Integrating Paddock and Catchment Planning: A Wool Producer-Driven Approach to Sustainable Landscape Management

Interim Report: Vegetation Management, Grazing and Arthropod Assemblages in the Traprock region



Biodiversity component of Traprock (USQ5) LWW/AWI project December, 2005





A collaborative research project involving:



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Integrating Paddock and Catchment Planning: A Wool Producer-Driven Approach to Sustainable Landscape Management (Biodiversity component of Traprock (USQ5) LWW/AWI project): Interim Report: Vegetation Management, Grazing and Invertebrate Assemblages in the Traprock region

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Background to the Report

Integrating Paddock and Catchment Planning: A Wool Producer-Driven Approach to Sustainable Landscape Management (referred to as 'Traprock USQ5 project') is a multi-faceted two-year research collaboration between the University of Southern Queensland, Queensland Murray-Darling Committee Inc. and Traprock Wool Association Inc. The research is funded through Land, Water and Wool, a joint initiative of Land and Water Australia and Australian Wool Innovation P/L as part of the Native Vegetation and Biodiversity Sub-Program.

The research was a response to a need to identify biodiversity values within the production landscape and link these to socio-economic and production components. The *Biodiversity Component* of the Traprock USQ5 project consists of a number of distinct but related studies, including the examination of the *Vegetation, Grazing and Invertebrates in the Traprock region,* which aims to provide a sound scientific assessment of the patterns in invertebrate diversity in response to the broad management practices employed in wool growing properties in the region. This component will contribute directly to the development of biodiversity monitoring procedures and guidelines, particularly through an enhanced understanding of the biodiversity value and potential of vegetation (land) types within the landscape.



Executive Summary

This interim technical report outlines the methods used in the study, the initial patterns in ground invertebrate assemblages, in relation to land management by landowners in terms of grazing and over storey tree density and provides some preliminary conclusions.

The presence of trees in a system is thought to be highly significant to a rich array of arthropod species, as trees provide a wide range of structural features and resources that can greatly increase niche availability, feeding options and interspecific interactions. There is also some evidence that grazing affects both abundance and diversity of arthropods.

Study sites were established according to vegetation type and density and three 'treatments' were set up: complete grazing exclosures; partial exclosures to exclude sheep while allowing access for native herbivores; and unexclosed sites. Pitfall traps were used to sample the arthropod fauna and specimens were identified and classified to order level. Various statistical tests were used to test for differences in arthropod abundance and taxon richness in relation to vegetation type and density, in addition to examining overall assemblage composition and structure via multivariate analyses.

Tree density was found to have a significant impact upon the abundance, richness and diversity of arthropods. Arthropod abundance was found to be significantly greater in low tree density sites than in medium or high tree density sites. Arthropod richness (at the taxonomic level of order) and diversity were found to be significantly greater in medium and high tree density sites compared to low tree density areas, although no significant difference was found for abundance, richness or diversity between medium and high tree density sites.

In general, arthropod richness and diversity increased as tree density increased, whereas arthropod abundance (number of individuals per site) decreased with increasing tree density. Overall arthropod abundance, richness and diversity did not differ between the two main vegetation types in the region, ironbark/gum woodlands and box woodlands.

As expected there was little difference between the exclosed and non-exclosed areas, given that the fencing work was undertaken shortly before the field work. It is anticipated that the next round of field work may reveal some differences in arthropod assemblages in relation to grazing exclusion.

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Summary

The modification of natural woodlands through tree removal or clearing and a history of livestock grazing are likely to be important factors affecting biodiversity. These variegated landscapes are found in many eastern states where both livestock grazing and tree removal represent significant anthropogenic disturbances on natural woodlands. An understanding of the effects of vegetation management and sheep grazing on a number of components of biodiversity is important to ensure more sustainable management of land units in any region.

The broad aim of this research project was to determine if vegetation management and grazing has an effect on arthropod assemblages in the Traprock wool-producing region of southern Queensland.

Eighteen study sites were established across the study area according to vegetation type (ironbark/gum woodland and box woodland), and density of mature trees (low [<6 trees/ha], medium [6-20 trees/ha] and high [>20 trees/ha]), in areas where there was an absence of woody regrowth in the understorey. Sample sites were established randomly within patches and three 'treatments' were set up using 6m x 6m exclosures: complete grazing exclosure (2m fully meshed fencing to exclude all vertebrate herbivores); partial exclosure (1m three wire fencing to exclude sheep but allow access for native herbivores such as wallabies and kangaroos) and unexclosed (unfenced plot marked with corner pegs).

Three to four pitfall traps (9 cm deep 11cm diameter, plastic food containers) were placed in each exclosure over a period of 3 days in April 2005 and opened at the same time for a period of 6 days. All arthropods were identified to order level, except for Formicidae, which were initially taken no further than family level and collembola and myriapods, which were only identified to the level of class.

One-way analysis of variance (ANOVA) was used to test for differences in arthropod abundance and taxon richness. Two diversity indices were calculated for the order level data: Simpson and Margalef. Patterns in arthropod abundance were examined using multidimensional scaling (MDS) and analysis of similarity (ANOSIM).

Tree density was found to have a significant impact upon the abundance, richness and diversity of arthropods collected in pitfall traps in the Traprock region of southern Queensland. Arthropod abundance was found to be significantly greater in low tree density sites than in medium or high tree density sites. Arthropod richness (at the taxonomic level of order) and diversity were found to

be significantly greater in medium and high tree density sites compared to low tree density areas, although no significant difference was found for abundance, richness or diversity between medium and high tree density sites.

Vegetation type and landscape position was found to have little effect upon arthropod abundance, richness and diversity, although this may have been be a function of the coarse taxonomic resolution employed rather than a lack of assemblage distinction between the sites.

These and other findings are discussed in relation to ecological theory, management recommendations and the practicalities of using arthropods as barometers indicators of system change and condition..



1. Introduction

1.1 General Introduction

The impacts of agriculture on biological diversity and ecosystems are a great source of debate and research (e.g. Benton *et al.* 2003). A rich variety of ecological responses have been reported, ranging from considerable losses of biodiversity due to the modification of native systems into production land (e.g. Brown *et al.* 2001), to the maintenance of high levels of diversity via traditional, extensive agricultural practices (e.g. Stoate *et al.* 2001; Kleijn and Sutherland, 2003). Much would appear to depend on the nature of the system, the type and intensity of agricultural management and the taxa under investigation.

