final report

Project code: ER.101 / B.ERM.0101

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Date published: June 2008

ISBN: 9 781 741 912 784

PUBLISHED BY

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Locked Bag 991
NORTH SYDNEY NSW 2059

Understanding the interactions between biodiversity and the management of native pastures in the Murray Darling Basin

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

Native pastures of the inland slopes of SE Australia are widespread and form the basis of a large proportion of temperate livestock grazing production systems. They are also the major form of native vegetation in these landscapes. However, little is known of the effects of livestock management systems in influencing the composition and diversity of native fauna and flora in native pastures. This project examined how plant, reptile and bird diversity was distributed among native pastures that differed in their grazing management (stocking rate and rotational versus continuous stocking), fertilization history and woodland tree cover. Native plants were most directly influenced by paddock management, declining in response to increasing available soil phosphorus and stocking rate but showed no response to rotational grazing systems. All three groups responded positively to increasing woodland tree cover. The results show that the persistence of native biodiversity in these landscapes in not compatible with high-input livestock production systems. Cover and diversity of native perennial plant species is directly reduced by high levels of fertilizer and stocking, while key habitats for birds and reptiles will not persist in the long-term under these management systems. Adoption of low-input production systems that may be compatible with native biodiversity is occurring but not widespread. Further exploration of low-input production systems is warranted.

Executive Summary

There is growing interest in the role of native pastures in landscape health and biodiversity conservation. There are between three and ten million hectares of native pastures on the south-western slopes of the Murray Darling Basin. This land use represents the most widespread form of native vegetation in these landscapes and is likely to be playing an important role in the persistence of native fauna and flora. Furthermore, increases in the cover of native perennial grasses within these areas could substantially contribute to improved ecosystem function and soil protection.

This project examines the composition, abundance and diversity of native plants, reptiles and birds in grazed native pastures on the south-west slopes of New South Wales and north-eastern slopes and uplands of Victoria. The key objective was to collect data that could better inform the management of native biodiversity in livestock grazed regions of the Murray Darling Basin.

The primary question underpinning this project was: "What is the impact on biodiversity of a range of native pasture livestock grazing scenarios relative to the impacts from other paddock, farm and regional influences?" The project tested the following hypotheses:

(1) Plant diversity in pastures is more strongly influenced by paddock management than landscape scale factors
(2) Bird diversity in pastures is more strongly influenced by landscape factors than by paddock management;
(3) Reptile diversity in pastures is influenced both by landscape and local paddock management;
(4) Biodiversity in native pastures is correlated with livestock production and profitability.

A key focus of the project was to contrast two broad grazing strategies (continuous stocking and rotational grazing), that can be defined in terms of the duration and frequency of grazing and rest periods. The project also contrasted paddocks that retained woodland tree cover with those that had previously been cleared.

Research data was collected from 24 properties spread across the study region. Most research data were collected during the drought conditions of 2006-07. This proved fortuitous – the results that emerged provide a picture of the livestock production system, native pastures and the biodiversity they support during a period of severe climatic stress.

The project results demonstrate that recent land management practices, in particular livestock grazing pressure and fertilizer (as indicated by available soil phosphorus) are the main determinants of native plant richness, composition and the cover of native perennial plant species. These factors also weakly influenced reptile abundance. No positive responses to rotational grazing were observed, although bird richness and abundance showed a negative response. While the groups varied in their response to grazing and fertility, they all showed increased diversity or abundance when woodland was present both in the paddock and in the wider landscape. Ground layer habitat features and shrub cover also influenced reptile and bird composition and diversity.

The loss of perennial grasses is considered a key factor in the deterioration of ecological condition, compromising the production base and increasing risk under conditions of drought.

Our results demonstrated that the live cover of native perennial plants during drought conditions was more closely related to the paddocks' recent stocking rate and fertilization history than it was to the degree of soil moisture deficit. In contrast the abundance of exotic plants was best explained by recent climatic conditions. In short, sites with a history of heavy stocking and high levels of available phosphorus were more vulnerable to the effects of drought. All the sites sampled had native plant cover of less than 50% and only two had total plant cover of over 50%. These are well below minimum levels required for the protection of soil and it can be concluded that the soil erosion risk is high.

Most indicators of native biodiversity were not correlated with the recent profitability of the livestock grazing enterprises. However profitability was positively correlated with available soil phosphorus and was negatively correlated with live plant cover during the drought conditions. High levels of profitability appear to be derived from over-utilisation of pastures leading to inevitable degradation of the resource base.

There is a clear trade-off between high input production systems and maintaining biodiversity (plants, birds and reptiles) in pastures. There is also a trade-off between high-input systems and indicators of ecosystem function (e.g. perennial plant cover). Production systems that are driven by a need to maintain high levels of soil fertility (>20 mg kg^{-1} Colwell Phosphorus) and high total stocking rates (>4-5 dse/ha) will tend to be species-poor and dominated by annual plants. While these pastures are often productive, they will be more vulnerable to climatic variability and hence soil erosion.

The adoption of low-input extensive grazing systems is likely to have benefits for maintaining native plant diversity and perennial cover in pastures. If such systems are also accompanied by increased habitat complexity, through increased woody debris, variable ground layer tussock structure and tree regeneration, benefits to reptile and bird diversity are also expected.

Our key conclusions from this project are:

1. The presence of woodland is critical to biodiversity in grazed landscapes. Property and catchment planning needs to implement minimum tree cover targets through protection, regeneration and planting.
2. High input pasture management is not compatible with maintaining native plant diversity and has a more indirect negative influence on birds and reptiles. There needs to be an appropriate balance of high- and low-input management on farms to maintain biodiversity in regions.
3. A range of grazing intensities should be provided within or between paddocks to create the variety of sward structure and defoliation intensities to cater for the range of species requirements. There is still some ambiguity about the role of rotational grazing, but it certainly cannot be assumed to enhance diversity.
4. Profitability in many native pasture grazing enterprises has come at a cost to the ecological condition of properties through loss of native perennial cover and loss of total plant cover.
5. Low-input production systems need to be further understood and promoted, even if there are reductions short-term profitability. The role of land management agencies is going to be important in providing a vision for the landscape, and incentives for land stewardship.
6. There is scope for individual action. Better profits overall from low-input systems are undoubtedly achievable with the right research focus and producer commitment. There are some highly motivated individuals who are actively managing for lower production as an acceptable trade-off to achieve lower risk, the enjoyment of wildlife, and improved resource condition.

7. Some forms of rotational or planned grazing may provide producers with a pathway to adopting low-input production systems.

In summary, the conclusions are consistent and are in accord with previous research i.e. there is a fundamental trade-off between higher levels of utilization and the amount of natural capital that is required to maintain the diversity and ecosystem function of the grassy eucalypt woodlands. There is a clear challenge for industry to tackle these issues.

Scientific results from this project were used to develop research papers and also formed the basis of a 30-page producer booklet. The producer booklet was developed after lengthy consultation with landholders and other stakeholders. This process of consultation assisted in the development of content and presentation and helped guide consideration of the implications for farm businesses and farm management.

Contents

1 Background

There is growing interest in the role of non-arable native pastures in landscape health and biodiversity conservation. It is estimated that there are between three and ten million hectares of native pastures on the south-western slopes of the Murray Darling Basin in eastern continental Australia (Simpson and Langford 1996; Dorrough and White, unpublished data). It has also been estimated that between 30% and 80% of grazed pastures in temperate Australia are "native pastures" (Garden *et al.* 2000a). Johnston (2001) argued that increases in the cover of native perennial grasses would improve productivity and water use in low nutrient recharge areas and given the extent of native pastures in these landscapes, the potential seems substantial. Native pastures are also the most widespread form of native vegetation and no doubt play an important role in persistence of native fauna and flora in these landscapes (McIntyre 1994). Low-input native pastures also seem to be crucial for on-going natural regeneration of woodland trees (Manning, Fischer & Lindenmayer 2006; Dorrough, Vesk & Moll 2008). A number of recent studies have argued that extensive management of native pasture and scattered paddock tree landscapes will be important to the long-term conservation of many native species (eg. Fischer *et al.* 2005; Manning *et al.* 2006; Dorrough, Moll & Crosthwaite 2007).

Changes in grazing management are seen as essential to improving the natural resource outcomes from native pastures. While government (e.g. Catchment Management Authorities and Departments of Primary Industries) and industry are investing in changes to grazing management, producers and producer organisations have also been major players in driving change. However there are still many crucial questions about the effects of different grazing management regimes on native pastures and the biodiversity they support that have received little attention.

There is an increasing body of research on the roles of grazing management systems, including timing and duration of grazing and rest, and impacts of fertilizer regimes on the persistence of native perennial grasses in pasture (Kemp, Dowling & Michalk 1996; Garden *et al.* 2000b; Garden *et al.* 2003; Earl & Kahn 2007). Little however is known about responses of most plant species. While we are increasingly developing an understanding of the floristic composition of native pastures, there are few data describing how different grazing systems modify composition. Most ecological research to date has contrasted grazed pastures with ungrazed reserves without considering duration and timing of grazing events or interactions with nutrient addition (McIntyre & Lavorel 1994a; Clarke 2003; Dorrough, Ash & McIntyre 2004). While previous research has yielded important data on general patterns, recent research has highlighted the importance of interactions between grazing management and fertilizer history (Kirkpatrick *et al.* 2005; Dorrough *et al.* 2006) and the role of grazing intensity and season of rest (Leonard & Kirkpatrick 2004; Kirkpatrick *et al.* 2005). The importance of changes in soil fertility are increasingly recognised (Prober, Lunt & Thiele 2002; Dorrough *et al.* 2006; McIntyre & Lavorel 2007) yet despite growing interest among producers in rotational or 'planned" grazing systems these issues are largely unexplored by researchers (but see Bruce 1998; Reseigh 2004; Earl & Kahn 2007).

Reseigh (2004) detected responses to grazing regime (e.g. rotational, continuous) in only about 10% of the 300-odd plant species recorded in the study. Some report a decline in unpalatable perennial grasses (Earl & Jones 1996; Bruce 1998) and increases in palatable grasses (Reseigh 2004).

There are also indications of declines in the forb component (Reseigh 2004), but the story for total native plant diversity is mixed, with reported declines (Bruce 1998; Reseigh 2004) and increases (Kemp *et al.* 2003). Finally, there are reports of fewer annual plant species responding positively to rotational grazing (Bruce 1998; Reseigh 2004).

Very little research has examined the significance of native perennial pasture as habitat for native vertebrate fauna (for discussion see Dorrough *et al.* 2004; McIntyre 2005). There is a even a paucity of data that simply describes the composition of fauna in native pastures, since most research has been conducted within remnants or planted sites within the production matrix, rather than within pastures themselves.

In seeking to understand the difference between grazing regimes in terms of habitat quality for fauna in native pastures and woodlands, it is necessary to focus on the ground layer, and in particular sward structure. Even if sward structure is not the most important factor explaining variation in the plant community, it may still be critical to the persistence of some species of woodland birds and reptiles in rural landscapes. Ground dwelling fauna in particular are likely to respond to changes in the heterogeneity of the pasture habitat structure (eg. Baker-Gabb, Benshemesh & Maher 1990; Brown 2001; Brown, Bennett & Potts 2008).

While we have some concept of how the structure of the grassy layer is affected by livestock grazing of different intensities we do not know whether there are consistent differences between continuous stocking (i.e. continuous grazing) and rotational grazing (the extreme form being cell grazing) in terms of sward structure. Practitioners of cell grazing observe less bare ground and more perennial grass (McCosker 2000; Sparke 2000) relative to continuous stocking, and this has also been observed in tactically grazed pastures (Michalk *et al.* 2003; Teague, Dowhower & Waggoner 2004). However, others note the importance of the timing of rest periods. Different perennial grasses respond in different ways (Earl & Jones 1996; Kemp, Dowling & Michalk 1996) and there may be grazing/environment interactions (Bruce 1998; Reseigh 2004). It is not always easy to detect changes in plant composition, as rainfall can be a dominating factor driving basal area of perennial grasses (Hart *et al.* 1988; Teague, Dowhower & Waggoner 2004) and previous fertilization practices can reduce the pool of potentially responsive species in grazing trial sites (Kemp et al. 2003).

The distribution of native fauna and flora within native pastures may also be influenced by other local and landscape features associated with the level of agricultural intensification. While not the only determinants, fertilizer application and tree cover can be important for both plant composition and presumably also affects the use of pastures by fauna. At larger scales the extent and pattern of native vegetation in the surrounding landscape has been demonstrated to influence the abundance and occupancy by fauna which are able to move through the landscape relatively easily, such as birds (Radford, Bennett & Cheers 2005). Responses by plants to landscape pattern are not well described in Australia, although research overseas has demonstrated that some plant species do respond to landscape-scale heterogeneity (Roschewitz, Gabriel & Tscharntke 2005).

This project endeavours to examine patterns of bird, reptile and plant diversity in native pastures. We will explore how these patterns vary according to paddock management and local and broader scale habitat availability.

2 Project Objectives

"Understanding the interactions between biodiversity and the management of native pastures in the Murray Darling Basin" (ER.101) is being undertaken by the Arthur Rylah Institute for Environmental Research (Victorian Department of Sustainability and Environment) and CSIRO Sustainable Ecosystems. The project aims to better inform the management of native biodiversity in livestock grazed uplands of the Murray Darling Basin by:

1. Developing predictive models of the influence of strategic grazing on plants, birds, and reptiles, relative to other site and system features such as rainfall, slope, soil fertility, tree cover, proximity to nature reserves and large remnants and livestock profitability.
2. Providing empirical evidence of the influence of grazing management on plant, bird and reptile species diversity relative to other site and systems features such as rainfall, slope, tree cover, livestock profitability, proximity to nature reserves and large remnants.
3. Combining the empirical evidence and the modelling outcomes into evidence-based management guidelines for the combined benefits of livestock production, water use and biodiversity conservation.
4. Testing the management guidelines with stakeholders in NSW and Victoria, including landholders, CMA staff, and state agency research & extension staff.
5. Communicating the evidence-based guidelines for better management of biodiversity in native pastures in the MDB.

The key question underpinning this project is: "What is the impact on biodiversity of a range of native pasture livestock grazing scenarios relative to the impacts from other paddock, farm and regional influences?" The project will test the following hypotheses:

(1) Plant diversity in pastures is more strongly influenced by paddock management (e.g. grazing strategy, cultivation, fertilization, and tree cover) than landscape scale factors (e.g. native vegetation cover, rainfall);
(2) Bird diversity in pastures is more strongly influenced by landscape factors than by paddock management;
(3) Reptile diversity in pastures is influenced both by landscape and local paddock management;
(4) Biodiversity in native pastures is correlated with livestock production and profitability.

A key focus of the project is to contrast two broad grazing strategies (continuous stocking and rotational grazing), that can be defined based on the duration and frequency of grazing and rest periods. Traditional grazing management in south-eastern Australia has been described as continuous stocking. This management regime typically involves large paddocks with fixed stock numbers and little rest from grazing. Over the last 10 years, in response to research and development activities (e.g. Sustainable Grazing Systems) and training by independent organisations (e.g. Holistic Management, Resource Consulting Services), there has been a shift towards managers incorporating frequent rests into their grazing management regimes. These changes in management are considered to benefit perennial grass cover and pasture diversity.

