	WSC	.093					<.01			pos.		
Pheidole sp. H	WSC	.085					<.01			pos.		
*Rhytidoponera*0001	WSC	.111					<.01			neg.		

8.6 Results for flora and fauna taxa common to the three survey regions analysed as GLMs with region as the first variable in the model. Region was a significant factor in most models. Results are restricted to those taxa and guilds for which the correlation with woody shrub cover (WSC) or density (WSD) was significant.

Taxa	r_{WSC}	p_{WSC}	r_{WSD}	p_{WSD}
Flora				
Alectryon oleifolius	-0.172	0.014	-0.188	0.022
Dodonaea viscosa ssp. *angustissima*	0.298	<0.001	0.386	0
Eremophila sturtii	0.41	<0.001	0.263	0
Senna artemisioides ssp. *filifolia*	0.538	<0.001	0.596	0
Sida fibulifera	-0.357	0.048		n.s.
Tribulus terrestris		n.s.	-0.277	0.045
Vertebrates				
Acanthagenys rufogularis	0.444	<0.001	0.405	0
Acanthiza uropygialis	0.283	0.001	0.214	0.012
Barnardius barnardi	-0.304	<0.001	-0.153	0.043
Cacatua leadbeateri	-0.31	<0.001	-0.258	0
Cacatua roseicapilla	-0.322	<0.001	-0.267	0
Capra hircus	0.129	0.003		n.s.
Cracticus nigrogularis	-0.281	0.012	-0.231	0.011
Ctenotus schomburgkii	0.305	0.001		n.s.
Diplodactylus steindachneri	-0.349	<0.001	-0.336	0
Gehyra variegata	-0.13	0.019	-0.244	0.002
Gymnorhina tibicen	-0.333	<0.001	-0.212	0.01
Macropus fuliginosus	-0.245	0.01		n.s.
Macropus giganteus	-0.297	<0.001	-0.291	0
Macropus rufus	-0.345	<0.001	-0.287	0
Manorina flavigula	-0.222	0.002	-0.177	0.002
Northiella haematogaster	-0.325	<0.001	-0.246	0
Ocyphaps lophotes	-0.313	<0.001	-0.269	0
Petroica goodenovii	0.146	0.016	0.066	0.045
Psephotus varius	-0.173	0.002		n.s.
Rhipidura leucophrys	-0.289	<0.001	-0.215	0
Smicrornis brevirostris	0.457	<0.001	0.571	0
Struthidea cinerea	-0.31	<0.001	-0.231	0
Trachydosaurus rugosus	-0.365	<0.001	-0.303	0

Taxa	r_{WSC}	p_{WSC}	r_{WSD}	p_{WSD}
Invertebrates				
Anochetus armstrongi	-0.184	<0.001	-0.085	0.008
Camponotus ephippium	0.275	<0.001	0.346	<0.001
Camponotus nigiceps	0.163	<0.001	0.219	<0.001
Crematogaster sp. A	0.325	<0.001	0.275	<0.001
*Iridomyrmex*0001	-0.059	<0.001	-0.036	<0.001
*Iridomyrmex*0004	0.342	<0.001	0.214	<0.001
*Iridomyrmex*0005	-0.079	0.013	-0.051	<0.001
*Iridomyrmex*0009	0.011	<0.001		n.s.
*Iridomyrmex*0010	0.234	<0.001	0.339	<0.001
*Iridomyrmex*0011	-0.118	<0.001	-0.08	<0.001
*Iridomyrmex*0012	-0.086	<0.001	-0.07	<0.001
Meranoplus sp. C	-0.094	<0.001	-0.121	<0.001
Meranoplus sp. E		n.s.	-0.083	0.001
Pheidole sp. A	-0.18	<0.001	-0.212	<0.001
Pheidole sp. B	0.362	<0.001	0.593	<0.001
Pheidole sp. C	0.326	<0.001	0.231	<0.001
Pheidole sp. H	0.653	<0.001	0.582	<0.001
*Rhytidoponera*0001	-0.22	<0.001	-0.208	<0.001
Rhytidoponera metallica	0.088	<0.001	0.246	<0.001
Rhytidoponera sp. A		n.s.	-0.173	0.001
*Stigmacros*0006	0.2	0.05		n.s.
Acarina	-0.128	<0.001	-0.16	<0.001
Collembola	-0.12	<0.001	-0.132	<0.001
Diptera		n.s.	0.145	0.001
Formicidae	-0.056	<0.001	-0.028	<0.001
Hemiptera	-0.198	<0.001	-0.175	<0.001
Hymenoptera	0.056	0.015	0.229	<0.001
Isoptera	-0.163	0.001	-0.131	<0.001
Larvae	-0.163	0.008	-0.064	0.037
Lepidoptera		n.s.	0.342	0.018
Thysanoptera	0.184	0.01		n.s.

Appendix 9: Landscape function results

9.1 Landscape organisation assessment data for all 35 study sites. Obstruction type, frequency, width summary and average separation distance (fetch) details are listed. Obstruction index = total length of obstructions/transect length. Width measurements were not collected at most Ivanhoe sites, and some Wanaaring sites. "P." = patch.