The Traprock region presents a scenario that is familiar in much of eastern Australia, namely woodland that has been partially cleared and further modified via livestock grazing. Whilst the primary focus of the Traprock grazing project is to examine vegetation responses to selective tree clearing and grazing, other taxa such as ground-dwelling arthropods have been included in the study in order to gauge their community responses to similar variables.

Whilst there are inevitable technical difficulties associated with studying arthropods due to taxonomic uncertainties, considerable spatial and temporal variability and the need for some expertise in identification, a number of other factors more than compensate for such potential obstacles. Insects and other arthropods constitute the overwhelming majority of known species on the planet (May, 1988; Wilson, 1994) and some groups (e.g. ants, spiders) are considered to be sensitive and reliable indicators of environmental change (see for example. Andersen and Majer, 2004), and have great potential as barometers of habitat condition. Many groups of arthropods are also considered to play important functional roles in ecosystem processes such as nutrient cycling, carbon sequestration, pest control and maintenance of soil structure (Altieri, 1999); as such, changes in arthropod assemblages may have important implications for the function and health of both natural and modified systems (Cardinale *et al.* 2004).

1.2 Responses to tree density

The presence of trees in a landscape or system is thought to be highly significant to a rich array of arthropod species, as trees provide a wide range of structural features and resources that can greatly

increase niche availability, feeding options and interspecific interactions. This in turn can result in an arthropod community that is both more complex and diverse. Whilst even a cursory overview of arthropod interactions with trees and other woodland components is beyond the scope of this report, suffice to say that from canopy to root tip, trees provide a wealth of ecological opportunities that a range of arthropods are able to exploit. One of the most important components of woodland for arthropods is that of dead and decaying wood, with a wealth of taxa being dependent upon some facet of coarse woody debris for at least part of its life cycle. Leaf litter is also a vital component of any woodland, as it simultaneously provides nutrients and maintains microclimate stability via the retention of moisture and the provision of shade. It also acts as an interface between the 'worlds' of above-ground and below-ground systems, with many taxa able to interact between these two spheres.

Whilst trees and woodlands are of undoubted importance for arthropods, little work appears to have been undertaken on the relationship of tree density and ground and litter arthropods. Of those that have been undertaken, Schowalter et al. (2003) investigated arthropod response to variable density thinning of Douglas fir plantation over storey, finding that whilst there were some short term community responses, these tended to be more influenced by the management history of the site rather than the level of thinning. Whilst studies examining arthropod communities in wooded habitats often include 'tree density' in a plethora of variables that are measured, stand density is unlikely to be independent of many of the other variables. However, several studies have examined arthropod assemblages in wooded sites compared to non-wooded or pasture sites (either proximate to woodland, or the same site before and after tree clearance). Such studies may be relevant to the low density' areas sampled in this study, as these are effectively pasture with (in some instances) scattered trees. In general, there was a tendency for studies to report greater diversity or taxonomic richness in woodland or forest habitats than in grassland or pasture. However, studies differed in the response they found. For instance, Decaens et al. (2004) reported a significant reduction in morphospecies diversity for a range of ground and soil invertebrates when forest was transformed into pasture. Conversely, Molnar et al. (2001) found that greater diversity of carabid beetles were found in grassland than in forest. Overall, this would appear to indicate that the nature, condition and management of the respective habitats may be just as important in determining arthropod biodiversity than merely whether trees are present in high or low numbers.

1.3 Responses to grazing

Given that ground-dwelling arthropods are likely to be highly influenced by soil structure, conditions and nutrient content, litter and debris abundance, ground vegetation structure and composition and disturbance intensity and frequency, it seems reasonable to suggest that assemblages will be affected by the presence, intensity and type of grazing in a system.

Pastoral landscapes may be described as variegated, where the landscape matrix is predominately native pastures with varying densities of trees (McIntyre and Barrett 1992). Two major anthropogenic disturbances influencing woodland communities in variegated landscapes are livestock grazing and the associated modification of natural tree densities (McIntyre and Barrett 1992; Clarke 2003). The combination of both livestock grazing & clearing in grassy woodlands can be detrimental to many native plant species (Prober and Thiele 1995; Clarke 2003). For example, in the grassy woodlands of New South Wales, Clarke (2003) found that native forb, shrub and twiner species richness was negatively affected by frequent grazing and the absence of a canopy.

Considerable research has been undertaken to determine the amplitude and direction of any grazing impacts on arthropod communities, with a range of responses being apparent for various taxa. Dombos (2001) examined the responses of collembolan communities to grassland heavily or lightly grazed with sheep. An interesting inverse relationship between abundance and richness was observed, with greater abundance in the heavily grazed areas, whilst there was greater richness in the lightly grazed areas. A similar relationship was found by Seymour and Dean for a wide range of taxa in heavily and moderately grazed grassland. Other studies appear to contradict the abundance increase in heavily grazed areas (e.g. Gibson et al. 1992; Treweek et al. 1997), others have found varied responses depending upon the taxa (e.g. Hutchinson and King, 1980), whereas others have found little tangible response of arthropod abundance to grazing intensity (e.g. Harris et al. 2003; Read and Andersen 2000). Most authors however seem to agree that as grazing intensifies, richness and diversity for many taxa may decrease. In a study that examined the impact of grazing disturbance on arthropods in Australian woodland (and hence of great relevance to this study), Abensperg-Traun et al. (1996) found that increased disturbance reduced the richness of a number of taxonomic groups, including functionally important taxa such as ants and termites. However, there is also evidence to suggest that low to moderate levels of grazing may actually be beneficial in maintaining high levels of biological diversity. For instance, Kirby (1992) emphasises the importance of maintaining a mosaic of grazing intensities for threatened arthropods in habitats such as heathland and calcareous grassland - such advice is now commonplace in management plans and conservation prescriptions in the UK.

Dennis *et al.* (2001) found no difference between spiders in treatments that varied according to livestock type (sheep, cattle, mixed) and sward height when sampled with pitfall traps, as with this study, whereas suction sampling indicated that lighter sheep only grazing resulted in a greater richness of lyniphiidae species.