3 Methodology

3.1 Introduction

This research project involved collection of new empirical data from field sites as well as analysis of prior datasets and exploration of hypotheses through expert workshop and producer interview. This section summarises the key methodology that underpinned hypothesis refinement and data collection.

3.2 Analysis of prior data

Existing data were analysed in order to identify the role of local and landscape tree cover and two key management factors (stocking rate and soil available phosphorus) in determining the composition of native and exotic plant species in pastures. The original dataset was collected from 17 farms in central Victorian uplands and inland slopes. The collection of the original data was funded by Land &Water Australia and Land Water & Wool and was collected by researchers with Department of Sustainability and Environment in Victoria. Further reference to this dataset is made in several publications (eg. Moll, Dorrough & Crosthwaite 2005; Crosthwaite *et al.* 2006; Dorrough *et al.* 2006; Dorrough, Moll & Crosthwaite 2007; Crosthwaite *et al.* 2008).

The methods for collection of data are mostly described in Dorrough *et al.* (2006). Additional variables, native tree cover within a 50 metre, 400 metre and 1000 metre radius from the centre of each quadrat, were obtained specifically for these analyses.

Tree cover at each scale was estimated from a binary tree cover layer derived from 10m x 10m SPOT imagery (Tree25 data-set) held by the Victorian Department of Sustainability and Environment.

3.2.1 Data analysis

Native Vegetation Cover at Multiple Scales

Generalised linear models were used to explore the response of total native and exotic plant richness and the cover of native perennial ground layer vegetation and exotic annual vegetation in plots. Models based on published analyses in Dorrough et al (2006) were initially constructed containing the variables livestock grazing frequency, soil phosphorus (Colwell, mg/kg) and cultivation. Additional models incorporating explanatory variables relating to vegetation cover at broader spatial scales were also explored.

Individual Plant responses to Grazing and Phosphorus

A novel analysis was applied to explore how individual plants responded along gradients of phosphorus and grazing intensity. In this case we wished not only to examine how individual plants responded but also wished to develop inference about whether plants sharing broad functional characters differed in their traits. If this was the case then we wanted to develop a technique that allowed us to infer the response of less frequent plants with known traits.

We directly modelled the occurrence of individual species using a Bayesian hierarchical generalised linear model with binomial distribution. Parameter estimates for random effects and fixed effects are derived using Monte-Carlo Markov chain. Individual species were modelled as random effects and their life-history traits as fixed effects (explanatory variables). Life-history traits used were plant origin (native, exotic), longevity (short-lived annual/biennial, perennial) and growth form (herbaceous dicot, woody dicot, fern, non-geophyte monocots [primarily poaceae, cyperaceae, juncaceae but also some liliacae and iridaceae with persistent above ground vegetation], geophyte monocots [mainly liliaceae, iridaceae and orchidaceae]). Response coefficients were obtained for the overall grazing and phosphorus effects and the grazing and phosphorus effects for each of the life-history traits. Phosphorus and grazing response coefficients were also obtained for the individual plants.

3.3 Fauna ground layer habitat workshop

This workshop was designed to address elements of the first two objectives of the project:

1. Developing predictive models of the influence of strategic grazing on plants, birds, and reptiles, relative to other site and systems features such as rainfall, slope, soil fertility, tree cover, proximity to nature reserves and large remnants and livestock profitability.
2. Providing empirical evidence of the influence of grazing management on plant, bird and reptile species diversity relative to other site and systems features such as rainfall, slope, tree cover, livestock profitability, proximity to nature reserves and large remnants.

More specifically, we aimed to develop predictions of fauna response to grazing through consultation with experts and to use these as the context for the design of field data collection. There is currently abundant scientific evidence to demonstrate that woodland birds in the study area respond to structural elements of the landscape such as tree cover at the site, tree cover in the wider landscape (Martin *et al.* 2006), trees of different ages (Gibbons & Lindenmayer 2002), and the presence of shrubs and fallen timber (Seddon, Briggs & Doyle 2003). However, there have been very few observations in Australia of the effect of grazing that has not been confounded with the effects of tree presence. One exception is a study that looked at the effects of three levels of grazing on woodland birds in sub-tropical native pasture (Martin & McIntyre 2007). The most common response to grazing was an intolerance of heavy grazing and a varied response to moderate grazing and high relative abundance under low grazing. Any level of commercial livestock grazing was detrimental to some woodland birds. However, provided trees are not cleared, a rich and abundant bird fauna can coexist with moderate levels of grazing. These observations were for continuously stocked cattle-grazed pastures.

3.3.1 Workshop methodology

Participants

Participants were people directly involved in the project *viz.*
Geoff Barrett (CSIRO Sustainable Ecosystems)
Geoff Brown (Arthur Rylah Institute)
Josh Dorrough (Arthur Rylah Institute)
Alex Drew (CSIRO Sustainable Ecosystems)
David Freudenberger (CSIRO Sustainable Ecosystems)

Sue McIntyre (CSIRO Sustainable Ecosystems)
Jacqui Stol (CSIRO Sustainable Ecosystems)

Other fauna experts who could make a valuable contribution also attended *viz.*
Mark Dunford (Environment ACT)
Joern Fischer (Australian National University)
Philip Gibbons (NSW Dept. Environment and Conservation)
Adrian Manning (Australian National University)
Julian Reid (Australian National University)

An additional four people were invited (David Lindenmayer, Julian Seddon, Vivienne Turner, Richard Loyn) but were not able to participate. The latter two people provided comments and other workshop inputs. It was intended to keep numbers small to enable more focussed and in-depth discussions to take place. The workshop program is presented as Appendix 1.

Setting the scene
As many of the faunal experts had not formally considered the effects of grazing on grassland in their work to date, we asked them to contribute up to five photographs that illustrated observations or ideas about the possible role of the grassland layer as habitat. These were used as an icebreaker, and while some participants arrived with a tree bias, others offered insightful observations about the grass layer which set a foundation for later discussion.

To establish some shared concepts and terminology, a short presentation was made describing the botanical understanding of the effects of grazing on the structure of the ground layer. Together with grazing, disturbance and nutrient enrichment are the three major management influences on sward structure and composition. In the rural landscapes of the study area, the three factors can be broadly represented as different land uses (Fig. 1), of which two, states 2 and 3, are the focus of this study.

In terms of grazing as a single factor, the effects of increasing grazing pressure on native-dominated grasslands were identified as:

- Reduced tussock height;
- Replacement of large tussock species with smaller species;
- Reduced amount of plant litter and increasing bare ground;
- Increased patchiness at intermediate levels of grazing (Fig 2)

As well as sward structure and the effects of patchy grazing, other ground layer elements, and their responses to grazing, were discussed (cryptogam crusts, forbs, sub-shrubs).

The presentation was followed by a short field trip to a grazed grassland. Here different sward structural elements were viewed first hand. The determinants of the structural elements, their potential to provide habitat for different fauna and issues such as scale of the elements in relation to faunal foraging were discussed.

Hypothesis development

There were two sessions for the development of hypotheses. In the first, individuals or groups (self-selected) wrote down their ideas or themes and pooled them, taking the initiative where desired to classify and summarize similar ideas. In the second session, participants were asked to distil and further develop these contributions into conceptual themes or hypotheses, again working in self-selected groups. These outputs were subsequently synthesized and refined.

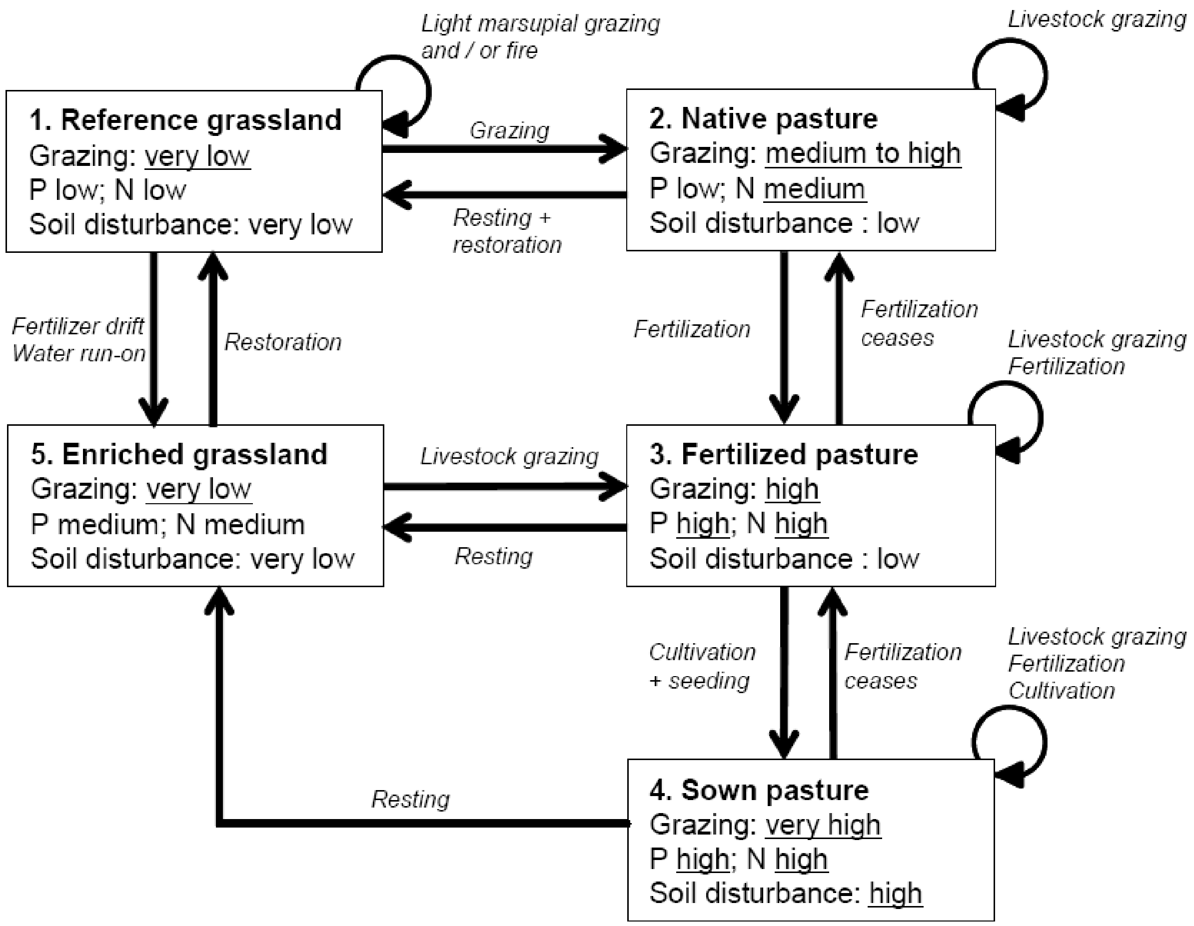

Figure 1 How grazing, nutrient enrichment and cultivation combine to form major land uses in temperate grassy ecosystems. This State and Transition framework was used to describe the cultural context of the study landscapes. The work of this project is focussing on the effects of rotational and continuous grazing on States 2 and 3. (From McIntyre & Lavorel, 2007)

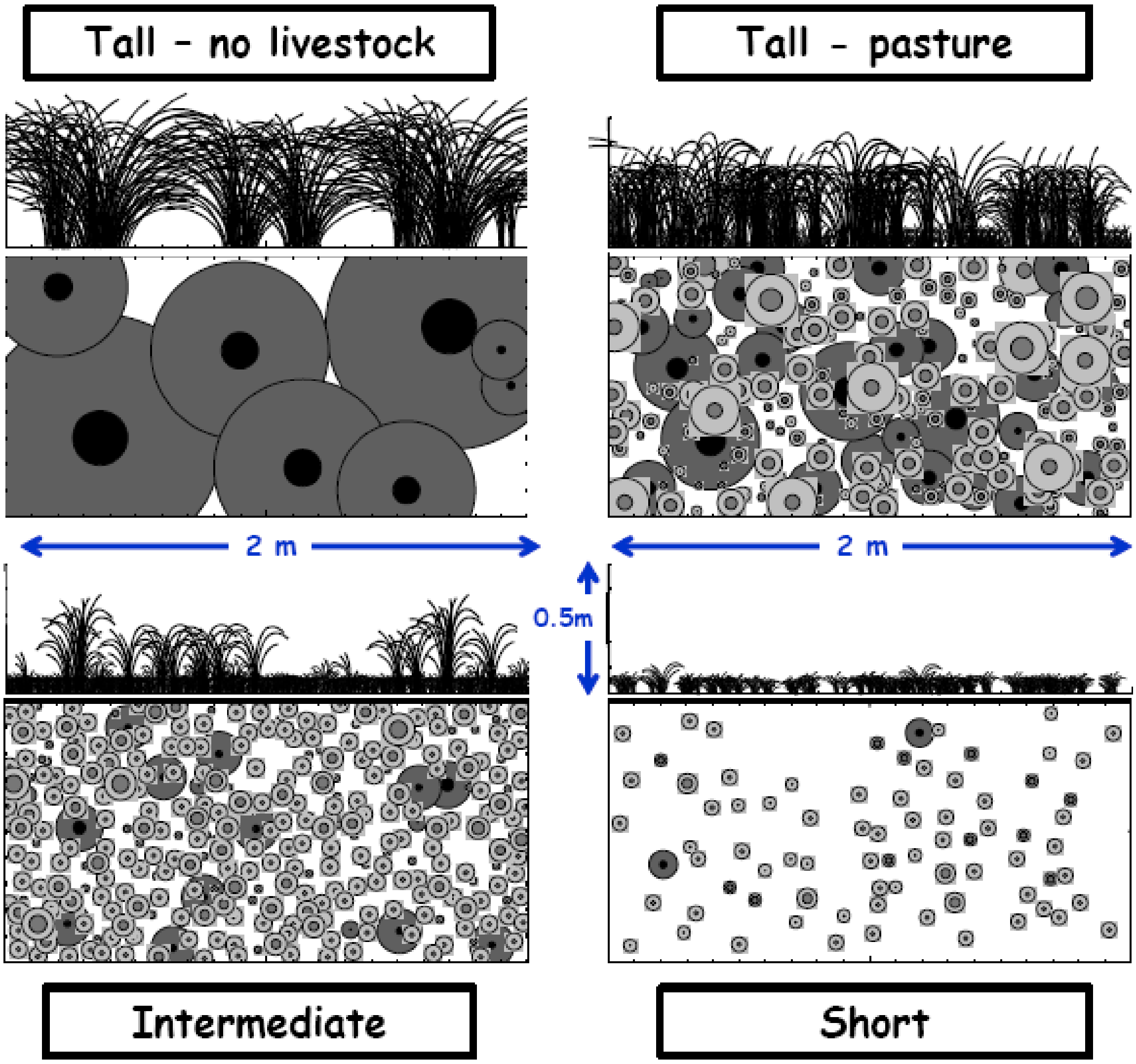

Figure 2 The effect of continuous stocking with cattle on the structure of the grassy sward, showing increasing levels of utilization. Each of the four levels of grazing shows the profile of a 2 metre strip of grassland and a bird's-eye view of a 1 x 2 metre area of grassland, in the latter case, indicating the size and density of tussock grasses. Forbs and litter are not shown. There is greatest small-scale patchiness at intermediate levels of utilization where grazing pressure is strong, but still selective. Tall, intermediate and short patches can all be found in varying proportions in continuously stocked paddocks owing to the patch-grazing behaviour of livestock, in which short-grazed patches tend to be more frequently re-grazed (from McIntyre & Tongway 2005).