Survey region	Site no.	No. of obstructions /10 m	Total obstruction width (m/10 m)	Average fetch length (m)	Obstruction index	Obstructions
Ivanhoe	1	2.2	18.52	3.25	0.29	logs (some with debris); Wooded P.
	2	0.7		7.28	0.48	log piles; Wilga P.; Belah P.
	3	1.4		5.89	0.20	logs; Open Wooded P.
	4	0.4		16.19	0.31	logs; Belah P.
	5	0.8		9	0.27	logs; Rosewood P.; Belah P.
	6	1.4	1.1	6.53	0.10	*Sclerolaena* P.; Belah P.; Rosewood P.
	7	1.5		4.07	0.41	logs and litter accumulations; Belah P.; Wilga P.
	8	0.4		21.27	0.06	logs; Rosewood P.; Belah P.
	9	0.5	0.93	19.69	0.00	logs with some debris
	10	1.3		6.69	0.14	log pile (some with litter); Belah P.
	11	1		7.23	0.28	*Sclerolaena* P.; Belah P.
	12	1.2		5.84	0.32	log piles; *Sclerolaena* P.; Open Wooded P.
Wanaaring-Louth	13	0.2	1.61	21.75	0.56	Rosewood P.; Turpentine P.
	14	0.7	3.16	10.88	0.25	Hummock; Rosewood P.
	15	0.3	3.09	20.89	0.29	Gidgee P.; Dead Mulga P.; *Eremophila longifolia* P.; Hummock; logs
	16	0.7	6.28	7.25	0.49	Hummock; Rosewood P.
	17	0.9		4.63	0.58	Rosewood P.; Hummock; 'Woody Weed' P.
	18	0.2	1.5	43.68	0.13	Gidgee P.; Hummock
	19	0.4		19.03	0.28	Gidgee P.; Turpentine P.
	20	1		6.52	0.34	Rosewood P., Hummock; Turpentine P.
	21	0.3	2.42	26.14	0.20	Rosewood Patch; Hummock; Turpentine P.
	22	0.6	2.36	13.6	0.18	Hopbush P.; branch; Hummock
	23	0.3	0.57	32.85	0.00	logs
	24	0.1	0.81	92.2	0.07	Gidgee P.

Survey region	Site no.	No. of obstructions /10 m	Total obstruction width (m/10 m)	Average fetch length (m)	Obstruction index	Obstructions
Cobar	25	0.4	2.94	22.53	0.19	Yarran P.; Wilga P.; Needlewood P.; logs; Disturbed Mound
	26	0.6	3.61	14	0.22	Woody Weed' P.; Wilga P.
	27	0.7	3.38	12.41	0.12	Red Box Patch; Dense 'Woody Weed' Patch; logs
	28	0.6	1.1	14.22	0.09	*Acacia* P.; Hopbush P.; logs
	29	0.8	4.12	5.16	0.56	Red Box P.; 'Woody Weed' P.; Wilga P.
	30	1.2	5.22	2.62	0.69	Rosewood P.; 'Woody Weed' P.; Wilga P.
	31	0.6	3.97	14.34	0.14	Mulga P.; 'Woody Weed' P.; Mound; logs
	32	0.5	6.55	12.41	0.34	Woody Weed' P.; Bimble Box/Wilga P.; Needlewood P.
	33	0.4	1.6	25.93	0.06	Treed P.; logs; Hopbush P.
	34	1.6	0.75	1.54	0.75	*Austrostipa* P.; Mound
	35	1.3	2.07	3.19	0.57	*Bothriochloa* P.; *Austrostipa* P.; *Themeda* P.

9.2 Mean Soil Surface Condition (SSC) index scores, with standard errors, for all 35 study sites. Contributions by each Patch Type are weighted in proportion to their relative area on the site. Soil Stability scores <40 are classified as "low", those >60 are classified as "high", and "moderate" is between these scores. Similarly, the splits for Infiltration are <25 (low), 25-40 (moderate), and >40 (high); and for Nutrient Cycling Status are <20 (low), 20-35 (moderate), and >35 (high).

Survey region	Site no.	Soil stability	Std err	Infiltration	Std err	Nutrient cycling status	Std err
Ivanhoe	1	53.74	2.28	36.58	1.32	23.30	2.11
	2	58.58	2.35	36.85	2.46	24.99	2.82
	3	55.11	2.61	37.91	1.79	23.18	2.01
	4	57.72	2.20	39.28	3.82	27.90	5.07
	5	57.89	1.95	39.30	1.35	21.64	1.74
	6	59.93	1.10	34.40	0.75	21.52	1.21
	7	57.42	1.40	34.25	0.95	21.29	1.64
	8	59.22	1.31	38.73	1.76	25.51	2.31
	9	56.95	2.53	34.23	0.48	20.24	1.07
	10	60.08	0.74	44.38	2.21	24.27	2.95
	11	58.40	1.52	36.41	2.01	22.36	3.37
	12	57.98	1.27	39.73	1.61	23.14	1.92
Wanaaring-Louth	13	51.97	3.17	39.59	2.82	27.41	4.75
	14	56.44	1.52	41.80	1.15	22.82	1.75
	15	46.54	1.39	34.70	1.43	19.56	1.84
	16	54.28	2.49	39.98	1.19	21.53	1.56
	17	54.58	2.27	42.60	2.52	24.81	2.44
	18	50.34	0.98	37.20	1.08	18.97	1.01
	19	49.40	1.93	41.10	1.28	20.07	1.26
	20	52.63	1.86	37.79	1.76	23.11	1.41
	21	47.74	1.67	40.34	1.62	20.88	1.38
	22	49.90	2.19	36.81	1.16	17.18	1.57
	23	54.97	2.23	28.62	3.58	21.12	1.54
	24	55.46	2.56	36.67	2.23	23.69	2.51
Cobar	25	63.43	2.02	41.23	1.30	25.62	1.75
	26	65.95	1.19	40.93	1.71	26.55	1.98
	27	60.83	1.73	35.59	0.64	21.56	0.76
	28	66.16	1.71	40.06	1.02	25.35	2.13
	29	59.73	2.16	39.87	1.62	25.64	1.97
	30	64.44	1.90	42.61	1.08	26.87	1.72
	31	64.07	0.76	38.27	1.38	24.56	2.21
	32	62.61	0.88	39.95	1.69	26.26	1.54
	33	59.33	1.68	38.40	1.91	23.09	1.14
	34	61.52	2.01	38.98	2.80	23.46	3.78
	35	66.15	1.39	45.82	1.55	29.29	1.75