The literature presents a range of arthropods responses to tree presence/density and grazing intensity. However, it can reasonably be anticipated that a reduction in tree density may lead to a reduction in arthropod diversity, whereas a reduction in grazing pressure may led to an increase in arthropod diversity.

Pastoral land management in Queensland often involves removing or reducing the tree layer to increase native grass production for livestock grazing (McIvor and McIntyre 2002).

1.4 Objectives

The research objectives specific to the arthropod component of the project are:

- 1. To determine if ground-dwelling arthropod communities are influenced by the density of trees in the region, and whether any such changes are discernable at coarse taxonomic levels (e.g. order level) as well as at finer taxonomic levels (e.g. genera, morphospecies);
- 2. To establish if the broad vegetation type and land form position (i.e. upper or lower slope) influences arthropod assemblages;
- 3. To investigate arthropod assemblage responses to grazing exclusion and subsequent responses of plant composition and structure;
- 4. To explore the relationship between arthropod community composition and a range of independent environmental variables, in order to determine which facets of an environment may have the greatest influence over arthropod assemblage structure.
- 5. To consider the suitability of arthropods as environmental indicators for landholders and community groups.

2. Study Area

2.1 Description of Study Area

The study was undertaken in the Traprock wool-growing region, west of the Stanthorpe-Wallangarra granite belt in southern Queensland. The region is approximately bounded by the major towns of Warwick and Stanthorpe to the east and Inglewood and Texas to the west.

The climate within the region is influenced by both tropical and temperate weather patterns (Queensland Murray Darling Committee 2004). The average minimum and maximum temperatures for the region range between 2.6 - 30.2°C for Warwick (28°22'S, 152°03'E) and 0.9 - 27.4°C for Stanthorpe (28°66'S, 151°93'E) (Bureau of Meteorology 2005). Rainfall is generally higher in summer months, although the winter proportion can be significant (Wills 1976). The average rainfall ranges from 701 mm at Warwick to 770 mm at Stanthorpe, but typically declines to the west of the study area (Wills 1976; Queensland Murray Darling Committee 2004).

The Traprock region was first settled over a century ago and since this time sheep have been grazed throughout the area (Wills 1976). Currently, the Traprock region supports approximately 300 000 hectares of sheep grazing country at a stocking rate of about 1-2 dse (dry sheep equivalent) per hectare (Queensland Murray Darling Committee 2004). Wool production is the dominant land-use, with limited winter and summer cropping and horticulture (Wills 1976; Queensland Murray Darling Committee 2004).

The soils developed on 'traprock' (metamorphic sedimentaries) are a complex pattern of shallow loams, shallow earths and shallow texture contrast soils characterised by a high content of angular parent rock (Wills 1976). The fertility of these soils ranges from low to fair and are associated with a generally high subsoil sodicity (Toohey 2004). The lower slopes and drainage lines are dominated by deeper texture contrast soils, while shallower soils generally occur on the upper slopes (Wills 1976).

The vegetation of the Traprock region is predominately grassy eucalypt woodland mainly comprised of narrow-leaved ironbark (*Eucalyptus crebra*), tumbledown gum (*Eucalyptus dealbata*), white box (*E. albens*) and, on the lower slopes, yellow box (*E. melliodora*), greybox (*Eucalyptus microcarpa*) or gum topped box (*Eucalyptus moluccana*). Remnant patches have been mapped by the Queensland Herbarium and classified as Regional Ecosystems 13.11.3/13.11.8, respectively

(Environment Protection Agency 2003). Both regional ecosystems are listed as of concern as a result of both grazing and clearing within the region (Environment Protection Agency 2003).

Native pastures are the main source of forage for grazing livestock within the study area (Wills 1976) but there are introduced pasture species in the some areas, either maintained or remnants of past attempts to increase carrying capacity. Past land management practices have largely consisted of ring-barking woody plants to encourage the growth of grasses and burning regularly to control woody regrowth and to remove unpalatable dry herbage (Wills 1976). Wills (1976) reported that between 60 to 100% of original timber on an average Traprock property (approximately 2000 ha) was often killed. More recently, chemical and mechanical control of regrowth have been used to maintain open grasslands. Natural grasslands are not considered to have been a common component before settlement (Wills 1976).

Regional ecosystems mapping by the Queensland Herbarium shows approximately 22 % of remnant vegetation remains in the Traprock region (Queensland Murray Darling Committee, 2004), although considerable areas of regrowth and other unmapped vegetation are evident throughout the area. Regrowth areas are considered an important component of the landscape, contributing to higher connectivity for wildlife movement than would be the case if these areas were absent (Queensland Murray Darling Committee, 2004).

Remnant vegetation in the region has been subject to some degree of forestry pressure with a number of species of forestry value. In ironbark/gum woodlands species of forestry value include *Eucalyptus crebra*, *E. cammaldulensis*, *E. tereticornis* and *E. blakelyi*. *Callitris* spp. also occur occasionally in this vegetation type. While *E. melliodora* and *E. macrocarpa* are of value from grassy box woodlands.

2.2 Experimental Design & Sampling

To ensure the major community types were sampled, site selection was stratified across the study area according to vegetation type, and density of mature over storey trees. Satellite imagery was used to select potential sample sites and actual sites were chosen in the field if all criteria were met.

Two dominant woodland communities were recognised using the regional ecosystem mapping by the Queensland Herbarium. The grassy box woodlands (RE 13.11.8) typically occur on lower slopes and are distinguished from ironbark/gum woodlands (RE 13.11.3) that typically occupy upper slopes and ridge lines. The box woodlands are dominated by *E. melliodora* (yellow box) and *E. microcarpa* (grey box), while *E. tereticornis*, *E. albens* and *Angophora floribunda* are occasional components of the community (Wills 1976). The box woodland community generally lacks a well

developed shrub layer, but occasionally *Acacia* spp. and *Cassinia* spp. may form a dense shrub layer to two metres tall (Wills 1976). The ground layer component is moderately dense and dominated by *Cymbopogon* spp., *Bothriochloa* spp., *Austrodanthonia* spp., *Dichelachne* spp., *Stipa* spp. and *Aristida* spp. (Wills 1976).