3.4 Field data collection, analysis and interpretation

A key component of this research was the collection of new research data from grazed native pastures on the south west slopes and inland slopes of Victoria.

3.4.1 Site Selection

Our study focussed on pastures that had not been sown to perennial legumes or grasses, nor cultivated or cropped in the last 30 years. The second criterion was to find properties that had been practising rotational grazing for at least 10 years. We judged that 10 years is likely to be the minimum time required for some ecological variables to respond to changing grazing management. Our definition of *rotational grazing* required a system of four or more paddocks on which alternating periods of grazing and rest were imposed. Each paddock is grazed for relatively short durations (less than 56 days) and followed by a rest of at least 21 days, though generally the rest periods must exceed the grazing periods (Fig 3). Once a rotational system was identified we searched for a neighbouring farm in which continuous stocking was practised. *Continuous stocking* was defined as having no regular pattern of grazing and rest, with livestock being allowed unrestricted access to paddocks on a more sustained basis. The grazing period was typically greater than 3 months with rest periods usually less than 3 months and, over a year, paddocks can be stocked for more than 6 months.

Potential rotationally grazed properties were classed according to fertilization history and landscape tree cover to ensure a good range of these co-variates across the study area.

Identifying suitable rotationally grazed properties was found to be the limiting factor in site selection. In particular we found that very few properties had been operating for 10 or more years and we were forced to revise our lower limit down to five years. Below we outline the process we applied to identify suitable properties.

Figure 3 High densities of stock in a "paddock scale" rotation of approximately 2-4 days graze and 90-150 days rest. In this system there are two mobs with a mob of sheep following behind the cattle with each mob grazing for approximately 1-2 days. This combination of grazing animals was believed to provide better pasture utilisation.

Initial contact lists were prepared that covered a broad range of stakeholders, these were then used to obtain second and third order contacts (more if required), at each point narrowing the search towards actual property holders. The initial search window included producer group facilitators (Best Wool, Best Lamb, Beef Check), agronomists, pasture researchers (including Jim Virgona and Meredith Mitchell) and government production extension officers in Victoria, a small number of graziers that were known to be undertaking rotational grazing (including individuals outside of the study area) and national producers groups (Resource Consulting Services, Holistic Management, Stipa, Grasslands Society of Southern Australia). This initial consultation with these primary contacts had several purposes; (1) obtain general information on the dominant grazing and production systems in the study region (2) ascertain the relative frequency and role of rotational grazing systems, (3) assist in better defining rotational grazing, (4) get feedback on project objectives (detailed further in stakeholder report) and (5) obtain secondary contacts. These secondary contacts (typically 2-3 per primary contact) could either be producers or further extension officers and facilitators. The primary contacts were also asked to distribute project summary information which included requests for possible sites using their mail or email networks.

In addition to following up secondary contacts obtained directly from the primary contacts, further communication was undertaken through CMA's, Grassy Box Woodland Conservation Management Network, Beef Improvement Society, Fine wool groups and Landcare networks throughout the region.

Secondary contacts provided some project feedback but were primarily contacted for the purposes of possible site identification. Secondary contacts were asked for further possible contacts, names of producers and asked to place project information on any networks they were involved with.

Semi-structured interviews were conducted by phone with potential rotational grazing property managers. The information gathered during this process assisted in prioritising those most suitable for on-farm inspections. Essential information collected at this stage included the number of years that producers had been rotationally grazing, a broad description of management style and aims (e.g. four paddock rotation, tactical grazing, cell grazing, holistic management, summer deferred grazing) and the approximate timing of grazing and rest. Information on the average paddock size, mob size and fertilizer history gave some indication of the level of intensification, a variable in the experimental design.

Farms with multiple native pasture paddocks that had been rotating stock on a relatively strict basis for more than 5 years were visited throughout April 2006. During the visit further details on the management system were obtained via semi-structured interviews. Potential paddocks were identified and photographed, their location recorded using a GPS and contact details for two or more potential neighbouring farms were obtained.

For paired farms to be included in the sample, they had to have both cleared areas and areas with woodland subjected to the appropriate rotational and continuous grazing regimes. We were also looking for sites covering a range of fertility levels, inferred from fertilizer history. Twelve pairs of farms were selected as suitable for sampling (Table 1). On average, the twelve rotationally grazed farms had been using rotational grazing management for 7 years (standard deviation 1.6 years). The twelve paired farms covered a spatial range of approximately 450km running along the inland slopes of the Great Dividing Range in south-eastern Australia (Fig. 4).

Within each *farm* two 1 ha *plots* were identified that either still retained some woodland tree cover (*tree*) or had been completely cleared of tree cover (*open*). Treed plots had a minimum of 4 mature trees with diameter at breast height >60cm. Across all the tree plots there was an average of 9.1 trees ha^{-1} (± 6.82 standard deviation). Plots were often within the same paddock but their edges were always separated by a minimum of 200m. In summary, we sampled a total of 48 x 1 ha plots (24 open, 24 treed) across 24 farms (12 rotationally, 12 continuously grazed), a fully factorial design.

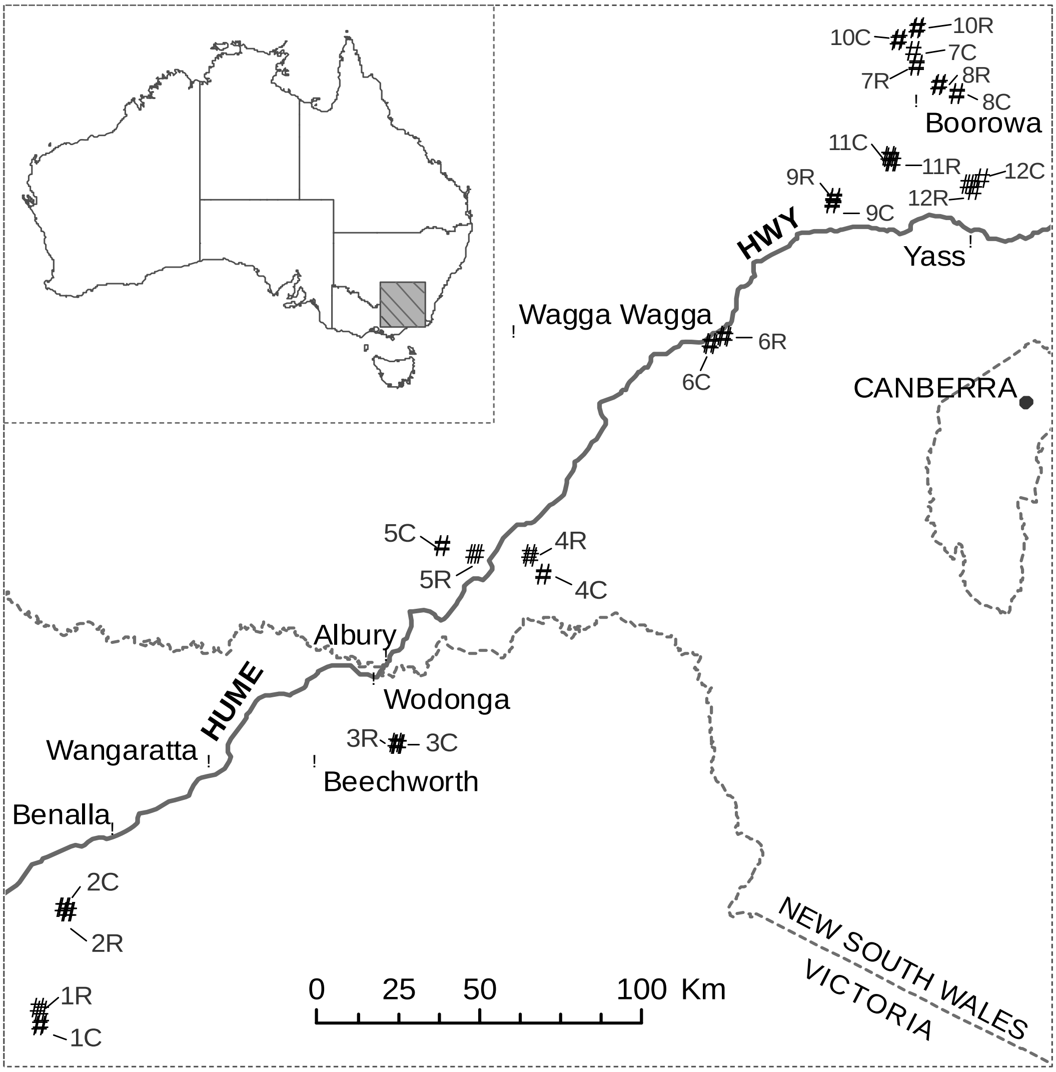

Figure 4. Location of the 24 properties in southern NSW and NE Victoria. Numbers indicate pair and letter indicates whether the property is managed using continuous (C) or rotational grazing (R).

Table 1 Summary of the management for each of the 24 properties

Pair ID	Regime	Location	Property Size (ha)	Paddock size (ha)	Years current manag.	Livestock	Min Graz. (days)	Max Graz. (days)	Min Rest (days)	Max Rest (days)	Nº grazing cycles/year	Av. dse/ha	Fertilizer	Herbicide	Enterprise
1	Continuous	Alexandra, Vic	530	160	30+	sheep, cattle	365	365	0	0	1	8	high	yes	beef / lambs / wool
1	Rotational	Alexandra, Vic	273	10	7	sheep	3	7	90	90	3.8	3	low	no	wool / meat
2	Continuous	Strathbogie, Vic	119	10-15)	10+	cattle	350	365	7	14	1	5	high	none	breeding / beef
2	Rotational	Strathbogie, Vic	682	50+	8	sheep	4	14	21	63	5.1	4	low-mod	no	wool / meat
3	Continuous	Yack., Vic	110	110	60+	cattle	365	365	0	0	1	3	low	yes	beef
3	Rotational	Yack., Vic	235	97	7	cattle	2	5	60	70	5.0	3.4	low	no	beef
4	Continuous	Holbrook, NSW	800	40-100	20+	cattle	300	365	0	60	1	8	high	frequent	breeding
4	Rotational	Holbrook, NSW	2600	30	7	cattle	2	3	120	165	2.2	3	low-mod	no	beef
5	Continuous	Holbrook, NSW	1000	485	10+	cattle	300	365	0	60	1	2	low	none	breeding
5	Rotational	Holbrook, NSW	1400 ha	50+	9	sheep, cattle	14	42	28	160	2.5	6	mod-high	no	breeding / lamb
6	Continuous	Gundagai, NSW	1740h	100	30+	cattle	300	365	0	60	1	9	high	frequent	agistment
6	Rotational	Gundagai, NSW	1682	20	6	sheep, cattle	2	4	90	120	3.0	5	low	no	beef / breeding / wool
7	Continuous	Boorowa, NSW	2400	380	20+	sheep	270	365	0	90	1	4	mod - high	occasionally	lamb / wool/ beef / breeding
7	Rotational	Boorowa, NSW	1500	variable	6	sheep, cattle	2	4	90	150	2.4	3	low	no	agistment
8	Continuous	Boorowa, NSW	2000	140	30+	sheep	365	365	0	0	1	3	low	no	wool
8	Rotational	Boorowa, NSW	414	6	7	sheep	1	2	80	100	3.6	12	mod	no	wool / meat
9	Continuous	Jugiong, NSW	490	10-130	10+	sheep	180	180	30	180	2	3-8	low	no	lambs / wool
9	Rotational	Jugiong, NSW	600	17	11	sheep	3	42	60	120	3.5	5	mod	no?	wool / meat
10	Continuous	Boorowa, NSW	7000	200	100+	sheep, cattle	365	365	0	0	1	4	mod	no	wool / lambs
10	Rotational	Boorowa, NSW	1409	120-240	8	sheep	4	56	56	56	5.0	7	mod	no?	wool / meat
11	Continuous	Binalong, NSW	507	80-145	40+	sheep, cattle	365	365	0	0	1	3	low	no	wool/ lambs / beef
11	Rotational	Binalong, NSW	500	20-40	6	sheep	7	56	35	45	4.8	6	high	no?	wool / meat
12	Continuous	Yass, NSW	1450	100	100+	sheep, cattle	shifting to RG	shifting to RG	shifting to RG	shifting to RG	shifting to RG	4	low	no	beef /breeding / wool
12	Rotational	Yass, NSW	1100	20+	5	sheep	2	21	160	160	2.1	6	high	no	wool

3.4.2 Data collection

Reptiles

At every 1 ha plot a standardised array of 30 Onduline tiles was deployed. Each array comprised six equally-spaced rows of five tiles. Onduline is a corrugated light-weight roofing material that is made from recycled organic fibres (plastic, paper) and saturated with bitumen under intense pressure and heat (http://www.onduline.co.nz/index.html).

Each plot was visited three times during the study: December 2006, March 2007, October 2007. During each visit to a site, all tiles were inspected for sheltering reptiles; in addition, an active search was undertaken across the study plot. The time taken to carry out each search varied according to the structural complexity of the site (amount of timber, rocks and logs), though this typically amounted to 45 minutes. Searches were only undertaken in dry weather and above a threshold ambient temperature of 17^{o}C so as to record active individuals in addition to sheltering or cryptic reptiles.
One observer searched the sites during the initial visit; two observers searched each site during subsequent visits. Each pair of sites was surveyed on the same day, so that surveys were conducted under similar weather conditions. Because of the geographical spread of the study sites, it was not possible to randomise site visitation, except on a daily basis in locations where sites were clustered.

Birds

Birds were surveyed while walking an 800 m transect divided into four 200 m sections 50 m apart and covering a 4 ha area within which was nested the 1 ha plot. Surveys were undertaken over a 20 minute period. Only birds observed making contact with the 1 ha area were included in analyses presented here. All four plots within a paired set of farms were surveyed four times (twice by two separate observers) over a single day in spring 2006. For each observation the sighting distance and sighting angle were recorded and were used to calculate detection functions for treed and open plots (Buckland *et al.* 1993). Detection functions were derived using a hazard-rate key function with cosine series expansion using the DISTANCE software package. Although the mean sighting distance for birds in open plots (57.7 ± 5.1 se) was higher than in tree plots (38.9m ± 1.3 se), no significant difference was observed between the probability distributions of the detection functions for plots with or without trees (chi-square = 0.73, df = 2, p = 0.695).

Bird surveys

A line transect procedure was used, with birds being surveyed for 20 minutes along an 800m transect, located within each of the 48 plots. A survey consisted of four visits to each transect on a single day, between September and December 2006. Each transect was divided into four parallel 200m sections, each 50 metres apart and covering a 4ha area. Each 200m section was traversed over a 5 minute period and sightings were only included if the bird made contact with a 1ha area located at the centre of the 4ha survey area (Fig. 5). Birds were recorded as being either on the ground (includes long grass, low shrubs, woody debris and fences), in shrubs (0.5 to 2 metres) or in trees (>2 metres). Surveys were carried out by two professional observers, alternating between plots with and without trees, and plots in continual and rotational grazing plots. Surveys were also evenly spread between the morning and afternoon sessions. The number of bird species was tallied across the four visits while the number of individuals was averaged across the four visits.