9.3 Mean Soil Surface Condition (SSC) index scores, with standard errors, for each Patch Type present on each of the 12 Ivanhoe region study sites. All resource sink patches (marked) functioned as obstructions. Patch types are grouped into broader patch categories for further analysis. For each SSC index, linear model and multiple comparison results (of patch types within each site) are listed (n.s. = not significant linear model result, thus multiple comparisons were not undertaken). Patch types (represented by acronyms) are arranged in order of decreasing mean index score. Those patch types which were not significantly different are underlined or bolded. Score classifications (low, moderate, high) as for Appendix 9.2.

Site no.	Patch type (and acronym)	Resource sink?	Patch category	Soil stability			Infiltration			Nutrient cycling status (NCS)		
				Mean score	Std err	Within-site linear model results Stability vs patch type	Mean score	Std err	Within-site linear model results Infiltration vs patch type	Mean score	Std err	Within-site linear model results NCS vs patch type
1	Wooded Patch (WP)	✓	Treed	59.72	0.35	R^2=0.74; p=0.00 WP VCWC VCLC SP	46.67	0.91	R^2=0.89; p=0.00 WP **VCWC** **VCLC** SP	34.23	1.41	R^2=0.84; p=0.00 WP VCWC VCLC SP
	Vegetated Crusted with Cryptogamic Cover (VCWC)		Low veg	58.50	1.00		34.81	0.91		20.93	1.64	
	Sandy Patch (SP)		Bare	43.89	0.56		31.11	0.91		13.59	0.94	
	Vegetated Crusted less Cryptogamic Cover (VCLC)		Low veg	49.50	3.66		31.85	1.48		18.84	2.39	
2	Wilga Patch (WP)	✓	Treed	51.30	2.77	R^2=0.55; p=0.00 BP VC BC WP	35.51	2.17	R^2=0.55; p=0.00 BP WP VC BC	27.88	2.88	R^2=0.63; p=0.00 BP **WP** **VC** BC
	Bare Crusted (BC)		Bare	52.00	1.66		31.01	0.58		15.35	1.17	
	Belah Patch (BP)	✓	Treed	62.11	2.50		43.19	3.29		32.58	4.05	
	Vegetated Crusted (VC)		Low veg	60.50	1.84		32.50	2.06		21.51	1.35	
3	Open Wooded Patch (OWP)	✓	Treed	57.36	1.29	n.s.	48.89	2.16	R^2=0.84; p=0.00 OWP VC BC	30.70	3.25	R^2=0.58; p=0.01 OWP VC BC
	Vegetated Crusted (VC)		Low veg	56.50	1.00		36.30	1.39		22.44	0.97	
	Bare Crusted (BC)		Bare	50.11	4.95		32.59	0.74		18.72	1.52	
4	Bare Crusted (BC)		Bare	57.78	1.81	n.s.	37.04	2.87	n.s.	23.02	3.55	R^2=0.63; p=0.01 BP BC
	Belah Patch (BP)	✓	Treed	57.59	0.45		44.37	1.39		38.97	2.44	
5	Belah Patch (BP)	✓	Treed	61.22	2.77	n.s.	46.67	2.51	R^2=0.63; p=0.00 BP **VC** **BC** RP	29.75	4.57	n.s.
	Bare Crusted (BC)		Bare	55.61	1.45		37.00	0.69		22.44	0.98	
	Rosewood Patch (RP)	✓	Treed	54.76	1.23		33.91	2.54		21.45	1.59	
	Vegetated Crusted (VC)		Low veg	60.00	1.94		41.48	0.74		19.42	1.29	