The ironbark/gum woodlands are dominated by *E. crebra* and *E. dealbata* and occasionally *Angophora* costata (Wills 1976). *E. crebra* may be replaced by *E. sideroxylon* in some areas. The ground layer is typically sparse but has a well developed shrub layer consisting of *Acacia* spp., *Jacksonia* spp., *Leucopogon* spp., *Daviesia* spp. and *Olearia* spp. (Wills 1976). For the purposes of this study the ironbark/gum woodlands are labelled as upper (U) slope vegetation.

Within each of these vegetation types, sites were assigned to one of three mature tree density classes: low (<6 trees/ha), medium (6-20 trees/ha) or high (>20 trees/ha) based on the number and cover of mature trees observed on the satellite imagery. Potential sites were excluded if the vegetation patch was less than 5 ha in size, if fence lines and water points were less than 250 m from the patch, and if areas were recently cleared (<5 years ago) or burnt (< 10 years ago). Ease of access to sites, spatial spread of sites across the study area, and landholder's permission to access properties were also considered in site selection.

Study sites were stratified across the landscape to sample two dominant woodland communities (grassy box woodlands [RE 13.11.8], typically occurring on lower slopes and ironbark/gum woodlands [RE 13.11.3], occurring on upper slopes and ridgelines) with mature tree densities of low (< 6 trees/ha), medium (6 – 20 trees/ha) and high (> 20 trees/ha). This resulted in six different site treatments being assessed – Low tree density/upper slopes (LU), low tree density/lower slopes (LL), medium tree density/upper slopes (MU), medium tree density/lower slopes (ML), high tree density/upper slopes (HU) and high tree density/lower slopes (HL). Each of these treatments was replicated three times, thus leading to 18 sites being sampled.

At each site, three 6 x 6 m (36m2) experimental 'plots' were established:

- 1. total exclusion: 2 m tall netted fencing with skirting to exclude all vertebrate graziers;
- 2. partial exclusion: 1.5 m five-strand wire fencing to exclude cattle and sheep;
- 3. unexclosed (no fencing).

In order to investigate the arthropod research objectives in the most cost effective manner, the sampling design was worked into the existing vegetation/grazing sampling design (Figures 1 & 2).



Figure 1. Pitfall trap placement in grazing exclosures



Three pitfall traps were placed via a random number sequence in each exclosure, with the exception of the unexclosed (control) plot where four traps were located in order to mitigate against the potential loss of traps due to livestock activity. The traps consisted of plastic food containers with a depth of 9 cm and a diameter of 11cm, thus giving a circumference of 34.5 cm per trap and a total 'trapping-edge' of 103.5 cm for each exclosure. Traps were placed in the ground over a period of 3 days in April 2005. Each trap was filled to 1/3rd its depth with 20% Ethylene glycol solution and a drop of detergent. Traps remained closed for at least 6 days in order to reduce the influence of 'digging-in' effects (Greenslade 1964).

The traps were opened for six consecutive 24-hour periods; all traps were then collected and removed to the USQ laboratory for the identification of the contents. All arthropods were identified to order level, except for Formicidae, which were initially taken no further than family level and collembola and myriapods, which were only identified to the level of class. 180 pitfall traps were processed in this way. Finer level taxonomic analysis has only recently begun for the Formicidae, which are being identified to genus and morphospecies level.

For the 2006 sampling season, only the 'upper' landscape sites were sampled, thus reducing the number sites to nine. This was primarily due to logistical issues with regard to covering all sites in the most expedient and cost effective manner. However, as the experimental design essentially remained consistent (all three tree densities and all exclosure types tested) with the project objectives, it was considered a valid option to pursue. In order to partially offset the potential reduction in robustness, 4 traps were set in each treatment, as opposed to the three in 2005. Due to logistical restrictions and concerns with heavy (if localised) precipitation, traps were only open for three days and nights compared to the 2005's six. It was considered that this loss of trapping time would be compensated by the greater arthropod abundance and activity associated with the time of year. As in 2005, all specimens were identified to the taxonomic level of order (with the exception of collembolans and myriapods), with ants (Formicidae) from two sites being identified to genera level at the time of writing. In all other respects the trapping techniques, storage and laboratory techniques remained identical to 2005's sampling regime.

2.2.1 Treatment comparisons and data analysis

Arthropod responses were examined for the following treatments:

- Tree density (L/M/H);
- Vegetation type/land form (U/L);
- Tree density and vegetation type combined (LU/LL/MU/ML/HU/HL);
- Exclosure type (total/partial/unexclosed);

One-way analysis of variance (ANOVA) was used to test for differences in arthropod abundance and taxon richness. Two diversity indices were calculated for the order level data: Simpson and Margalef and also analysed using ANOVA. Patterns in arthropod abundance were examined using multidimensional scaling (MDS) and analysis of similarity (ANOSIM). Multivariate analysis was undertaken to assess the degree of arthropod community dissimilarity (based upon abundance data for each taxa at order level) between sites of differing tree density.

3. Results

3.1 Effect of Tree Density

2005 data

In general, arthropod richness and diversity increased as tree density increased, whereas arthropod abundance (number of individuals per site) decreased with increasing tree density. Figures 3-6 display the results of these comparisons, depicting arthropod abundance, order level arthropod richness, order level arthropod diversity (Simpson's index) and order level arthropod diversity (Margalef's index).

The mean abundance of arthropods in areas of low tree density was significantly greater than in areas of medium or high tree density (Figure 3; F2, 51 = 20.22; P = ≤ 0.001). No difference was found between arthropod abundance in medium and high tree density sites. The mean richness (number of orders) of arthropods in areas of low tree density was significantly lower than in areas of medium or high tree density (Figure 4; F_{2,51} = 14.983; P = ≤ 0.001). No difference was found between arthropod richness in medium and high tree density sites.

The mean diversity (Simpson's reciprocal index) of arthropods in areas of low tree density was significantly lower than in areas of medium tree density (Figure 5; F2,51 = 14.507; P = ≤ 0.01) and between low and high tree density (F2,51 = 14.507; P = ≤ 0.001). No difference was found between arthropod diversity in medium and high tree density sites.

The mean diversity (MargalePs index) of arthropods in areas of low tree density was significantly lower than in areas of medium tree density and high tree density (Figure 6; F2,51 = 33.7; P = ≤ 0.001). A difference was detected between arthropod diversity in medium and high tree density sites, but it was not found to be significant (F2,51 = 33.7; P = 0.052).



Figure 3. Arthropod abundance across tree density classes.