For calculating the proportion of bird groups recorded on the different habitat strata during the transect surveys, the number of individuals per survey was averaged for each plot

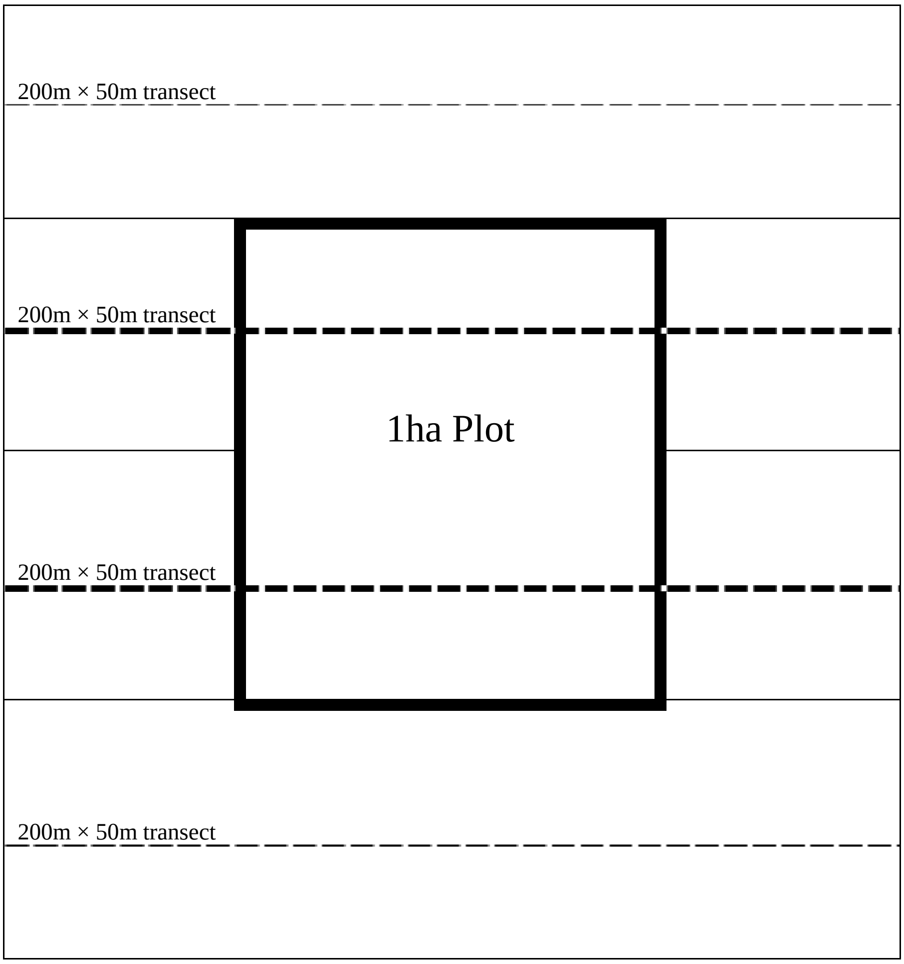

Figure 5: Birds were surveyed for 20 minutes along an 800m transect, divided into four parallel 200m transects (5 minutes per 200m section), and covering a four hectare area. Birds were only included in the analysis if they made contact with the central 1ha plot.

Ground-foraging

Ground-foraging surveys consisted of four 20-minute observation periods within each 1ha plot (Figure 2) on a single day, between September and December 2006. Two observers were alternated, as for the transect surveys. The number of species seen foraging and the number of foraging observations were tallied across the four visits. Foraging activity was recorded while observing the 1ha area for 20 minutes. When a bird was seen on the ground, the number of apparently successful foraging attempts over time was recorded. Foraging observations were tallied for the following strata; long grass (< 10cm tall), short grass (< 10 cm tall), tussock grass, leaf litter, bare ground, woody debris and hawking from the ground (including launches from dead branches and low shrubs < 0.5m). If the bird disappeared for a short period (less than 5 secs), the period the bird was out of view was deducted from the total observation time.

If the bird disappeared for more than 5 seconds the observation was terminated. The total observation time may be as little as 10 seconds but was a maximum of 5 minutes.
Where possible, different individuals were observed, however, where repeat observations were made on the same individual, these were separated by at least two minutes. If there were more than one individual present, a single individual was watched for at least 2 min, then another chosen.

Vegetation

Species richness was compiled from (a) close assessment of 30 x 0.5m^2 quadrats located in a grid pattern across each 1 ha plot; and (b) a 20 minute search, undertaken across the entire plot by a single botanist. All plant species encountered were recorded if their taxonomic identity was certain. Other plants were collected for later identification. One grass genus, *Austrodanthonia*, can be locally diverse and is difficult to identify without microscopic examination. For this genus, a minimum of ten widely-spaced inflorescences were collected within each plot for later identification. Collected plant species were identified using the Flora of NSW (Harden 1990) or the Flora of Victoria (Walsh & Entwistle 1994-1997).

Vegetation surveys were undertaken between October 31st and November 28th 2006. Differences in soil moisture among sites owing to the large spatial survey gradient and worsening drought conditions could be important in influencing vegetation composition. To examine the effects of variation in local soil moisture we estimated total rainfall and potential evapotranspiration (ETo, using the FAO Penman-Monteith equation) and calculated a ratio of rainfall to ETo at each site from April 1st, 2006 to the date the site was sampled. Sampling date and latitude were both positively correlated with ETo and the ratio of rainfall to ETo. Rainfall and evapotranspiration data were accessed from the SILO Data Drill (HUhttp://www.nrw.qld.gov.au/silo/datadrill/index.htmlUH) which stores grids of data interpolated from point observations held by the Australian Bureau of Meteorology. The interpolated surfaces are computed on a daily timestep and on a regular 0.05 degree grid. Full details of the interpolation methods can be viewed on the SILO website.

Detailed information on pasture structure was collected using a modified Ellinbank Rising Plate Meter (weight of 250 g) which estimates pasture stature. Because this compresses vegetation to a certain degree it is nearer to an estimate of the height of the bulk of the vegetation rather than maximum height. At each site 120 stature estimates were made (4 estimates spaced 1m from corners of each the 30 reptile tiles).

Other habitat attributes were visually estimated at both 1 ha and 4 ha scales and included percentage tree canopy cover, number of paddock trees >60cm dbh, % cover of woody debris, presence or absence or short or medium shrubs and % cover of shrubs.

Landscape native vegetation cover

The percentage cover of woody vegetation was used as a surrogate of both native vegetation cover and the level of agricultural intensification in the landscape surrounding each sampling site. For this study woody vegetation cover was estimated at three spatial scales with a radius of 500, 1260, or 5640 meters (Fig. 6).

Three sets of remotely sensed data were acquired to enable estimation of tree over across the entire study region. High spatial resolution (2.5 meters) low spectral resolution (1-band) SPOT5 panchromatic data, 10 meter 4 band SPOT5 multi-spectral data (Table X), and the Victorian Department of Sustainability and Environment Tree Cover Grid (TREE25) data

(HUhttp://www.giconnections.vic.gov.au/content/vicgdd/record/ANZVI0803002395.htmUH Last Accessed 18 September 2007), modelled from digital SPOT Panchromatic Imagery (10m pixels).

The TREE25 grid was used for estimates of woody vegetation cover for each of the three Victorian sampling locations (locations 1, 2, 3).

The SPOT5 panchromatic and multi-spectral satellite imagery was used to perform an unsupervised classification in combination with a class clumping procedure to delineate woody vegetation using the isodata algorithm. Both the pan and multi-spectral classification resulted in the generation of 10 pixel classes; using a visual comparison against the original SPOT5 data the 10 classes were aggregated to delineate woody vegetation.

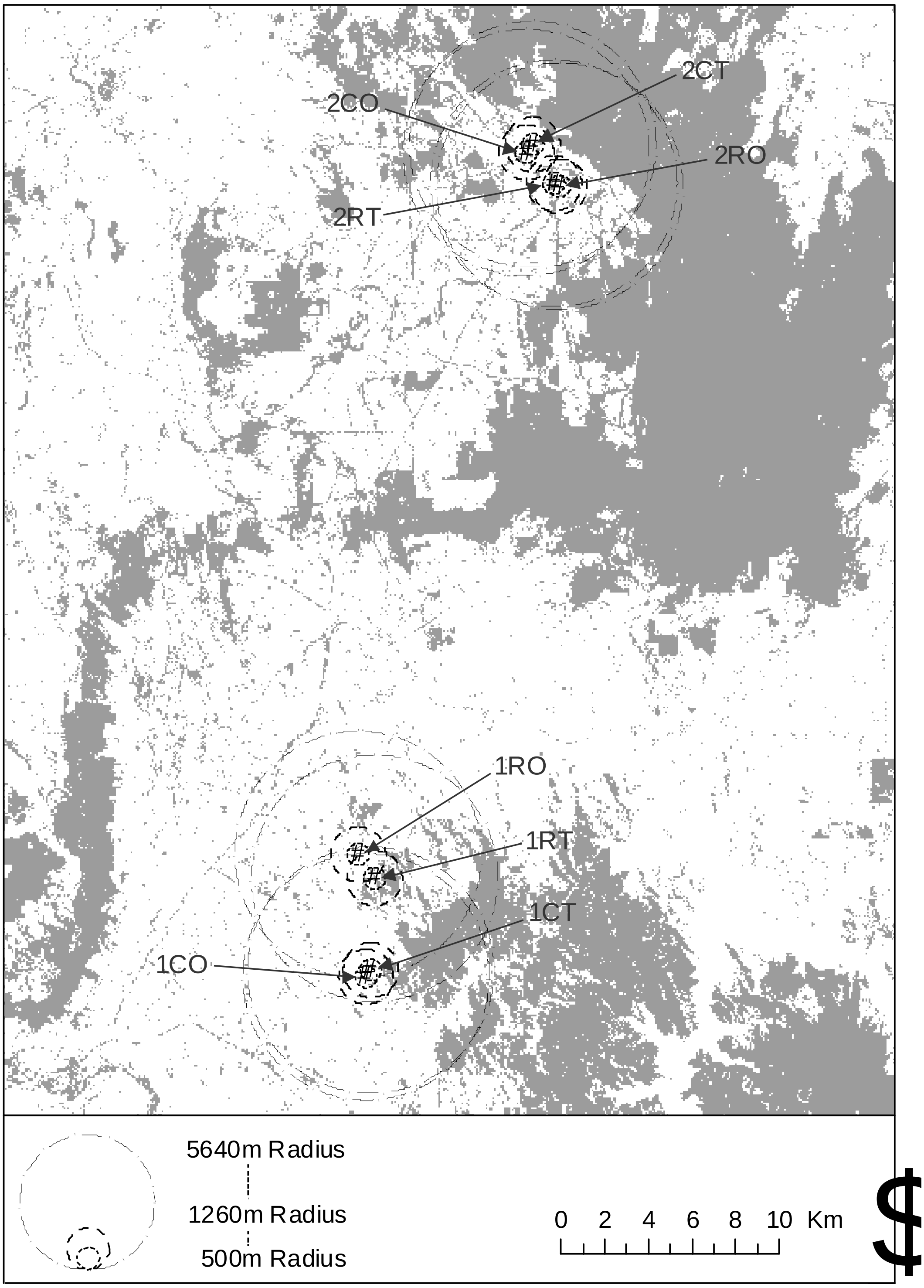

Figure 6 A binary representation of native tree cover and examples of the three spatial scales used to estimate landscape native tree cover. The image is for a small section of the study region within central Victoria and shows the location of eight plots across four farms.

Soils
Thirty soil cores (0-10 cm) were sampled on a 5 x 6 grid, adjacent to the reptile sampling tiles, within each 1 ha plot. These were pooled for each plot and subsequently analysed for available and total phosphorus, total carbon and nitrogen, available nitrates and organic matter content. Analyses were undertaken by the Victorian Department of Primary Industries, State Chemistry Laboratory.

Stocking rate
Stocking rates as dry sheep equivalents (DSE, a standard measure of livestock densities based on feed intakes of different classes of livestock) per hectare were estimated for each paddock based on discussion with landholders. These represented the average stocking rate prior to severe drought conditions in 2006. Stocking rate is often confounded with high fertility and farmers match stocking to productivity. However, a graph of this suggests that this is not a major issue (Fig. 7).

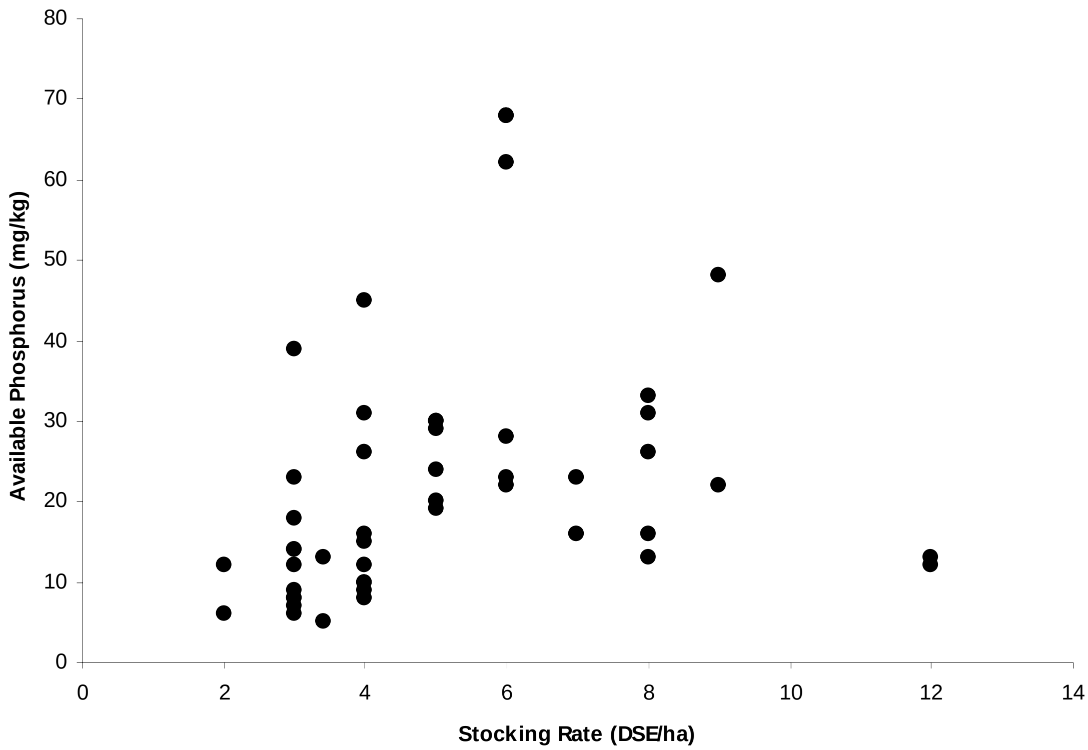

Figure 7 Relationship between stocking rate and available phosphorus. Data from 48 one hectare plots across 24 farms.

3.5 Pasture Management and Paddock Gross Margins

Current (2005-2007) and recent (1994-1998) farm and paddock level production system information for the 24 properties was obtained via semi-structured face to face or phone interview. Information collected included: (i) current and recent livestock types (steers, breeders, cross-bred, merinos), purpose (breeding, wool, meat), and densities/numbers; (ii) areas cropped or sown; (iii) fertilizer rates and type; (iv) property and paddock sizes; (v) other property improvements such as recent establishment of water points and subdivision of paddocks.

The interviews also attempted to elicit information on proposed or desired changes in production systems over next 10 years. This was of a general, not specific, nature (ie. changes in enterprise mix, increases/decreases in cropped area, major changes in grazing management, including more subdivision, shift in livestock types).