Site No.	Patch Type (and acronym)	Resource sink?	Patch category	Soil stability			Infiltration			Nutrient cycling status (NCS)		
				Mean score	Std err	Within-site linear model results Stability vs patch type	Mean score	Std err	Within-site linear model results Infiltration vs patch type	Mean score	Std err	Within-site linear model results NCS vs patch type
6	Rosewood Patch (RP)	✓	Treed	59.54	1.07	n.s.	35.80	2.47	n.s.	21.32	1.85	n.s.
	Vegetated Crusted		Low veg	59.50	1.22		34.81	0.91		22.21	1.39	
	Bare Crusted (BC)		Bare	61.00	0.61		33.33	0.00		20.12	0.35	
	Belah Patch (BP)	✓	Treed	59.00	0.61		34.81	0.91		21.98	1.52	
7	Belah Patch (BP)	✓	Treed	53.75	1.55	n.s.	33.33	1.35	R^2=0.38; p=0.05 WP BP BC	21.71	1.97	n.s.
	Bare Crusted (BC)		Bare	59.00	0.61		33.33	0.00		20.12	0.35	
	Wilga Patch (WP)	✓	Treed	57.00	1.84		38.52	2.22		24.65	3.17	
8	Bare Crusted (BC)		Bare	60.00	0.79	n.s.	37.78	0.74	R^2=0.67; p=0.00 RP TP BC	20.70	0.75	R^2=0.71; p=0.00 RP TP BC
	Turpentine Patch (TP)		Woody shrub	57.78	1.33		38.74	2.38		30.58	3.27	
	Rosewood Patch (RP)	✓	Treed	61.13	1.14		47.41	0.74		38.13	2.03	
9	Bare Crusted (BC)		Bare	57.00	1.46	n.s.	33.33	0.00	R^2=0.52; p=0.02 TP BC	19.42	0.23	n.s.
	Turpentine Patch (TP)		Woody shrub	56.67	2.47		39.68	2.16		25.23	3.39	
10	Bare Crusted with Litter (BCWL)		Bare	58.50	0.61	R^2=0.50; p=0.00 BP WP **TP** **VCWL** BCWL	43.70	2.96	R^2=0.44; p=0.02 **BP** **WP** BCWL VCWL TP	22.44	3.87	R^2=0.54; p=0.00 BP WP BCWL VCWL TP
	Belah Patch (BP)	✓	Treed	63.71	1.24		50.31	1.55		35.46	2.09	
	Turpentine Patch (TP)		Woody shrub	61.50	1.50		41.48	0.74		20.81	0.85	
	Vegetated Crusted with Litter (VCWL)		Low veg	60.50	0.50		42.22	0.91		21.63	1.36	
	Wilga Patch (WP)		Treed	63.50	0.61		45.93	1.89		26.49	2.98	
11	Belah Patch (BP)	✓	Treed	59.93	2.46	n.s.	37.20	3.01	n.s.	27.84	4.72	n.s.
	Bare Crusted (BC)		Bare	60.50	0.50		37.78	0.74		21.51	1.35	
12	Open Wooded Patch (OWP)	✓	Treed	57.93	2.00	n.s.	43.32	1.79	R^2=0.43; p=0.03 OWP VC BC	28.12	2.68	R^2=0.48; p=0.02 OWP VC BC
	Bare Crusted (BC)		Bare	58.00	0.50		37.78	0.74		20.47	0.70	
	Vegetated Crusted (VC)		Low veg	58.00	0.50		38.52	1.48		21.40	1.39	

9.4 Mean SSC index scores, with standard errors, for each Patch Type present on each of the 12 Wanaaring region study sites. All resource sink patches (marked) and hummocks functioned as obstructions. Patch types are grouped into broader patch categories for further analysis. For each SSC index, linear model and multiple comparison results (of patch types within each site) are listed. Patch types (represented by acronyms) are arranged in order of decreasing mean index score. Those patch types which were not significantly different are underlined, bolded or italicised . Score classifications (low, moderate, high) as for Appendix 9.2.

Site No.	Patch Type (and acronym)	Resource sink?	Patch category	Soil stability			Infiltration			Nutrient cycling status (NCS)		
				Mean score	Std err	Within-site linear model results Stability vs patch type	Mean score	Std err	Within-site linear model results Infiltration v patch type	Mean score	Std err	Within-site linear model results NCS vs patch type
13	Rosewood Patch (RP)	✓	Treed	60.44	2.43	R^2=0.66; *p*=0.00 RP TP SA BS	44.54	0.84	R^2=0.65; *p*=0.00 TP RP BS SA	37.05	0.51	R^2=0.63; *p*=0.00 RP TP BS SA
	Bare Slope (BS)		Bare	43.39	0.96		32.59	1.39		18.61	1.95	
	Turpentine Patch (TP)	✓	Woody shrub	58.39	4.39		45.19	3.59		34.27	6.69	
	Slumped Area (SA)		Bare	44.25	2.21		31.92	2.47		15.70	1.82	
14	Turpentine Patch (TP)		Woody shrub	60.00	1.29	R^2=0.81; *p*=0.00 RP TP H SS WP	41.98	0.78	R^2=0.90; *p*=0.00 RP H TP **SS** **WP**	22.29	1.66	R^2=0.90; *p*=0.00 RP H TP SS WP
	Soil Surface (SS)		Bare	51.57	1.62		40.12	1.49		21.37	2.05	
	Hummock (H)		Hummock	58.33	1.05		42.59	0.83		22.67	0.78	
	Woollybutt Patch (WP)		Low veg	49.39	2.06		37.78	1.39		18.51	1.53	
	Rosewood Patch (RP)	✓	Treed	68.89	1.36		58.52	0.74		50.00	2.43	
15	Gidgee Patch (GP)	✓	Treed	62.04	3.56	R^2=0.81; *p*=0.00 ELP *DMP* ***GP*** **VC** H DWP C	47.53	3.50	R^2=0.70; *p*=0.00 ELP DMP **GP** ***VC*** *H DWP* C	28.74	4.30	R^2=0.66; *p*=0.00 ELP DMP **GP** **VC** DWP C H
	Crusted (C)		Low veg	41.50	1.27		31.85	1.48		15.47	1.37	
	Vegetated Crusted (VC)		Low veg	56.50	1.00		40.74	0.00		21.05	0.87	
	Degraded Woollybutt Patch (DWP)		Low veg	43.33	0.68		34.07	1.81		17.18	1.63	
	Hummock (H)		Hummock	52.78	2.32		34.81	0.91		15.13	1.14	
	Dead Mulga Patch (DMP)	✓	Treed	66.28	3.60		48.15	4.06		33.49	5.52	
	Eremophila longifolia Patch (ELP)	✓	Treed	69.44	1.52		53.33	2.22		45.13	5.79	