Figure 4. Arthropod richness (order) across tree density classes.



Figure 6. Margalef's diversity index across tree density classes.

Figure 7 presents an ordination derived using Bray-Curtis similarity, data square root transformed, multi-dimensional scaling (MDS) with 100 restarts, stress = 0.15. Whilst there is considerable overlap between the high and medium tree density sites, there is a distinct separation between the low tree density sites and many of the medium and high sites based upon arthropod assemblage structure.



Figure 7. MDS ordination of arthropod assemblages in sites stratified by tree density.

Table 1. ANOSIM comparisons of arthropod similarity between tree density treatments. (Global R sample statistic: 0.267 Significance level of sample statistic: ≤0.001)

Pairwise Comparison	R Statistic	Significance level
Low/medium density	0.316	≤0.001
Low/high density	0.446	≤0.001
Medium/high density	0.046	0.01

The arthropod assemblages in the low tree density sites are significantly different to those in the medium and high sites, but the medium and high sites are not significantly different from each other. SIMPER output indicated that ants, collembola and hemiptera contributed most to the dissimilarity in arthropod assemblages between the tree density sites.

2006 data

In contrast to the 2005 data, overall arthropod abundance at the level of order did not show the trend of decreasing with increasing tree density. As Figure 8 shows, there appears to be no clear pattern of arthropod abundance. Accordingly, there was no significant difference found in arthropod abundance between the three treatments.



Figure 8. Mean arthropod abundance across tree density classes.

Arthropod richness for 2006 displayed a similar pattern to the 2005 data, with greater richness as tree density increased (see Figure 9). Significantly greater arthropod richness was found in the high tree density sites than the low density sites ($F_{2, 24} = 4.902$; P = 0.005), but no significant differences were apparent between the low and medium density sites and the medium and high density sites.





Figure 10 presents an ordination derived using Bray-Curtis similarity, data log+1 transformed, multi-dimensional scaling (MDS) with 100 restarts, stress = 0.19. As in the 2005 data, there appears to be a continuum of tree density based upon arthropod community composition. There appears to be considerable contrast between the arthropod communities of the high and low tree density sites.



Figure 10. MDS ordination of arthropod assemblages in sites stratified by tree density.

3.2 Effect of Vegetation Type

Overall arthropod abundance, richness and diversity (both indices) did not differ between the ironbark/gum woodlands and box woodlands (figures 11 & 12). Arthropod composition, as indicated the results of MDS ordination (Bray-Curtis similarity, data square root transformed, 100 restarts, stress = 0.15) was also not different between the two vegetation types.



Figure 11. Mean arthropod abundance in different vegetation types (upper = ironbark/gum woodlands; lower = box woodlands) (Non-significant, F1, 52 = 0.117; P = 0.734).





Figure 13. MDS ordination of arthropod assemblages in sites stratified according to vegetation type/landscape position. (upper = ironbark/gum woodlands; lower = box woodlands)

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The arthropod assemblages are not significantly different between the ironbark/gum woodlands and box woodlands shown in Figure 10 (ANOSIM, Global R sample statistic: 0.051, Significance level: 0.03).

3.3 Effect of Tree Density and Vegetation Type

Low density box woodlands and ironbark/gum woodlands contained significantly greater overall arthropod abundance than medium and high density woodlands (p<0.05) with the highest arthropod abundance in the low density box woodlands (Figure 14). No differences in arthropod abundance were found between any of the medium or high tree density sites, regardless of vegetation type (p>0.05) Figure 14).

Low density box woodlands and ironbark/gum woodlands contained significantly fewer arthropod taxa (richness) than medium and high density woodlands (p<0.05; Figure 15).







Figure 15. Arthropod richness across tree density and vegetation type. (Results of LSD post hoc test are indicated by letters, treatments sharing the same letter are not significantly different (p>0.01)).

Figure 16 displays the results of an MDS ordination (Bray-Curtis similarity, data square root transformed, 100 restarts, stress = 0.15) for arthropod assemblage structure in sites stratified according to both tree density and vegetation type/landscape position.





Whilst the results are somewhat ambiguous, there do appear to be some reasonably distinct groupings, such as between 'low-lower' (LL) and 'high-lower' (HL) and between 'low-upper' (LU) and 'high-upper' (HU).

3.4 Exclosure Type

2005 data

No differences were apparent for arthropod abundance, richness or diversity (using either indices) between the three different exclosure types.

Figure 17 displays the results of an MDS ordination (Bray-Curtis similarity, data square root transformed, 100 restarts, stress = 0.15) for arthropod assemblage structure in sites stratified according to exclosure type. It is apparent that there is no evident grouping.



Figure 17.MDS ordination of assemblages in sites grouped according to exclosure type.

Figure 18 displays an ordination of arthropod assemblage structure at sites stratified according to all three treatments (tree density, vegetation type and exclosure type). Little pattern is evident, which may be a function of the highly variable nature of the exclosure data apparent in Figure 17.



Figure 18.MDS ordination of assemblages in sites grouped according to tree density, vegetation type and exclosure type.

Comparison	R Statistic	Significance level
LU/LL	0.112	0.082
LU/MU*	0.267	0.011
LU/ML*	0.306	0.003
LU/HU*	0.422	≤0.001
LU/HL*	0.383	0.001
LL/MU*	0.558	≤0.001
LL/ML*	0.449	0.001
LL/HU*	0.528	≤0.001
LL/HL*	0.545	≤0.001
MU/ML	0.209	0.021
MU/HU	0.228	0.018
MU/HL	0.19	0.034
ML/HU	0.089	0.121
ML/HL	-0.109	0.971
HU/HL	0.046	0.237

Table 2. Pairwise ANOSIM comparisons of arthropod similarity between treatments. (Global R sample statistic: 0.28; Significance level of sample statistic: ≤0.001. Comparisons with an R statistic greater than 0.25 are deemed to have significantly different arthropod assemblages, and are indicated by an asterisk (*)).

2006 data

No significant differences were found in arthropod abundance between exclosure types (see Figure 19). However, arthropod richness was found to be significantly greater in the 1m 'sheep-only' exclosure than the open control 'exclosure' ($F_{2, 24} = 2.593$; P = 0.034). See Figure 20.







Figure 20. Mean arthropod richness between different exclosure types.