Information was also collected on estimated annual costs for pasture and livestock inputs and costs (e.g. fertilizer and herbicide inputs, feeding costs, livestock health) and current paddock level gross margins. The work was undertaken by Jim Moll (Goulburn Broken CMA, Victoria).

4 Results and Discussion

4.1 Management of native pastures

4.1.1 Grazing management

There is a diversity of grazing management strategies currently applied to native pastures. For this project we concentrated on contrasting continuous grazing (which also included some set stocking and ad-hoc deferment) with rotational grazing systems.

Excluding ad-hoc systems, most rotational grazing systems that met our definition had been operating for less than 10 years. Most of the training programs for planned or cell grazing began on the SW slopes and inland slopes of Victoria post-1998. All the rotational grazing systems in this project had been implemented for a minimum of 5 years, but we noted that a much larger number of properties (not included in this research project) have been using rotational grazing for 1-2 years. Anecdotally, based on the high levels of attendance at field days and strong interest shown in Catchment Management Authority grazing management programs, the uptake of rotational systems is continuing to grow. Among the 12 continuously grazed properties involved in this research one has begun rotational grazing while another intends to switch to a rotational system.

Variation in rotational grazing systems on native pastures was considerable (Table 1 and Fig 8). The number of grazing cycles ranged from an average of 2 up to 5 per year. Rest times varied within and among properties from a minimum of four weeks up to 22 weeks. Rest times were often most influenced by the number of paddocks and property size. Grazing times also varied considerably among and within properties. Some properties with sheep breeding enterprises had the most variation in grazing periods owing to slower rotations or set-stocking during lambing. However, it is worth noting that a number of producers did not slow down rotations during lambing.

A number of producers using continuous grazing also applied rest, typically seasonally, as part of their management of native pastures. These rests were typically over warm seasons and of the order of 60 to 90 days although one property regularly rested their native pastures for a full six months. These seasonal rests were not employed every year.

Owing to the variation in grazing systems, when analysing response variables (relating to fauna and flora diversity) we used the factor ‘Grazing Management’ with two levels (rotational or continuous) as well as several continuous variables to describe the variation in rest and grazing periods. One such variable was the ratio of the maximum rest days to the minimum number of grazing days within a grazing cycle (Fig 8).

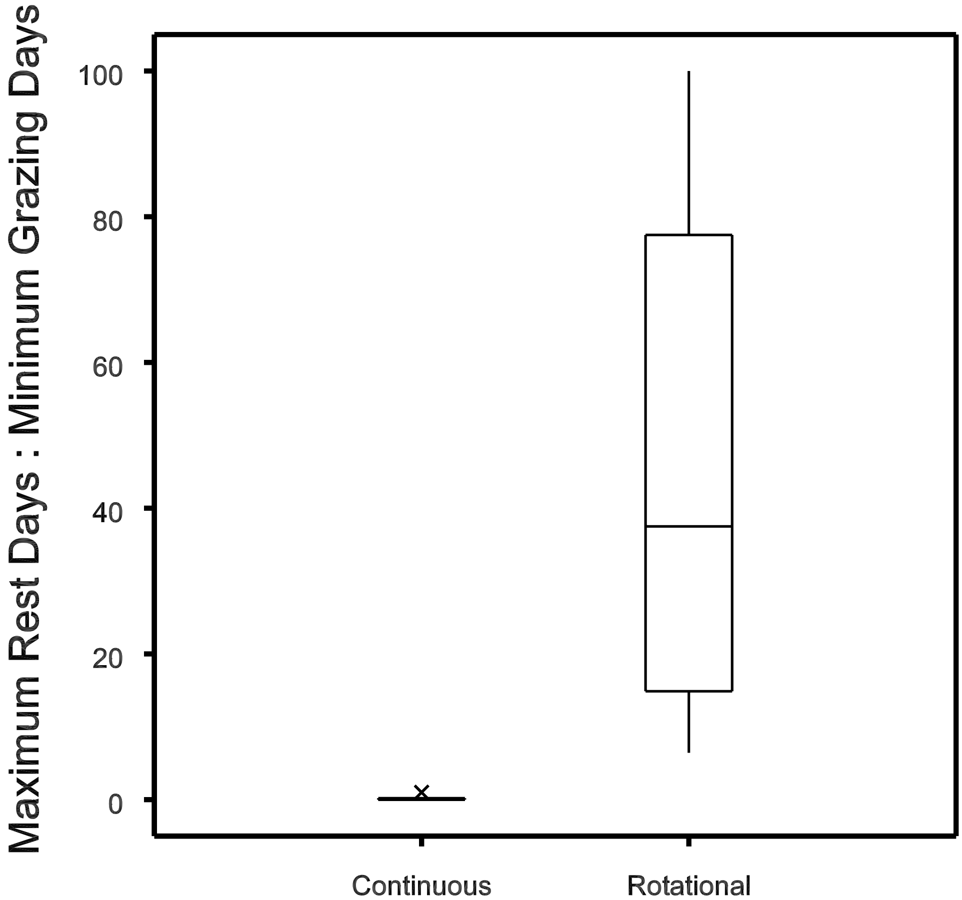

Figure 8 The ratio of the maximum number of rest days to the minimum number of grazing days varied between continuous and rotational systems as well as showing considerable variation within rotational systems themselves.

4.1.2 Fertilizer management

Half of the 24 properties fertilized their native pastures and of these most used single super every 2-3 years. Over the next ten years, only 3 producers are planning to increase the area of native pasture that they fertilize. Of these, one intends to fertilize more than 50% of their native pasture. There is only one landholder who is currently fertilizing and plans to cease fertilizer applications during the next 10 years. Nine of the 24 landholders intend to maintain zero fertilizer applications in the future.

4.1.3 Pasture sowing

Historically there were strong drivers to replace native-based systems with sown exotic pastures. Although most of the landholders viewed the native pasture as an important part of their farm business our discussions revealed that of the 24 producers, 25% (six) are intending on reducing the proportion of native pastures on their property over the next 10 years in favour of increasing the area of sown pastures or sowing introduced species into native pasture. Although none are planning on completely replacing their native pastures some producers are intending on replacing up to 70% of what is present. There are only 2 properties (rotational) that plan to increase the area of their native pastures, through grazing management.

It is unknown whether these patterns are representative of the broader population. However, this does suggest that replacement of native pastures is an ongoing and relatively widespread practice.

4.1.4 Drought management

Approaches to managing the 2006–2007 drought conditions varied widely among producers. There was a general trend that those employing continuous grazing were more likely to have stocked their native pastures throughout the drought and combined this with supplementary feeding. Only one producer using continuous grazing did not supplementary feed and this was an exception because the stock were sold after 3 months.

Of the 12 rotational graziers, six had the paddock stocked for six months or less during the drought, with four of these only stocking the paddock for a month or not at all. Of these, two used a separate containment area to maintain core breeding stock with supplementary feeding. Five of the rotational graziers did not use any supplementary feeding and also stocked their native pastures largely throughout the drought (10 - 12 months), albeit at slower rotations or using lower stocking rates. Under pre-drought conditions, these five rotationally grazed properties tended to use longer rest days per grazing cycle, relative to the number of grazing days. The average ratio of rest to grazing days for any one grazing cycle was 66.5 days (±8.4 standard error) for the properties that stocked throughout and did not use supplementary feeding compared to 31 days (±7.2 standard error) for the other rotationally grazed properties.

Fourteen properties reduced stocking rates during the drought compared to their long-term average. Seven properties managed to maintain stocking rates during the drought and of these, four were continuous graziers who all supplementary fed during the drought, and three were rotational graziers, of which two did not use supplementary feeding to get their stock through. Continuous graziers on average, had their paddocks stocked at a slightly higher average rate of 4.28 DSE/ha, compared to rotational grazers of 3.26 DSE/ha.

In summary it would appear that the typical response to drought of those employing continuous grazing, was to supplementary feed in an attempt to retain stock. In contrast, rotationally grazed properties used diverging strategies. Some sold stock (typically non-core breeding stock) early (some were discussing the sale of stock as early as March/April/May of 2006) and completely de-stocked before the drought reached a peak (a minority used separate containment areas). Another group managed their rotation speed, duration of rest and reduced stock numbers to enable them to continue grazing through the drought. A number of producers commented that since they adopted rotational grazing it had become easier for them to “predict” drought conditions enabling them to sell stock early. However, the comment was also made that predicting feed shortages was only one aspect of drought management, it was the commitment to make the necessary stock reductions that really counted. Stud operations tended to find this sort of decision-making harder and some producers had opted to run non-breeding operations and trade or take on agistment to increase flexibility in the system.

4.2 Ground-layer habitat structure

4.2.1 Sward as habitat workshop

The workshop developed several key hypotheses. These recognized the likely importance of individual animal responses to the ground layer, the role of heterogeneity in the ground layer in time and space, and the importance of combinations of ground layer elements in providing suitable fauna habitat. The predicted effects of rotational grazing on sward structure include the likelihood of a more even sward structure compared to continuous stocking.

Below we describe in more detail those hypotheses that were addressed to some extent by empirical work collected in this project.

1) Responses to particular features of pasture swards will differ between animal species.
This hypothesis would be consistent with many fauna studies that have shown varying responses to the same habitat type. In this sense, there will never be a black-and-white answer to the question of a particular grazing strategy being optimal for all fauna. However, when particular species are identified as occurring on the study properties, it will be possible to refine predictions concerning their habitat response. This can be achieved by considering individual species needs in terms of feeding, avoiding predators, breeding and sleeping. The same could be done for species that are absent from the properties but which could reasonably be expected to occur there.

2) Sward structure is a key ground layer habitat variable for fauna.
The physical structure of the swards, rather than the plant species composition of the ground layer, was considered important by most workshop participants. This is a reasonable hypothesis, but it may also reflect a lack of awareness of the role of individual plant species as specific resources for fauna. There may well be some significant responses to individual plant species, as suggested by observations of birds feeding on the abundant seeds produced by some annual exotic plants. However, in terms of community patterning, the magnitude of this response is likely to be smaller than the response to sward structure overall. In any case, separating out the effects of sward structure and plant composition will be not be operationally possible, as they are highly interrelated in the field.

3) Heterogeneity in sward features at multiple spatial scales will provide diverse habitat for a range of animal species.
This follows on as a logical extension of hypothesis 1 that if animals vary in their sward requirements and are responding at different spatial scales, then the habitat requirements of more species could be met if there was variation in the swards at different scales. A simple example is that one species (e.g. a small lizard) might require variation in sward height at a small patch scale of less than a metre. A second species (e.g. a quail) may respond to intermediate patches 10's of metres in extent. In both these cases, a continuously stocked, patch-grazed paddock would be suitable. A third species (e.g. a bandicoot) might require more extensive blocks of short and tall swards due to different feeding and predator avoidance patterns. In the latter case, adjacent paddocks of even tall and short swards would provide suitable habitat.

Participants predicted that sward heterogeneity within a paddock is decreased by increased fertility, smaller paddock size, increased stocking rate, increase in temporal intensity (e.g rotational grazing); heterogeneity is maintained by low fertility, larger paddock size, reduced stocking rate, decrease in temporal intensity (e.g continuous stocking).

4.2.2 Empirical results

During the drought conditions of 2006 most paddocks had very short and uniform pasture structure. Under these conditions the important determinants of ground-layer habitat structure were identified to be soil fertility (available soil phosphorus; negative effect), stocking rate (negative effect) and rainfall relative to evapotranspiration in the 6 months preceding sampling (positive effect) (Dorrough, Stol & McIntyre 2007). Grazing regime (rotational versus continuous grazing) also appears to influence pasture sward structure, but its' effects were less important (Table 2). Live plant ground cover and the height of the sward were reduced by heavy stocking rates, higher soil fertility and a drying climate. The later was most important in annual dominated pastures but least important in perennial dominated pastures (see below). The presence or absence of trees appeared to influence many ground layer habitat elements (Table 2).

Table 2 Variation in habitat variables and stocking rate in continuous grazing plots, rotational grazing plots, as well as plots with and without trees. (Means ± SE)

Variable	Continuous grazing		Rotational grazing	
	Trees present	Trees absent	Trees present	Trees absent
Average stocking rate (dse)	5.08 ± 0.7	4.7 ± 0.7	5.4 ± 0.7	5.4 ± 0.7
% low shrub cover (1ha)	0.9 ± 0.4	0.3 ± 0.2	0.7 ± 0.4	1.3 ± 1.2
% litter cover	31.3 ± 6.3	13.2 ± 4.5	29.2 ± 7.8	24.3 ± 4.9
% woody debris cover (1ha)	9.9 ± 3.5	0.9 ± 0.4	7.0 ± 2.0	1.5 ± 0.9
% woody debris cover (4ha)	8.5 ± 3.5	1.1 ± 0.3	4.6 ± 1.0	1.8 ± 0.9
No. trees (1ha)	10.5 ± 2.6	0 ± 0	7.7 ± 1.4	0 ± 0
No. trees (4ha)	19.7 ± 2.6	1.8 ± 0.5	18.3 ± 3.3	2.3 ± 0.5
Average % live veg cover	13.4 ± 2.6	28.9 ± 5.1	13.8 ± 3.5	20.5 ± 5.1
Average pasture height (cm)	3.4 ± 0.5	3.1 ± 0.6	3.5 ± 0.4	4.4 ± 0.5
Index of pasture structure	1.0 ± 0.5	0.2 ± 0.7	1.0 ± 0.5	1.7 ± 0.5

Pasture heterogeneity could be partly linked to grazing management regime. Most continuously grazed pastures had little heterogeneity, dominated by short swards and bare ground. Only very lightly stocked continuously grazed pastures retained any structure. These paddocks were characterised by a variable habitat structure with a few tall tussock patches surrounded by short lawns. In contrast many rotationally grazed pastures, particularly those with long rest and short graze periods, had little bare ground and had a more even sward structure.

Droughts are likely to be critical times for persistence of many species in native pastures. Droughts also place stress on pastures, soils and livestock. The amount of live vegetation that persists through a drought will determine how well that pasture responds to rainfall and provides soil protection. Additionally it is likely to be linked to the habitat and food resources that pasture may provide to fauna that utilise the native pasture.

The severe drought that prevailed during this research provided us with an opportunity to explore those factors that contribute to variation in live plant cover within native pasture (short research paper in preparation).

The live cover of native plant species was found to be strongly related to management with only weak (although highly significant) effects of worsening drought conditions. In contrast the abundance of exotic plants was primarily driven by recent climatic conditions. During worsening drought conditions of 2006-07 live native plant cover in pastures was found to be negatively correlated with increasing soil fertility (available phosphorus, soil nitrate) and recent stocking rates, with only weak negative effects of soil drying (Table 3, Fig 9). Live exotic plant cover (both annuals and perennials) was best explained by an index of the available soil moisture and were shown to decline rapidly as soils dried (Table 3, Fig 9). No measure of grazing strategy was found to influence either the live cover of exotics or native pastures species.