Site No.	Patch Type (and acronym)	Resource sink?	Patch category	Soil stability			Infiltration			Nutrient cycling status (NCS)		
				Mean score	Std err	Within-site linear model results Stability vs patch type	Mean score	Std err	Within-site linear model results Infiltration v patch type	Mean score	Std err	Within-site linear model results NCS vs patch type
16	Rosewood Patch (RP)	✓	Treed	59.44	0.68	R^2=0.40; *p*=0.03 *RP WC H* **CD WP**	47.41	1.39	R^2=0.76; *p*=0.00 RP *H* ***WP*** **WC** CD	28.97	1.69	R^2=0.64; *p*=0.00 RP H *CD WC WP*
	Woollybutt Crusted (WC)		Low veg	56.00	2.03		37.78	0.74		20.35	1.55	
	Woollybutt Patch (WP)		Low veg	48.67	3.16		40.00	1.39		17.30	1.44	
	Hummock (H)		Hummock	55.50	2.78		41.48	1.39		23.37	1.74	
	Crusted Depression (CD)		Bare	52.00	1.66		34.81	0.91		20.47	0.85	
17	Rosewood Patch (RP)	✓	Treed	62.22	1.88	R^2=0.56; *p*=0.00 RP WWP H SP	47.41	1.81	R^2=0.43; *p*=0.03 WWP RP **H SP**	36.03	3.47	R^2=0.63; *p*=0.00 **RP WWP** H SP
	Sclerolaena Patch (SP)		Low veg	47.22	1.24		37.04	2.03		16.67	2.01	
	Hummock (H)		Hummock	57.89	4.34		42.38	4.36		25.67	3.74	
	Woody Weed' Patch (WWP)	✓	Woody shrub	60.44	1.71		48.89	1.39		32.33	1.18	
18	Gidgee Patch (GP)	✓	Treed	62.70	2.10	R^2=0.86; *p*=0.00 TP GP **WP H** PA SP	51.18	1.82	R^2=0.78; *p*=0.00 GP TP H **WP** **PA** SP	35.90	2.92	R^2=0.79; *p*=0.00 GP TP H WP **PA SP**
	Sclerolaena Patch (SP)		Low veg	43.44	0.73		33.49	1.05		14.52	0.81	
	Ponding Area (PA)		Bare	49.50	1.46		37.04	0.00		19.30	0.47	
	Turpentine Patch (TP)		Woody shrub	64.00	1.87		43.70	1.81		28.95	2.54	
	Woollybutt Patch (WP)		Low veg	61.50	1.27		40.00	1.39		22.67	1.09	
	Hummock (H)		Hummock	57.22	1.37		42.22	1.89		20.99	1.27	
19	Bare Hummock (BH)		Bare	43.50	0.61	R^2=0.81; *p*=0.00 TP GP SP WP BH	35.56	0.91	R^2=0.74; *p*=0.00 TP GP WP SP BH	15.93	0.57	R^2=0.76; *p*=0.00 TP GP SP BH WP
	Woollybutt Patch (WP)		Low veg	43.67	1.59		38.52	0.91		15.51	0.51	
	Turpentine Patch (TP)	✓	Woody shrub	63.78	2.44		48.89	1.81		32.41	2.32	
	Sclerolaena Patch (SP)		Low veg	47.50	2.85		37.78	1.39		17.21	1.95	
	Gidgee Patch (GP)	✓	Treed	58.33	1.76		48.15	2.62		26.92	2.97	
20	Rosewood Patch (RP)	✓	Treed	59.44	2.58	R^2=0.67; *p*=0.00 TP RP SP BC RkP H	50.92	2.31	R^2=0.66; *p*=0.00 RP **TP** **RkP** H SP BC	34.62	2.33	R^2=0.68; *p*=0.00 RP TP H RkP SP BC
	Bare Crusted (BC)		Bare	49.56	2.67		33.08	1.62		18.49	1.53	
	Hummock (H)		Hummock	45.76	1.27		38.13	2.67		23.64	2.48	
	Sclerolaena Patch (SP)		Low veg	51.44	1.73		35.85	1.40		21.74	0.83	
	Turpentine Patch (TP)	✓	Woody shrub	61.22	1.38		44.73	2.84		30.03	1.73	
	Rocky Patch (RkP)		Bare	48.50	1.87		38.52	1.48		22.09	1.92	