Formicidae (ant) community responses (2006 only).

Ants are renowned as one of the arthropod groups most responsive to environmental variables. Furthermore, extensive research regarding ant community responses to a variety of habitat types and disturbance, has resulted in the development of a sophisticated understanding of how communities are shaped by their environment, natural and anthropogenic disturbance processes and management of habitat.

Whilst ants were collected from twelve pitfall traps at each of nine sites in 2006, financial and time constraints resulted in only 16 pitfall traps of ants being identified to genera level at time of writing. However, the data is presented in this report as it provides an intriguing snapshot of what may prove to be dramatic shifts in ant community composition along a gradient of tree density. It also indicates that responses to grazing exclusion may also become discernable in ant communities over time.

Sites and treatments identified:

- Site 1 (low tree density) 2m exclosure;
- Site 1 (low tree density) Control 'exclosure';
- Site 15 (high tree density) 2m exclosure;
- Site 15 (high tree density) Control 'exclosure';

Comparison 1 – Tree density

Abundance.

Ant abundance was greater in the low tree density site, with 1566 individuals collected compared to 661 in the high tree density site (see Figure 21).





This trend appears to continue when the data from all nine sites is used (derived from 'order-level data'). The abundance of ants in the low and medium tree density sites appears to be similar, but a considerable decrease is noted in the high tree density sites (see Figure 22).





A one-way analysis of variance found that there were significantly greater numbers of ants in the LTD sites than the HTD sites ($F_{2, 24} = 3.931$; P = .017) and in the MTD sites than the HTD sites ($F_{2, 24} = 3.931$; P = .033).

Richness.

Ant richness was slightly greater in site 1 (LTD) with 17 genera identified compared to site 15 (HTD) with 15 genera (see Figure 23).



Figure 23. Ant richness (number of genera) in sites 1 (low tree density) and 15 (HTD)

Comparison 2 – Exclosure treatment

Abundance

Ant abundance was greater in the 2m exclosure (treatment 1) at site 1 (LTD), with 990 individuals collected compared to 576 collected in the control 'exclosure' at the same site. A similar trend was observed at site 15 (HTD), with 496 individuals trapped in the 2m exclosure and 165 trapped in the control 'exclosure' (see Figure 24).



Figure 24. Ant abundance (number of individuals) in 2m and control exclosures at sites 1 (LTD) and 15 (HTD)

This trend does not appear to continue when the data from all nine sites is used (derived from 'order-level data'). The abundance of ants in the 2m, 1m and control exclosures appears to vary only slightly (see Figure 25).



Figure 25. Mean ant abundance in 2m, 1m and control exclosures (N = 9)

Richness

Ant richness was slightly greater in the 2m exclosure (treatment 1) at site 1 (LTD), with 14 genera collected compared to 13 collected in the control 'exclosure' at the same site. At site 15 (HTD), 10 genera were trapped in the 2m exclosure and 12 trapped in the control 'exclosure' (see Figure 26).



Figure 26. Ant richness (number of genera) in 2m and control exclosures at sites 1 (LTD) and 15 (HTD)

Functional group community composition.

Due to the highly complex nature of ant communities and the high degree of variability often observed between species and genera present at different sites, the concept of ants compartmentalised into functional groups has been developed and employed in a wide range of research situations. The functional group approach can be applied to the data thus far analysed from the Traprock study.

Functional group comparison 1 - Tree density

The low tree density site was found to be comprised mostly of 'dominant dolichoderinae' ants, consisting in this instance of the highly competitive genera *iridomyrmex*. Conversely, the high tree density site contained fewer iridomyrmex ants, but more opportunistic taxa such as the ruderal genus *rhytidoponera* and generalised myrmicinae taxa such as the genus *pheidole*. See Figure 27.





Little difference was apparent in the functional group composition observed between the total exclosure and the unexclosed control treatment in site 1. However, a slight trend may be apparent in the lower iridomyrmex domination and the greater percentage of opportunistic taxa in the open control plot (see Figure 28). For site 15, again there appears to be little difference between the composition of the two different grazing treatments (see Figure 29).





Figure 29. The functional group community composition of ants in 2m exclosure and control 'exclosure' at site 15 (HTD).

Key to functional groupings:

- SubCamp Sub-dominant camponotus
- SpecPred Specialised predators
- Opp Opportunistic species
- GenMyrm Generalised myrmicinae
- DomDol Dominant dolichoderinae
- Cryptic Cryptic species
- ClimSpec Climate specialists

The only ant data that is available for all sites is that of ant abundance, with the observed increase in ant abundance in the low and medium tree density sites compared to the high tree density sites potentially due to a range of factors. Areas of lower tree density are likely to be subjected to greater levels of disturbance, both historical tree clearing and current grazing. Graham et al. (2004) found that ant abundance was greater in highly disturbed sites in forested habitat in the United States (although conversely reported reduced species diversity in highly disturbed areas). Several authors have indicated that in more highly disturbed environments the abundance of ants belonging to the sub-family dolichoderinae is particularly high (Andersen, 1997; Majer and Nichols, 1998). This

dominance pattern was certainly observed in the one LTD site that was examined to genera level in this study, with considerable numbers of iridomyrmex (belonging to dolichoderinae) being caught, and if reflected throughout the other sites, could feasibly contribute to a high abundance in areas of lower tree density. Insolation is likely to be greater in areas with low to moderate tree density and many ant species and dolichoderinae ants in particular are known to be favoured by high rates of insolation (Vanderwoude et al. 2004). The reduced quantity of leaf litter in low tree density sites may increase the activity and the trapability of ground-foraging ants, thus giving an impression of increased abundance in low tree density (and hence low-litter) areas.

Whilst it is very difficult to postulate about the findings and implications of the data restricted to sites 1 and 15, it appears that differences in functional group community composition may be present between different tree density sites. In particular, the relationship between tree density, dominant dolichoderinae ants, generalised myrmicinae ants and opportunistic ant species may become apparent if further investigation is undertaken. As with the vegetation data, ant responses to grazing exclusion are likely to become apparent over time. However, it is feasible that ant communities may detect changes in vegetation that are too subtle to be detected by the vegetation research and respond accordingly. If this is the case, then such responses may be discernable from the present data set after one year of exclusion.