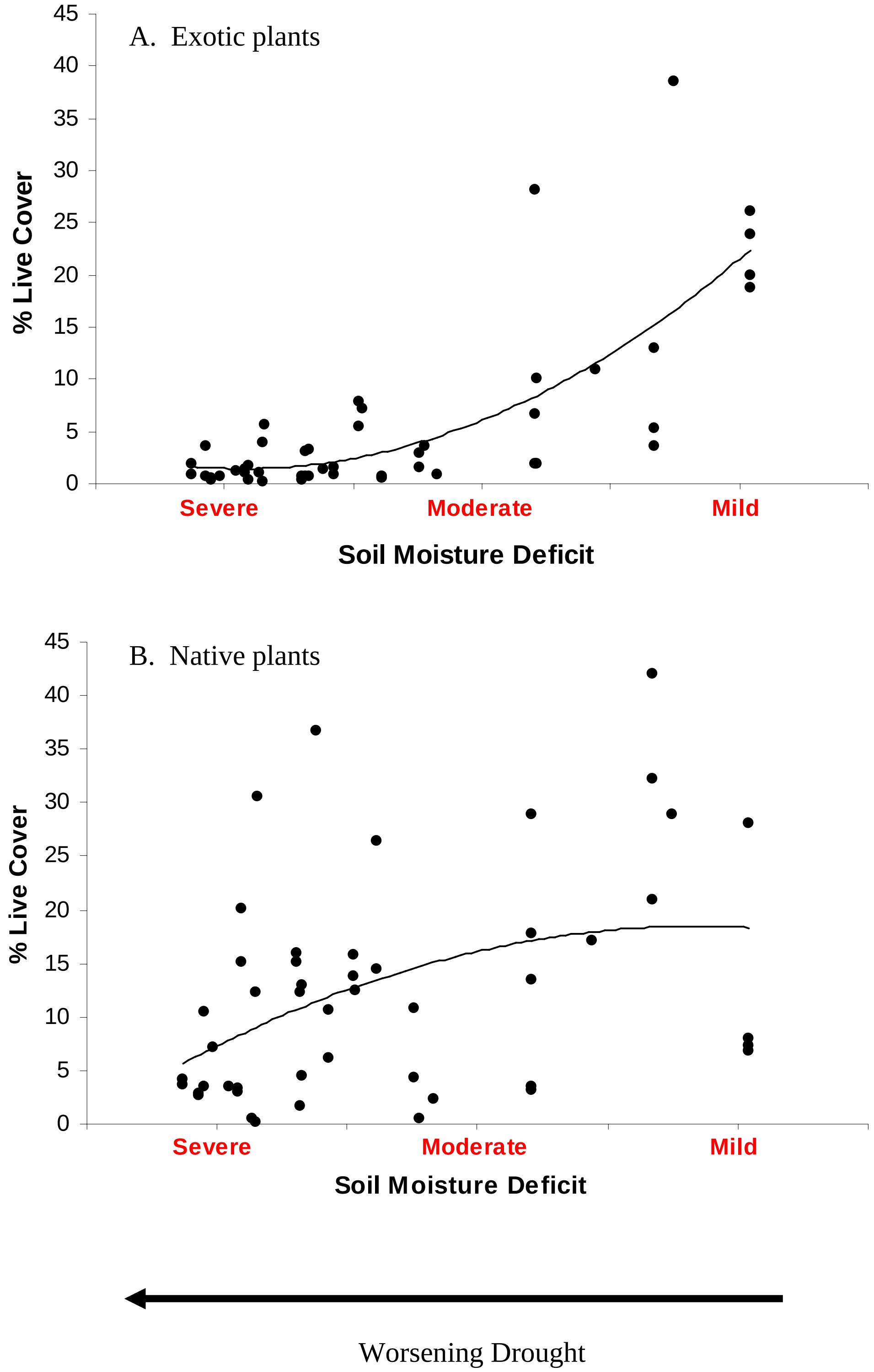

Figure 9 Relationships between plant live cover (A. exotics; B. natives) with an index of soil moisture deficit (ratio of rainfall to evapotranspiration – see methods for details)

Table 3. Generalised linear models (logistic link) of average exotic and native plant live cover in 1 ha plots. Response coefficients (estimate), their upper and lower confidence intervals and p-value are shown.

	Estimate	upper	lower	p-value
Exotic plant live cover				
Constant	-7.294	-6.475	-8.113	
Stocking Rate (dse/ha)	0.141	0.220	0.062	<0.001
Maxrest : Mingraze	-0.001	0.005	-0.006	0.820
Phosphorus (Colwell)	-0.015	-0.004	-0.026	0.005
Rainfall: Evaporation	8.352	9.446	7.259	<0.001
Nitrate N	-002	0.007	-0.011	0.654
Native plant live cover				
Constant	1.7834	1.3852	2.1817	
Stocking Rate (dse/ha)	-0.0682	-0.0143	-0.1221	0.013
Maxrest : Mingraze	0.0004	0.0036	-0.0028	0.820
Phosphorus (Colwell)	-0.0352	-0.0260	-0.0444	<0.001
Rainfall: Evaporation	2.524	3.170	1.879	<0.001
Nitrate N	-0.012	-0.005	-0.019	<0.001

These results have significant implications for livestock management systems, drought management and ecological functioning of native pastures. The results strongly demonstrate that maintaining perennial dominated pastures at high fertility and high stocking pressure is unrealistic. Further, such high input management leads to a pasture system that is far less able to provide live groundcover during drought conditions. High input pastures are more vulnerable to erosion and rapid water run-off and are likely to have poor summer water use. Our results do not suggest that adoption of rotational grazing systems has significant influence on these outcomes.

Fauna responses to habitat structure

No fauna groups were found to vary in abundance or diversity owing to ground-layer pasture structure. However, bird foraging activity and abundance of birds on the ground was lower in pastures that were managed with longer rest periods and short grazing. We interpret this as a response to an absence of bare ground. Birds and reptiles were also positively correlated with the amount of woody debris on the ground (logs and branches). This observation has been made in several prior studies.

The absence of response to pasture sward structure could be interpreted in several ways. This could arise if the current fauna are favoured by open ground-layer structures (i.e. short pastures) and more dependent on scattered trees and remnant woodland. Certainly this is partly true – the reptile fauna is dominated by small skink species and the bird fauna lacks those species that require dense tussocks/pastures. Alternatively, assuming some species are responsive to pasture structure, perhaps owing to drought conditions there was too little variation in habitat structure for differences to arise.

4.3 Paddock scale versus landscape scale influences

4.3.1 Plants

Our initial analyses based on the experimental design factors(see Dorrough *et al.* in preparation) indicated that the diversity of native plants in pastures was most strongly influenced by paddock management, in particular fertilizer, grazing pressure and past tree clearing (see Table 5). However, we also detected some landscape scale effects suggesting that in paddocks with some tree cover more native plant species are supported when the cover of native vegetation across the landscape is high (>30%). This result, while intuitive, was not expected.

A separate set of analyses examining patterns of occurrence for individual plant species showed that native perennial geophytes (orchids and lilies) and native perennial shrubs were most sensitive to both increased available soil phosphorus and increased grazing pressure (as stocking rate)(see Figs 2 & 3 in Dorrough & Scroggie in press). Part of the sensitivity of these groups to increased soil phosphorus is thought to be via competition with annual exotic species with high relative growth rates (Allcock 2002), interactions with grazing mediated disturbances (e.g. Chaneton, Lemcoff & Lavado 1996) and declines in associated soil mycorrhiza (Hartnett & Wilson 2002). Prior research has shown that many shrubs and geophytes rely on symbiotic associations with mycorrhiza for establishment and uptake of phosphorus (e.g. Rasmussen 2002). Toxic effects of increased phosphorus have also been observed in some native shrub species (e.g. Heddle & Specht 1975; Thomson & Leishman 2004). Research into the mechanisms of species loss as a result of increased soil phosphorus would be a worthy avenue for further research.

A more exhaustive analysis of covariates provided further evidence that changes in soils, rather than measures of livestock grazing, are most significantly related to variation in native species diversity in these long-grazed pastures. We used generalised linear models to explore a range of variables and variable combinations. One such model is described in Table 4. The variables most strongly related to changes in native plant species richness in 1 ha plots were (in order of deviance explained) available soil phosphorus (negative effect), tree canopy cover (positive effect), carbon : nitrogen ratio (positive effect) and the live cover of exotic plant species (negative effect). These same analyses suggest the effects of rotational grazing (either as a factor or continuous variable based on rest) and increasing stocking rate could be anywhere between positive and negative. Thus, the highest diversity of native plant species was found in sites with soils low in available soil phosphorus and with a high carbon to nitrogen ratio, some woodland tree cover, and little exotic plant cover – these results are consistent with previous studies (e.g. Prober, Lunt & Thiele 2002; Clarke 2003; Dorrough *et al.* 2006). It is however worth noting that this same combination of factors are most likely to arise in locations where stock grazing pressure, relative to carrying capacity, has been low.

It is important to consider the absence of a response to grazing management strategy or stocking rate in the context of the long-term management of these pastures. All of the properties now practicing rotational grazing, have only been doing so for the past 5-11 years. The previous 150 years of continuous grazing is likely to have filtered the prior pool of native plant species, largely eliminating grazing sensitive species. Grazing sensitive species are primarily restricted to small linear roadside reserves, cemeteries and other infrequently grazed areas (e.g. travelling stock reserves) (McIntyre & Lavorel 1994b; Prober & Thiele 1995). When present in grazed pastures their abundance is expected to be low.

Implementing frequent rest through rotational grazing systems is therefore unlikely to promote species richness in the short-term even if species likely to be favoured by such a regime exist in the landscape. Indeed, reductions in species richness should not be unexpected (e.g. Reseigh 2004).

Table 4 Summary of model coefficients for a generalised model of native plant species richness in one ha plots within native pastures. Response coefficients that do not overlap with 0 tend to indicate those that are significantly correlated with plant species richness.

Variable	Estimate	upper CI	lower CI
Constant	2.4	3.2	1.5
Soils			
C:N	0.06	0.11	0.01
Phosphorus (Colwell)	-0.01	-0.004	-0.017
Habitat/Vegetation attributes			
Exotic plant cover	-0.01	-0.002	-0.02
Tree Canopy Cover (%)	0.008	0.01	0.002
Litter Cover	-0.004	0.00	-0.008
Grazing Management			
Stocking Type: Rotational	-0.06	0.2	-0.3
Continuous	0.0		
Max rest : Min graze	0.0	0.005	-0.004
Average Stocking Rate	-0.025	0.013	-0.06

As part of this project we have also been developing novel approaches to statistical modelling of plant species responses to soil phosphorus and grazing pressure in collaboration with Dr Michael Scroggie (Arthur Rylah Institute, DSE) and Dr Tara Martin (University of British Columbia and CSIRO SE). This work is demonstrating that we can often provide reasonable predictions for the response of a large number of plant species (Dorrough *et al.* in prep). A significant advance arising from this work is the use of prior information on simple trait and species specific responses. We were able to demonstrate that some prior information, even for simple broad traits (e.g. perennial versus annual, grass versus forb) can lead to improvements in predictive capacity. This research has significance for land management as it is starting to provide us with species specific information that can be used to guide decision making[1]. This methodology is also enabling us to develop predictive capacity for rarer species. We often have very little information on how rare species respond to management, even though these species are of the greatest concern for the conservation of biodiversity.

[1] The application of these results is demonstrated through the development of an indicator species graph presented in the management guidelines prepared for this project.

Table 5 Summary of results determined from the analyses presented in Dorrough *et al.* (in preparation). Species richness of reptiles was too low to analyse.

Response Variable	**Plot scale** Trees (treed / open)	**Plot scale** Grazing management (rotational / continuous)	**Plot scale** Available soil phosphorus ($mgkg^{-1}$)	**Plot scale** Stocking rate (dry sheep equivalent ha^{-1})	**Landscape context** Native tree cover at radius of 500m, 1260m and 5640 m
Native plant richness	Slightly higher richness where trees were present	No effect on richness	Declining richness with increasing phosphorus	Decline with increasing stocking rate	Treed plots had increased richness with increasing tree cover at 1260m and 5640m scale
Reptile abundance	More individuals where trees were present	No effect on abundance	Decline in abundance with increasing phosphorus	Increased abundance with increasing stocking rate	Treed plots had increased abundance with increasing tree cover at 500m, 1260m and 5640m scales
Bird richness and abundance	Greatly increased richness and abundance where trees were present	Richness and abundance reduced under rotational grazing	No response to phosphorus	No response to stocking rate	Weak increase in richness (not abundance) on treed plots with increasing tree cover at 5640 m scale only

4.3.2 Reptiles

Reptile abundance and diversity in native pastures were influenced by local habitat (tree cover and woody debris on the ground) (Table 5 and Fig. 10). While these variables both generally have positive effects, some species tend to prefer more open, grassy pastures (e.g. Olive Legless Lizard *Delma inornata*). Our initial analyses also indicated that some forms of current paddock management were also correlated with reptile abundance. There were weak trends to suggest that reptile abundance was lower in more fertile pastures and increased at higher stocking rates (Table 5). The first relationship could be a response to the types of ground layer habitat that develop under different soil fertilities. Low fertility soils typically have a greater range of different plant types represented in the pasture, including small tussocks and sub-shrubs.

The very weak positive relationship with stocking rate appears to be largely driven by an increase in the abundance of small generalist skink species that may be favoured by the increased light availability and bare ground (e.g. Howard, Williamson & Mather 2003; Driscoll 2004). It is also worth noting that the two habitat variables (tree cover and woody debris) are both also influenced by management activities. The results suggest that managers can increase the abundance and diversity of reptiles by retaining branches and fallen timber, encouraging natural regeneration and implementing strategies to increase the health and persistence of existing trees.

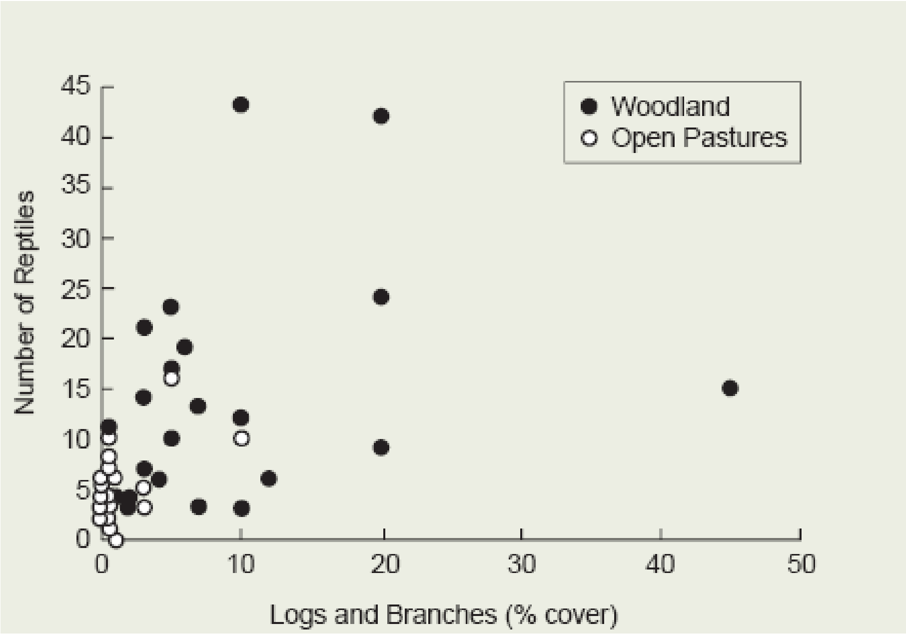

Figure 10 The abundance of reptiles tends to be positively correlated the percentage cover of logs and branches in a one hectare plot.