Site No.	Patch Type (and acronym)	Resource sink?	Patch category	Soil stability			Infiltration			Nutrient cycling status (NCS)		
				Mean score	Std err	Within-site linear model results Stability vs patch type	Mean score	Std err	Within-site linear model results Infiltration v patch type	Mean score	Std err	Within-site linear model results NCS vs patch type
21	Woollybutt Patch (WP)		Low veg	42.08	3.03	R^2=0.84; p=0.00 RP TP PA OWP WP	38.94	0.83	R^2=0.66; p=0.00 RP **TP** **OWP** WP PA	16.30	1.61	R^2=0.80; p=0.00 RP TP OWP PA WP
	Rosewood Patch (RP)	✓	Treed	62.78	1.11		51.11	0.74		34.74	1.79	
	Ponding Area (PA)		Bare	46.50	1.27		34.81	0.91		17.67	0.91	
	Open Woollybutt Patch (OWP)		Low veg	45.44	0.44		40.74	2.62		20.58	0.70	
	Turpentine Patch (TP)	✓	Woody shrub	60.44	2.11		45.48	3.36		30.07	3.00	
22	Hopbush Patch (HP)		Woody shrub	53.89	1.11	R^2=0.58; p=0.00 VC HP H **WP** **C**	40.00	2.16	R^2=0.41; p=0.02 VC HP WP H C	18.08	3.36	R^2=0.39; p=0.03 VC HP WP C H
	Crusted (C)		Bare	47.36	1.82		32.98	1.00		16.49	1.13	
	Woollybutt Patch (WP)		Low veg	50.33	2.74		40.00	0.74		17.53	1.42	
	Hummock (H)		Hummock	53.83	2.73		40.00	1.39		15.97	1.98	
	Vegetated Crusted (VC)		Low veg	61.89	1.09		41.32	3.08		24.88	1.32	
23	Belah Patch (BP)		Treed	55.56	1.24	R^2=0.45; p=0.03 BP WC BC	39.26	1.48	R^2=0.59; p=0.00 BP BC WC	16.92	2.31	R^2=0.41; p=0.04 WC BP BC
	Bare Crusted (BC)		Bare	49.61	1.56		32.75	0.58		15.93	0.93	
	Woollybutt Crusted (WC)		Low veg	55.50	1.78		27.41	3.10		21.98	1.14	
24	Gidgee Patch (GP)	✓	Treed	68.33	0.68	R^2=0.73; p=0.00 GP TP VC PA OTP BC	51.85	1.17	R^2=0.77; p=0.00 GP **TP** **VC** BC OTP PA	38.46	2.65	R^2=0.67; p=0.00 GP TP VC PA OTP BC
	Bare Crusted (BC)		Bare	47.00	2.55		32.59	1.39		18.72	1.89	
	Ponding Area (PA)		Bare	47.50	1.37		30.37	0.74		20.47	0.43	
	Open Turpentine Patch (OTP)		Woody shrub	47.50	3.06		31.85	1.48		19.19	2.48	
	Turpentine Patch (TP)		Woody shrub	59.50	3.74		39.26	3.81		25.47	3.74	
	Vegetated Crusted (VC)		Low veg	57.50	1.58		34.07	1.81		22.09	1.96	

9.5 Mean SSC index scores, with standard errors, for each Patch Type present on each of the 11 Cobar region study sites. All resource sink patches (marked) and mounds functioned as obstructions. Depressions functioned as run-on patches only where groundcover vegetation was significant. Patch types are grouped into broader patch categories for further analysis. For each SSC index, linear model and multiple comparison results (of patch types within each site) are listed (n.s. = not significant linear model result, thus multiple comparisons were not undertaken). Patch types (represented by acronyms) are arranged in order of decreasing mean index score. Those patch types which were not significantly different are underlined, bolded or italicised . Score classifications (low, moderate, high) as for Appendix 9.2.