4. Discussion

4.1 General Patterns

Over 40,000 arthropods were collected during the study, representing 23 taxonomic orders. On average, approximately 200 individual arthropods were caught in each pitfall trap.

It would appear from the data presented in figures 3-7 and the results of the BIO-ENV analysis that the density of trees exerts a considerable influence over arthropod abundance, richness and diversity. However, the only statistically significant differences were derived from the comparisons between low tree density sites (< 6 trees/ha) and medium or high sites (6 – 20 trees/ha and >20 trees/ha respectively). This is not altogether surprising; most of the low density sites were open grazing paddocks, whereas the medium and high density sites were effectively woodland, and therefore represented a marked difference in habitat type, composition and structure.

The 2006 data recapitulates the relationship between order level richness and tree density observed in 2005. The findings for arthropod abundance are somewhat less clear cut however, with no significant difference between treatments.

Exclosure type did not appear to have a marked effect on arthropod abundance, but arthropod richness at order level was significantly greater in 1m exclusion plots than the open control areas.

Ant abundance in 2006 was found to be significantly higher in low tree density compared to high tree density sites and medium tree density compared to high tree density sites.

Of the two sites examined for ant community composition, the low density site was predominantly composed of dominant dolichoderinae taxa, whilst the high tree density site was dominated by generalized myrmicinae and opportunistic species.

4.2 Abundance and Tree Density

Whilst it may initially seem counterintuitive that as a habitat is simplified (e.g. reduced tree density), the number of individual arthropods increases, there is considerable evidence from the literature to suggest that this may not be an uncommon phenomena. Much of the observed increase in abundance was due to far higher numbers of collembola in the more open, low tree density areas compared to areas with higher tree density. Collembola (along with ants) were also found to be the taxa that contributed most to the dissimilarity between sites of differing tree density. This appears to correspond to the findings of Goehring *et al.* (2002), who found much higher abundance of collembolans in highly disturbed coffee monocultures compared to adjacent native forest. Increases in abundance of collembolans (and other taxa) in more open and frequently disturbed habitats could be due to a range of factors, including:

- Increased disturbance and habitat simplification associated with a move from woodland to more disturbed and open habitats, may have resulted in a decrease in arthropod species richness, thus allowing the remaining species to proliferate in the absence of interspecific competition.
- More disturbed environments may provide more suitable conditions for hot-climate specialists, disturbance specialists and (in particular) introduced exotic species.
- Disturbed environments may contain more ubiquitous, early successional, r-selected taxa which, may be present in large numbers (Begon *et al.* 1996).

- The resource concentration hypothesis (Andow, 1991) suggests that certain taxa may become highly abundant where there is a high concentration of a particular resource. This is perhaps more likely to occur in a simplified and more homogeneous habitat, such as pasture, than in a more complex and diverse habitat such as woodland. Pasture in particular has been reported as supporting very high numbers of collembolans, with 20,000 – 30,000 individuals being present in 1 square metre (King and Hutchinson, 1976).
- The sampling technique (pitfall trapping) may have inadvertently favoured the capture of organisms in more open habitats, compared to more structurally complex areas (Bogya and Marko 1999; Dombos 2001).

The implications of the observed increased abundance in fewer taxa in more disturbed areas is difficult to gauge without a more detailed taxonomic and functional examination of the specific taxa, but there would appear to be greater potential for increased pest species proliferation in simplified environments, that may be less controllable due to a possible reduction in predatory taxa.

4.3 Richness, Diversity and Tree Density

Arthropod richness and diversity were found to increase at greater tree densities, particularly when comparing a low density to a medium or high density site. In addition to the habitat and resource value of trees and associated habitat components (e.g. leaf litter, coarse woody debris), there are a number of other factors that may reduce biological diversity in simplified, more intensively managed areas:

- In highly disturbed areas (such as heavily grazed pasture), biological community composition may not have an opportunity to progress beyond early successional stages due to the intensity and frequency of disturbance. This may lead to a reduction in overall taxonomic richness and diversity due to the paucity of mid- to late-successional taxa.
- Areas of less disturbed and more structurally complex habitat are likely to contain more microhabitats and have greater niche availability than areas that are highly disturbed and structurally or compositionally simplified (Bengtsson, 1993). This in turn may lead to greater species coexistence and consequently greater observed richness and diversity.
- Whilst this study did not specifically focus on predators, there are a number of studies that have found greater predator abundance in woodland compared to pasture. Therefore, it is possible

that greater overall diversity is being maintained through the process of predator mediated suppression of competitively dominant taxa, which in the absence of high levels of predation pressure would proliferate.

• The shading and microclimate regulatory effects of tree cover may result in a ground story that is more conducive to a range of thermoregulatory requirements rather than favouring taxa that may be hot climate specialists.

4.4 Abundance, richness, diversity and vegetation type/landscape position

No differences were detected in the arthropod assemblages on the basis of vegetation type or landscape position. It could reasonably be anticipated that one would expect to find some differences amongst the more specialist phytophagous taxa and their parasites, but such subtle changes are unlikely to be detected by identification of arthropods to order level alone. Whilst broad scale differences such as the presence and absence of trees seem to be readily detectable at a coarse taxonomic resolution, it appears that less dramatic environmental differences (such as the *type* of woodland) are not discernable through such means. To ascertain if such changes are quantifiable through fine scale taxonomic analysis (e.g. genera, species, morphospecies) is an ongoing concern of the project, with ants being identified to at least genera level.

When vegetation type/landscape position was analysed in tandem with tree density, a number of abundance, richness and diversity comparisons yielded significant results. However, it was particularly apparent from the ANOSIM results that differences are likely to be a function of the variation in tree density rather than vegetation type.

4.5 Exclosure type

One of the aims of the Traprock invertebrate project is to examine changes in arthropod assemblages due to grazing exclusion. After approximately one month of the exclosures being erected, no pattern was discernable in arthropod composition between the three exclosure types. This is exactly as one would predict over such a short time period (and during a period of poor vegetative recovery, due to prolonged drought) and provides an excellent baseline from which to chart arthropod assemblage development due to grazing management over an extended time period.