Reptile abundance also positively responded to increasing landscape tree cover, although this pattern was driven by a couple of very high tree cover landscapes (>40% cover of remnant vegetation). Reptiles, like plants have relatively low mobility and their ability to disperse into populations in modified native pasture situations may be greater where a larger proportion of the surrounding landscape is remnant vegetation.

Multivariate analyses were undertaken in an attempt to correlate the distribution of reptile counts at each site with environmental variables. Two analyse were undertaken. The first was multivariate regression trees (MRT), which is a relatively new multivariate technique for modelling species-environmental relationships. MRT tries to cluster sites by repeated splitting of the data based on the environmental variables; the splits are designed to minimise the dissimilarity of the sites within a cluster. The second technique was based on redundancy analysis (RDA), which attempts to model the ordination of species composition with ordinations of environmental variables.

Seventeen environmental variables, those mostly associated with stocking and pasture improvement regime, substrate components, and tree presence, were used in the analysis to model the occurrence of reptiles (species and abundance).

For MRT, the best predictive tree for the reptile data consisted of splits on two variables, 'Latitude' & 'Logs', suggesting influences on reptile occurrence at two scales — a regional (biogeographical) scale, and a local (site) scale (Fig 11). The results of the RDA reflected those from the MRT. That is, the variables 'Latitude', 'logs' and 'litter' were found to be significant in terms of reptile occurrence, though the overall model is not particularly strong (all 17 components combined only explained 42% of the total variance). These results, while not strong, support findings from other studies of reptiles in rural landscapes (i.e. reptile occurrence is influenced by multiple factors operating at different scales) (Fischer, Lindenmayer & Cowling 2004).

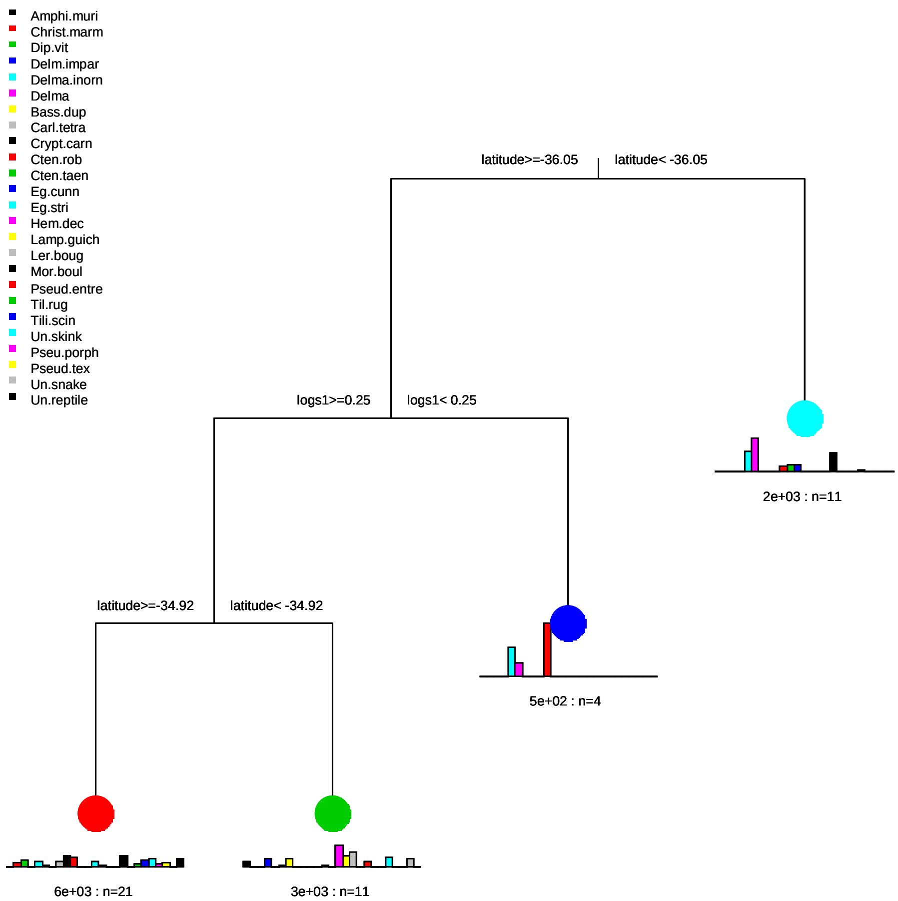

Figure 11 Multivariate Regression Tree (MRT) resulting from the best predictive model of the reptile species/environment data, selected by crossvalidation. Terminal nodes show the number of sites in the node and barplots show the frequency distribution of species predicted by the node. Logs1 is the percentage of woody debris within the 1ha plot (from Brown et al in prep).

4.3.3 Birds

Our initial analyses found that bird richness and abundance were most strongly determined by local tree cover, although weak negative effects of rotational grazing systems were observed (Table 5 and see Dorrough *et al.* in preparation).

A more detailed analysis of bird composition within native pastures highlighted the importance of local habitat, in particular tree cover, ground-layer shrubs and woody debris (Barrett *et al.* in preparation). These results also suggested that the negative effect of rotational grazing systems was primarily within pastures managed with long rests. Our analyses suggest that the apparent reduction in bird abundance and richness was due to an increased proportion of woodland birds observed on the ground rather than in trees and shrubs within continuous grazed plots with their shorter rest periods from grazing by livestock. The number of ground-foraging insectivorous open country bird species was also greater in continuous grazed plots. Most observations of ground foraging were either on bare ground or in short grass. Continuous stocking would lead to a greater availability of these habitat elements. Long rest rotational systems were found to often have a greater cover of litter between tussocks and little bare ground (see section 4.2).

Birds that 'tunnel' through long grass such as quail, were absent from our surveys, and species that forage in tall-grass habitat, such as songlarks, robins and finches were under-represented. These species are most likely to be favoured by light stocking rates and rotational grazing systems that maintain litter and standing dead vegetative cover. Anecdotal reports by rotational graziers also support these suggestions (Phil Diprose per. comm.). The idea that birds sensitive to grazing were largely excluded from our analysis due to the history of intensive land use across all sites, was further supported by an increased proportion of the less common bird species (those occurring in fewer than three sites), observed foraging on long grass in rotational grazing plots.

The presence of trees, woody debris and shrub cover were correlated with variation in bird abundance, diversity and foraging activity. Clearly woodland birds require patches of woodland, but our results also support research that has emphasised the importance of paddock trees as a keystone resource for maintaining bird diversity within the agricultural matrix (Manning, Fischer & Lindenmayer 2006). The association between woody debris, shrub cover and bird diversity has also been described in a number of other studies (e.g. Arnold & Weeldenberg 1998). Both of these habitat features tend to be negatively impacted on by livestock grazing management practices. Our results also suggested that species diversity among the less common bird species was associated with shrub cover supports the view that smaller, shrub-dependent birds are particularly vulnerable in grazing landscapes.

It was interesting to notr that there were no trends to suggest that bird abundance or richness were higher in paddocks that occurred in landscapes with more remnant vegetation cover. This was contrary to expectations as much prior research has shown the opposite to be the case. However, birds are highly mobile and their dispersal and movement through landscapes will be less affected by loss of remnant vegetation than will the movement of less mobile organisms such as plants and reptiles. Our prediction based on this data is that if a paddock is locally suitable, for many bird species these landscapes may be adequately connected. The role of paddock trees, although not quantified in this research, in enabling dispersal of birds through the grazed landscapes could underlie the patterns we have observed.

Overall these results highlight that an interesting tension that exists in the conservation of birds within these grazed landscapes. On the one hand, continuous grazing management appears to promote many open country and woodland bird species. Yet, on the other hand, without periods of rest from livestock grazing, tree and shrub regeneration will be restricted, resulting in the long-term loss of woodland and scattered tree ecosystems which are no doubt essential for the persistence of most birds in these landscapes.

While rotational grazing systems appear to be detrimental for many of the more widespread ground foraging woodland and grassland bird species, it has potential to provide habitat for a small number species that seem to be less frequent in these grazed landscapes.

4.4 Diversity, livestock production and profitability

Gross margin information was collected for each enterprise. Information was often compiled from farmers' own figures and estimations, and NSW Agriculture farm budgets when required. These calculations try to reflect averages over recent years. However, these were found to vary widely depending on costs of supplementary feeding, wool and beef prices etc.

Gross margins on native pastures vary considerably but within our sample cattle tend to have generated the highest gross margins on native pastures over recent years. Out of the 13 properties running cattle, there were eight properties with gross margins of less than $105 /ha. There were two properties lying between $150 - $200 /ha, and 3 properties between $200 and $252 /ha.
Out of the 13 properties with sheep enterprises, there were four properties with gross margins of $50/ha or less for their sheep enterprise, six properties between $51 and $100 /ha, and three properties between $101 and $170 /ha.

The estimated average gross margins for a paddock showed no significant correlation with any measure of plant, reptile or bird diversity (see Figs 12-14). However it is worth noting that the greatest richness of plants and one of the highest abundances of reptiles were recorded in a paddock with particularly low gross margins.

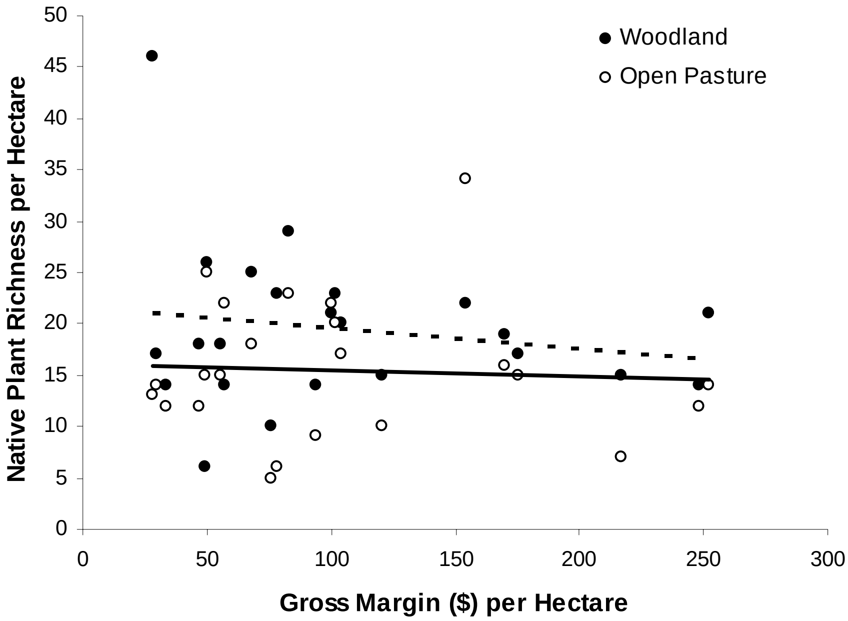

Figure 12 Native plant richness per hectare and gross margin per hectare estimated for 48 plots across 24 farms.

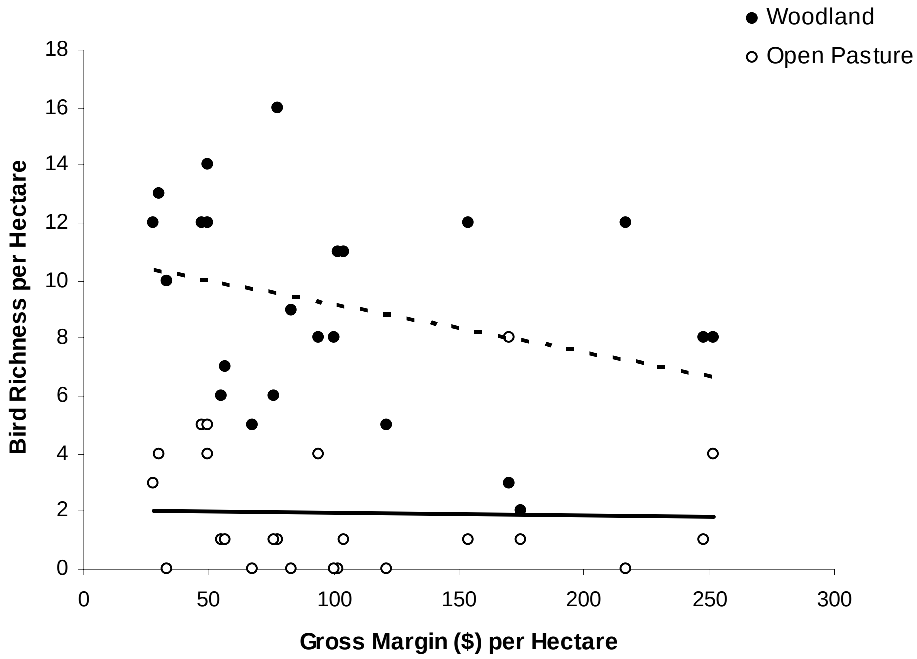

Figure 13 Bird species richness per hectare and gross margin per hectare estimated for 48 plots across 24 farms.

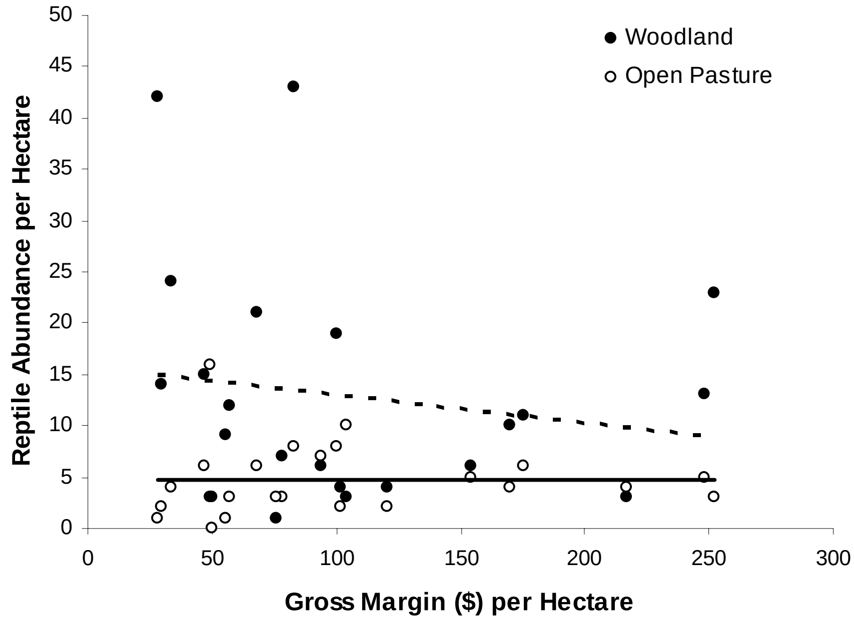

Figure 14 Reptile abundance per hectare and gross margin per hectare estimated for 48 plots across 24 farms.

Gross margin was found to be negatively correlated with the live cover of native perennial plants and total live vegetation cover during the drought of 2006-07 (Figs 15 & 16). Not surprisingly there was also a positive correlation, albeit weak, with available soil phosphorus (Fig 17). While this later result was not surprising, the first was not initially expected. The negative correlation with live vegetation cover during the drought does suggest that high gross margins are obtained at the expense of future drought resilience of the pastures.