Site No.	Patch Type (and acronym)	Resource sink?	Patch category	Soil stability			Infiltration			Nutrient cycling status (NCS)		
				Mean score	Std err	Within-site linear model results Stability vs patch type	Mean score	Std err	Within-site linear model results Infiltration vs patch type	Mean score	Std err	Within-site linear model results NCS vs patch type
25	Yarran Patch (YP)	✓	Treed	67.22	3.45	R^2=0.38; *p*=0.02 **DM** **SD YP WP NP CD** *VC* *BC*	52.59	4.60	R^2=0.70; *p*=0.00 WP YP **DM** **SD NP VC** *CD* *BC*	43.72	9.39	R^2=0.59; *p*=0.00 WP *YP* ***NP*** **DM SD CD** VC BC
	Bare Crusted (BC)		Bare	58.00	0.50		33.33	0.00		21.16	0.35	
	Vegetated Crusted (VC)		Low veg	62.92	3.25		40.12	1.77		22.58	2.10	
	Wilga Patch (WP)	✓	Treed	66.27	0.82		53.97	1.78		45.19	3.48	
	Needlewood Patch (NP)	✓	Treed	65.38	2.13		43.86	1.19		34.19	1.28	
	Crusted Depression (CD)		Bare	65.00	0.79		38.52	0.91		23.60	1.28	
	Disturbed Mound (DM)		Low veg	69.50	1.22		45.93	1.48		26.51	1.38	
	Small Depression (SD)	✓	Low veg	68.50	1.70		44.44	1.66		24.65	1.73	
26	Woody Weed' Patch (WWP)	✓	Woody shrub	68.83	2.29	R^2=0.64; *p*=0.00 WWP WP GP CP	45.19	3.39	R^2=0.77; *p*=0.00 WP WWP GP CP	28.73	3.09	R^2=0.51; *p*=0.01 WP WWP GP CP
	Crusted Patch (CP)		Bare	58.00	1.84		31.11	0.91		23.60	1.28	
	Grassy Patch (GP)		Grassy	66.50	0.61		40.74	1.17		25.70	1.39	
	Wilga Patch (WP)	✓	Treed	67.22	1.04		51.11	1.39		36.67	3.28	
27	Red Box Patch (RBP)	✓	Treed	66.61	1.74	n.s.	49.63	2.22	R^2=0.70; *p*=0.00 RBP DWWP OWWP	35.75	3.38	R^2=0.59; *p*=0.00 RBP DWWP OWWP
	Open 'Woody Weed' Patch (OWWP)		Woody shrub	60.50	0.94		33.33	0.00		19.77	0.00	
	Dense 'Woody Weed' Patch (DWWP)	✓	Woody shrub	60.33	3.91		44.44	3.10		27.19	3.33	
28	Grassy Patch (GP)		Grassy	65.00	1.37	R^2=0.63; *p*=0.00 AP HP GP	37.78	0.74	R^2=0.89; *p*=0.00 AP HP GP	21.86	1.28	R^2=0.76; *p*=0.00 AP HP GP
	Hopbush Patch (HP)	✓	Woody shrub	69.50	1.22		43.70	2.16		34.19	3.42	
	Acacia Patch (AP)	✓	Treed	72.78	1.04		55.56	0.00		46.31	3.13	

Site No.	Patch Type (and acronym)	Resource sink?	Patch category	Soil stability			Infiltration			Nutrient cycling status (NCS)		
				Mean score	Std err	Within-site linear model results Stability vs patch type	Mean score	Std err	Within-site linear model results Infiltration vs patch type	Mean score	Std err	Within-site linear model results NCS vs patch type
29	Red Box Patch (RBP)	✓	Treed	71.11	3.99	R^2=0.75; *p*=0.00 *RBP* ***WP WWP*** **VC** *BC AP BP* SDP	58.52	3.59	R^2=0.84; *p*=0.00 RBP WP WWP **VC AP BP BC** SDP	53.72	7.24	R^2=0.76; *p*=0.00 RBP *WP* ***WWP*** **VC AP** BC BP SDP
	Bare Patch (BP)		Bare	47.44	2.09		33.33	1.17		16.61	0.96	
	Woody Weed' Patch (WWP)	✓	Woody shrub	64.21	2.62		43.21	2.07		28.31	2.40	
	Austrostipa Patch (AP)		Grassy	52.13	3.97		34.11	2.43		19.90	2.77	
	Vegetated Crusted (VC)		Low veg	61.00	1.27		36.30	1.39		23.60	1.57	
	Bare Crusted (BC)		Bare	54.00	0.61		32.59	0.74		18.72	0.53	
	Wilga Patch (WP)	✓	Treed	65.56	2.08		48.89	1.81		36.67	4.51	
	Sandy Deposition Patch (SDP)		Bare	43.38	1.86		29.11	1.38		15.41	1.33	
30	Rosewood Patch (RP)	✓	Treed	65.89	1.80	n.s.	50.37	2.22	R^2=0.84; *p*=0.00 WP RP WWP VC	36.36	4.78	R^2=0.60; *p*=0.00 WP RP WWP VC
	Woody Weed' Patch (WWP)	✓	Woody shrub	64.50	2.15		43.70	1.39		28.02	1.97	
	Vegetated Crusted (VC)		Low veg	63.50	0.61		37.04	0.00		21.16	0.35	
	Wilga Patch (WP)	✓	Treed	67.22	2.80		53.33	0.91		36.45	0.99	
31	Mulga Patch (MP)	✓	Treed	75.67	3.48	R^2=0.66; *p*=0.00 MP VC **WWP M OC**	48.89	3.19	R^2=0.43; *p*=0.01 MP **WWP M VC** OC	38.96	5.09	R^2=0.40; *p*=0.00 MP WWP VC M OC
	Vegetated Crusted (VC)		Low veg	65.83	0.53		40.12	1.14		27.23	2.16	
	Open Crusted (OC)		Bare	61.25	0.56		34.57	0.78		20.06	1.18	
	Woody Weed' Patch (WWP)	✓	Woody shrub	64.86	1.24		43.16	3.89		28.39	4.91	
	Mound (M)		Bare	64.00	1.00		40.74	2.03		25.00	2.38	