The 2006 data had the potential to provide a more insightful picture of the responses of arthropods to grazing exclusion, as a year had elapsed following the erection of the fencing, and seasonal rainfall had ensured that a good growing season had contributed to biomass accumulation. Whilst the order level abundance and ant abundance data did not show any discernable pattern with regard to exclosure type, order level richness was significantly greater in the 1m exclosure than in the 'unexclosed' control plot. This may be the beginning of a discernable recovery in arthropod diversity due to grazing reduction, and it is tempting to interpret this finding as an example of the intermediate disturbance hypothesis (Connell 1978), where more species are present in areas of moderate (rather than high or low) disturbance. However, it may also be a function of utilising a very coarse taxonomic resolution to depict richness - would the same patterns be observed if the incumbent taxa were identified to family, genera or species? This, in part is the purpose of pursuing the ants to a finer taxonomic (and subsequent functional grouping) level. This potential causal factor aside, there is a wealth of literature that examines and reports increases in arthropod (and other taxa) richness as a result of a reduction in stock grazing intensity. For instance, Topping and Lovei (1997) found greater spider richness in ungrazed grassland than grassland under various grazing regimes, whilst Seymour and Dean (1999) reported higher arthropod richness in moderately grazed compared to heavily grazed habitats.

Ant data.

The only ant data that is available for all sites is that of ant abundance, with the observed increase in ant abundance in the low and medium tree density sites compared to the high tree density sites potentially due to a range of factors. Areas of lower tree density are likely to be subjected to greater levels of disturbance, both historical tree clearing and current grazing. Graham et al. (2004) found that ant abundance was greater in highly disturbed sites in forested habitat in the United States (although conversely reported reduced species diversity in highly disturbed areas). Several authors have indicated that in more highly disturbed environments the abundance of ants belonging to the sub-family dolichoderinae is particularly high (Andersen, 1997; Majer and Nichols, 1998). This dominance pattern was certainly observed in the one LTD site that was examined to genera level in this study, with considerable numbers of iridomyrmex (belonging to dolichoderinae) being caught, and if reflected throughout the other sites, could feasibly contribute to a high abundance in areas of lower tree density. Insolation is likely to be greater in areas with low to moderate tree density and many ant species and dolichoderinae ants in particular are known to be favoured by high rates of insolation (Vanderwoude et al. 2004). The reduced quantity of leaf litter in low tree density sites

may increase the activity and the trapability of ground-foraging ants, thus giving an impression of increased abundance in low tree density (and hence low-litter) areas.

Whilst it is very difficult to postulate about the findings and implications of the data restricted to sites 1 and 15, it appears that differences in functional group community composition may be present between different tree density sites. In particular, the relationship between tree density, dominant dolichoderinae ants, generalised myrmicinae ants and opportunistic ant species may become apparent if further investigation is undertaken. As with the vegetation data, ant responses to grazing exclusion are likely to become apparent over time. However, it is feasible that ant communities may detect changes in vegetation that are too subtle to be detected by the vegetation research and respond accordingly. If this is the case, then such responses may be discernable from the present data set after one year of exclusion. Continued assessment of the ant (and order level) responses to grazing exclusion may yield valuable insights into the long-term relationship between arthropods and grazing, as well as offering potentially valuable information relating to the functional condition of the landscape.

4.6 Management Implications

Using order level data, it is possible to make some broad observations and comments regarding the maintenance of arthropod biological diversity in variegated grazing landscapes. Much as the botanical data has revealed that medium tree cover strikes a workable compromise between biodiversity conservation and production aims, so the richness and diversity of arthropods shows a considerable increase from low tree density to medium tree density, and as such, the same recommendation holds. It is likely that continued fine scale taxonomic work on ants would reveal a great deal about the intricacies of the relationship between tree density, grazing pressures, general arthropod biodiversity and ant functional group responses. The potential for arthropods to 'detect' initial changes in vegetation as a response to grazing manipulation is an area that may also be profitable to explore, both as an 'early warning system' of habitat degradation and as a barometer of system recovery.

4.7 Arthropods as a community monitoring tool

The ability of arthropods to respond rapidly to environmental changes, disturbance, system degradation and recovery is generally not in doubt. One of the main issues is the pragmatic feasibility of their use as a monitoring tool by community groups and the non-specialist. This initial study has shown that broad scale land use differences can be detected even at very coarse taxonomic levels. This is an area that needs to be explored further, particularly from the perspectives of using surrogates for taxonomy (e.g. investigating pasture management/grazing intensity and beetle species' body sizes) and an appraisal of the practicality of community groups engaging ecological consultants, academic institution researchers or amateur experts in fine scale taxonomic identification of particular groups such as ants.

4.7.1 Future arthropod research recommendations:

It is considered that the following activities would be high priorities for future research and/or extension:

Fine-scale taxonomic analysis of ants from sampled land use units – it is unlikely to be necessary to go beyond genera (and in some specific cases, species group – e.g. monomorium), in order to categorise ants into functional groups and chart the development or transitions of community structure in response to tree density, vegetation type and grazing management.

Order level arthropod responses to grazing exclusion over a number of seasons in order to assess long-term implications of grazing exclusion, vegetation trajectory and arthropod assemblage succession;

Objective consideration of feasibility of arthropod assemblages for detecting broad scale land use changes, fine scale management changes and pragmatic options for community utilisation.

Development of workshop and extension materials that seek to communicate the significance of invertebrates to landholders and enable participants to learn the rudiments of arthropod ecology, surveying and identification.

5. Conclusions

Arthropod abundance, richness and diversity are influenced to a considerable extent by tree density. However, the greatest changes in arthropod assemblages were evident as one moved from low density areas to medium density areas; further assemblage changes from medium to high density sites were far less pronounced. This implies that, for coarse taxonomic resolution at least, medium tree density may be sufficient to retain significant components of arthropod biodiversity.

Vegetation type had little discernable influence over arthropod assemblage composition and structure, with no differences being apparent in arthropod abundance, richness, diversity or community structure when comparing ironbark/gum woodland and box woodland sites. This appears to indicate that vegetation type is not strongly influential with regard to shaping arthropod assemblages, or (more probably) that the taxonomic resolution of order is insufficiently sensitive to detect such habitat differences.

Arthropods, whilst being traditionally the domain of the entomological specialist, may be a usable tool for community groups to examine broad land use changes. Using arthropods at finer taxonomic resolution to detect more subtle environmental changes may require expertise that are likely to lie outside the domain of many community groups. However, the engaging of such expertise by community groups may still be a viable and rewarding option.

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