Site No.	Patch Type (and acronym)	Resource sink?	Patch category	Soil stability			Infiltration			Nutrient cycling status (NCS)		
				Mean score	Std err	Within-site linear model results Stability vs patch type	Mean score	Std err	Within-site linear model results Infiltration vs patch type	Mean score	Std err	Within-site linear model results NCS vs patch type
32	Vegetated Crusted (VC)		Low veg	62.92	0.42	R^2=0.92; *p*=0.00 WWP **BWP VC** NP BC S	37.65	2.23	R^2=0.80; *p*=0.00 BWP WWP **NP VC BC** S	23.64	1.38	R^2=0.72; *p*=0.00 BWP WWP NP VC BC S
	Bare Crusted (BC)		Bare	59.50	0.94		33.33	0.00		21.51	0.00	
	Woody Weed' Patch (WWP)	✓	Woody shrub	71.50	1.27		50.37	3.01		35.00	2.76	
	Bimble Box/Wilga Patch (BWP)	✓	Treed	65.28	2.78		54.81	3.59		43.66	6.79	
	Needlewood Patch (NP)	✓	Treed	60.44	1.21		39.68	1.38		25.17	1.37	
	Scald (S)		Bare	39.39	0.69		28.89	0.74		11.88	0.91	
33	Treed Patch (TP)	✓	Treed	69.93	1.60	R^2=0.80; *p*=0.00 TP HP CGP GP BP	52.59	1.39	R^2=0.64; *p*=0.00 TP HP CGP GP BP	42.31	4.83	R^2=0.72; *p*=0.00 TP HP **CGP GP BP**
	Grassy Patch (GP)		Grassy	60.83	1.67		37.04	0.96		22.38	0.70	
	Bare Patch (BP)		Bare	50.83	1.05		35.80	3.12		20.06	1.08	
	Crusted Grassy Patch (CGP)		Grassy	61.67	1.79		41.36	2.42		24.71	1.39	
	Hopbush Patch (HP)	✓	Woody shrub	67.28	1.27		48.89	2.46		30.10	2.06	
34	Wilga Patch (WP)		Treed	49.06	1.05	R^2=0.88; *p*=0.00 AP M WP S	33.33	2.34	R^2=0.56; *p*=0.00 AP **M** **WP** S	18.87	2.75	R^2=0.53; *p*=0.01 AP **M** **WP** S
	Austrostipa Patch (AP)	✓	Grassy	67.50	1.94		42.22	3.43		27.44	4.49	
	Mound (M)		Grassy	61.00	2.18		38.52	0.91		22.09	0.94	
	Scald (S)		Bare	45.00	1.37		29.63	0.00		11.40	0.93	
35	*Bothriochloa* Patch (BP)	✓	Perennial grass	73.56	1.73	R^2=0.91; *p*=0.00 BP TP AP VC WP S	59.26	0.00	R^2=0.87; *p*=0.00 BP TP AP VC WP S	39.32	0.77	R^2=0.78; *p*=0.00 BP TP **AP VC** WP S
	Vegetated Crusted (VC)		Low veg	62.92	1.36		40.12	1.77		24.71	1.64	
	Austrostipa Patch (AP)	✓	Grassy	67.50	0.91		45.68	1.23		29.36	1.90	
	Themeda Patch (TP)	✓	Perennial grass	72.00	2.15		52.59	2.96		35.12	2.64	
	Scald (S)		Bare	43.00	1.46		30.37	0.74		14.65	1.14	
	Wilga Patch (WP)		Treed	56.50	1.50		36.30	2.16		23.49	2.93	

Appendix 10: Data storage and availability

10.1 Data storage

The following data storage methods have been employed with the data collected during the Woody Weeds and Biodiversity Project:

- flora and vertebrate fauna data are stored in the NSW NPWS Atlas of NSW Wildlife, which is widely accessible to all stakeholders (albeit with accuracy restrictions to allow species protection)
- invertebrate data are stored in excel spreadsheets,
- LFA data are stored in LFA program (excel),
- site location details are stored in the NSW NPWS Flora Survey Database (access) and an excel spreadsheet,
- site and pitfall trap attributes, shrub cover etc. are in excel.

The latter three data sets are held by NSW NPWS, Dubbo.

10.2 Data and report availability

Hard copies of the Project community report (Ayers *et al.* 2001) and this technical report are available from NSW NPWS, Dubbo.

The Project data are owned collectively by those agencies and organisations involved in the Project (DLWC, NSW NPWS, NSW Agriculture, CSIRO), despite the commissioning of the Project by DLWC (via WEST 2000) and the Project Management by NSW NPWS (via the Project Manager, Dani Ayers). A CD-Rom will be produced for each of these agencies and organisations involved, containing the following:

- site locality information;
- all raw data sets,
- metadata statements for each data set,
- copies of the statistical analyses conducted to date (SPLUS scripts and results),
- copies of each of the Project reports (Hassall and Associates 1999, Ayers *et al*. 2001 (community report), and this technical report).

These CD-Roms will be stored in the respective agency libraries, but access will be restricted for approximately three years (until the end of the WEST 2000 Plus program in 2004) to allow preparation of scientific papers for publication. Requests for use of the data may be forwarded to the WEST 2000 Plus Board of Management (c/- DLWC, Dubbo) until this time.

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