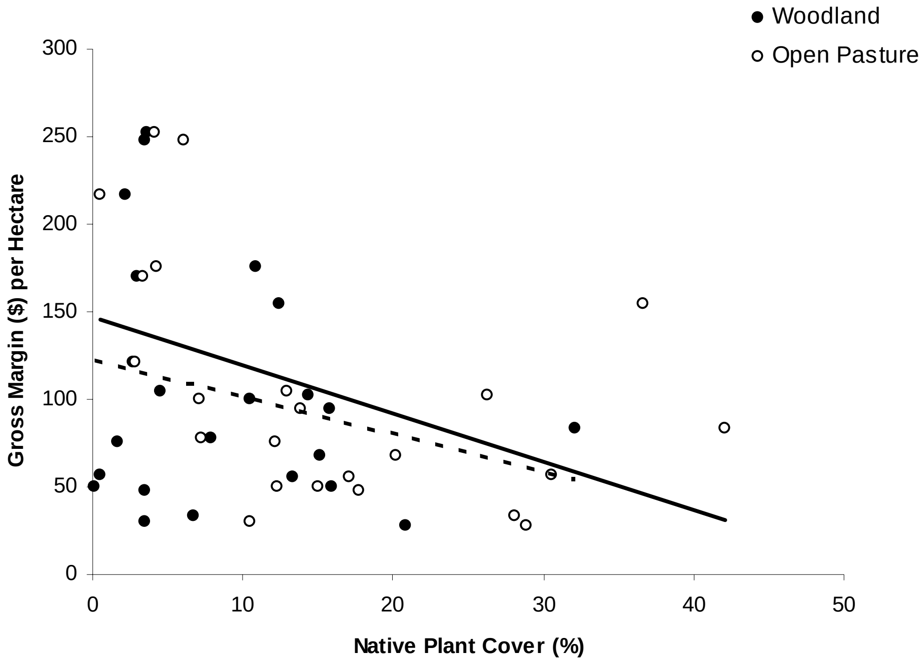

Figure 15 The gross margin ($) per hectare tends to be negatively correlated with the live cover of native vegetation. Data from 48 one hectare plots.

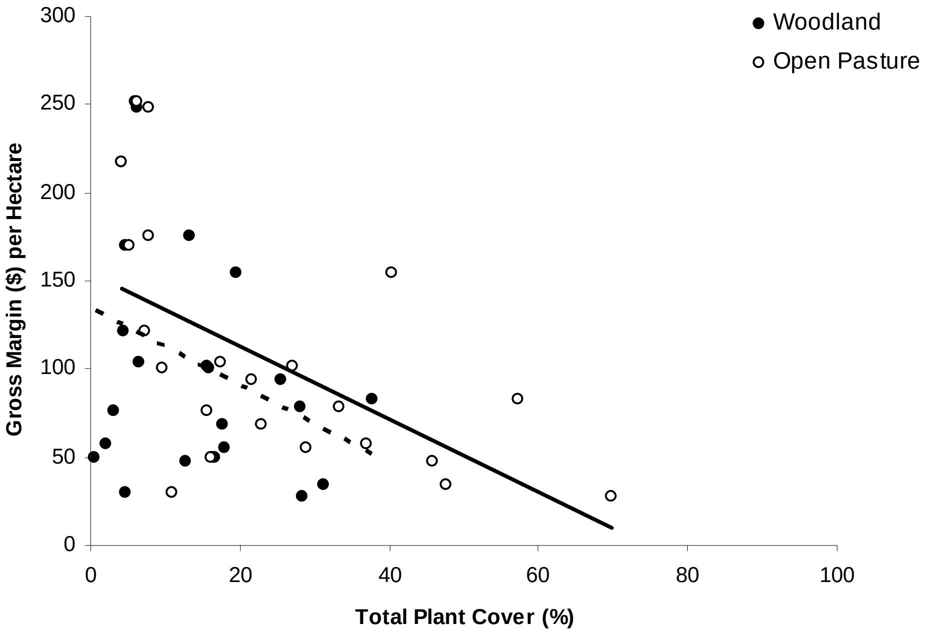

Figure 16 Gross margin per hectare is negatively correlated with total live plant cover. Data from 48 one hectare plots.

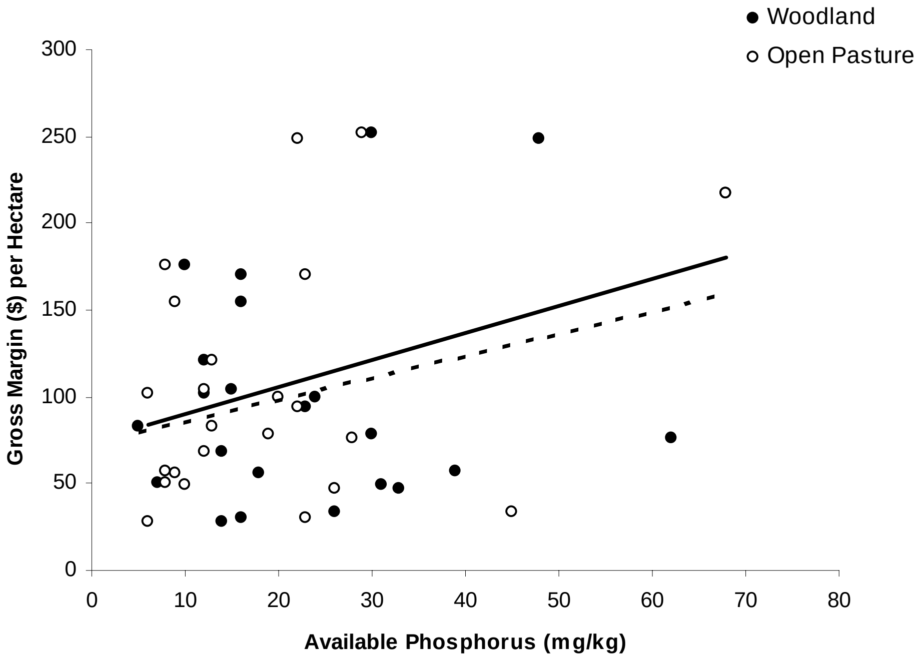

Figure 17 Available phosphorus (Colwell, mg/kg) is weakly positively correlated with paddock level gross margin per hectare.

5 Success in Achieving Objectives

5.1 Stakeholder consultation and community field days

5.1.1 Overview of stakeholder consultation

Stakeholder consultation was undertaken over the life of the research project to assist in site selection, communicate research results and obtain feedback and information (see Table 6). The most intensive periods were during the initial and final phases of the project. During the initial phase of the project extensive consultation was undertaken to enable the researchers to develop a better understanding of the role of native pastures in production system and the range of grazing management strategies for native pastures. This consultation assisted greatly in site selection and experimental design. It also proved to be invaluable later in the project for communicating research results and providing a context for the management guidelines that were developed. During the later stages of the project (the last 12-18 months) consultation focused on communicating key research results (Fig 18 & 19) and seeking feedback to improve presentation and to investigate implications for farm businesses and management. This consultation led into the development of management guidelines. The last 6 months of the project concentrated on presenting key messages within those guidelines and seeking feedback on the information content, layout and format of those guidelines.

The early consultation process was broad and was summarised in detail in Milestone Report 3. In summary over 150 individuals were consulted. A number of major issues were raised during this initial consultation and these subsequently informed the project design, data collection, analysis and presentation. The May 2006 milestone report summarised these issues:

"Throughout the consultation process it was apparent that there is very little knowledge of the role native pastures play in providing habitat for native plants or animals in the study landscapes. Moreover there is even less knowledge of whether changes in grazing management are likely to impact on these roles. There is a general perception that improved management to enhance perenniality will improve biodiversity outcomes, but this is not quantified. As funding is currently available to assist producers to make the transition towards rotational grazing management, evidence to support or refute this funding would be welcomed. These observations provide strong endorsement of the importance of the research being undertaken in this project.

It is widely recognised that native pastures are important for meeting native vegetation and other natural resource management goals throughout the region. Further understanding of the impact of grazing management and other practices on persistence of native pastures will greatly assist in regional NRM.

There is a general perception that rest is important for managing native pastures and that incorporating longer rest leads to better native pasture persistence. The impact of such duration and frequency of rest from grazing for other components of biodiversity are unknown. Our research will need to consider variation within rotational grazing strategies in providing rest as well as variation between rotational and continuous stocking management."

The frequency of positive responses towards this research project, and high rates of attendance at presentations and field days, has been a strong endorsement of the timeliness and applicability for the information being generated. We believe this in part reflects a growing interest and understanding of the diverse economic and ecological values of low input grazing systems as well as a general interest in biodiversity on-farm.

Figure 18. Grazing management field day, Boorowa March 2008.

Figure 19 Jacqui Stol made three presentations on grazing management, native pastures and biodiversity at the Kosciuszko to Coast Open Day, March 2008.

Table 6 Summary of communications 2006 - May 2008

Field days	Workshops	Conferences	Media	Publications	Stakeholder consultation & interaction
(1) May, 2007 Holbrook Stakeholders and community field day (approx. 50) (2) May, 2007 Holbrook Landholder Field Day (30) (2) May 2007 Crookwell Landholder Field Day – (25) (3) September 2007 Binalong Landholder Field Day (30) (4) November 2007 Bonnie Doon Landholder/CMA Field Day (40) (5) March 2008	(1) March, 2006 "Sward structure as fauna habitat" to develop conceptual models for predicting fauna response to vegetation structure and grazing management (12) (2) May 2007 CMA workshop Holbrook. (25) (4) November 2007 Southern Rivers Grazing Management / landholders workshop (30) (5) May 2008 NSW Department of Primary Industries workshop Yass –(25)	(1) August 2007 Academy of Science Conference "Vegetation Dynamics and Climate Change" (approx 50) (2) October, 2007 5th Stipa National Native Grasses Conference, Mudgee (approx 100) (3) September 2007 "Better Bush on Farms" Conference, Albury –	(1) September 2006 Article in 'Focus on Salt', edition no. 38 (2) December 2006 Article in 'Salt Magazine' Volume 15 (3) May 2007 Media release re. Holbrook field day. Interviews for regional ABC and local newspaper (4) June 2007 Quirindi Advocate article (5) September 2007 Producer article in "Farming Ahead"	(1) October, 2007 Conference Proceedings "Drought , grazing management and habitat structure in native pastures". (2) February 2008 Manuscript "Integrating ecological uncertainty and farm-scale economics when planning restoration" (3) June, 2008 Manuscript "Plant responses to agricultural intensification" (4) June 2008 "Biodiversity in the paddock: a land managers guide" 32	(1) MLA Milestone 3, May 2006, Report on Stakeholder Consultation 13 pages. Details process and outcomes of developing a stakeholder network and site selection. (2) May –December 2006 Consultation on experimental design and methodology, communications (3) May, 2007 Major review of research by stakeholder consultation, Holbrook (4) CRC Node meetings (Victoria 2006, 2007, NSW 2008) (5) November 2007 Input to Lachlan CMA Conservation Grazing Investment Strategy Consultative Committee (6) 2007 Future Farm Industries CRC

Boorowa Grazing Management Field Day, landholders & Lachlan CMA (approx 60) (6) March 2008 Michelago Kosciusko to Coast (K2C) Conservation Management Network Open Day (approx 250) (7) April 2008 Holbrook landholders & Murray CMA (approx 50)	(6) February 2008 International Grasslands Congress Organising Committee, CSIRO (15) (7) May 2008 CSIRO science program meeting (approx 100)	approx 300 (4) April 2008 Australian Network for Plant Conservation 7th National Conference, Sydney (approx 150)	(6) Spring 2007 Prograzier article (7) September 2007 Harden-Murrumburrah Express article on field day (8) November 2007 Media release re. Bonnie Doon Field day:-Mansfield Courier article (9) Release of management guidelines booklet - forthcoming	page booklet (5) June 2008 Draft Manuscript “Responses of birds, reptiles and plants to management and tree cover in grazed native pastures” (6) June 2008 Draft Manuscript “Livestock grazing and ground-foraging birds”	biodiversity program Strategic input into planning and project design, incorporating results from current project (7) 2007 Box-Gum Woodland Stewardship Project – Federal DEW Strategic advice and input provided by Sue McIntyre and Josh Dorrough. (8) 2007 Victorian Green Graze Trial Strategic advice and input provided by Josh Dorrough (9) 6-12 monthly updating to key contacts on project progress ie. participating landholders, landholders and CMA (email and newsletters).

5.1.2 Consultation and preparation of management guidelines

There was extensive consultation and feedback from a large range of stakeholders during the development of the management guidelines booklet:

(1) prior to development potential content and the amount of detail was discussed at a number of field days and workshops (e.g. Holbrook managers workshop, producer workshop at Bonnie Doon and Lachlan grazing management field day)
(2) following development of draft text and initial layout development most project participants and their families were supplied with copies and encouraged to provide feedback via email or phone; farmers and property managers attending field days were shown draft copies of booklet sections and asked to provide either immediate comment or email more detailed feedback at a later date; Lachlan, Murray and Murrumbidgee Catchment Management Authority staff were emailed draft sections: agronomists and state agency staff were either emailed draft sections or supplied copies during workshops; a number of senior science managers and scientists undertook peer review; three science communication officers were provided with copy at mid-production stage and a science communicator was consulted through the whole process.

There was a very broad range of responses from a very positive general endorsement of the overall content, design and presentation to very detailed analysis of sub-components, draft booklet sections and their implications for property management. Producer response to early discussions and following presentation of drafts of the text was that the information was very interesting ("loved it") and that it provided a good level of detail and factual information (ie. actual project results) without being too technical. Results and more detailed text on how management actions (past and present) affected biodiversity were positively received and the importance of avoiding generalised statements was emphasised. There were strong requests for a range of "levels" of information to capture a range of readers. One comment was that the "Tips and Tools" series of pamphlets relating to grazing were about the right level of detail – "basically they tell you what you need to know to do the job".

A number of people requested specific information, that obviously directly interested them (e.g. how to get some eucalypt recruitment and the use of electric fencing to facilitate the process). As always there are a range of interests that are not within the scope of this booklet from impacts of pesticides or best methods to spreading desirable seeds across paddocks. Sections such as "Business matters" were viewed as important, as producers were interested in the cost of production and "how native pastures fit into the picture"

The final text of the booklet was specifically designed to address these types of comments by providing information within a hierarchical framework. Clear, succinct and overarching information within each section were presented as "key messages". These were intended to distil all content into readily readable, simple messages. The body text was designed to provide the context to the key messages and explore some of the uncertainties that still exist and areas essential for future research. Farmer quotes were then strongly utilised to create a short and readily readable, succinct summary of the preceding paragraph. The complementary quotes from producers often highlighted alternative ways that others were approaching the management of native pastures. These quotes were essential to capturing reader attention by providing another "voice" and perspective and validation of the message by a 'peer' land manager.

Finally the more detailed science and graphs and any management guidelines were generally presented within a 'stand out box' in order to highlight their content.

In addition to the information pages we developed two pictorial graphs that captured two key aspects of the research and also dealt with feedback relating to the need for species specific information on management actions. The first of these provided images of plant species commonly associated with differing levels of available soil phosphorus, a primary determinant of plant species composition in pastures. The second graph provided images of birds and reptiles our research showed to be associated with open pastures, wooded pastures or able to utilise both. There has been a high level of sustained positive feedback towards these pictorial graphs. The benefits of this type of graphic is that a complex set of data can be represented in a readily understand format. These graphs graphically communicate the message about how the diversity of plant and animal species varies among habitats. The complex message that biodiversity will respond differently according to different taxonomic level and that these responses can be positive / neutral or negative are clearly illustrated and provide a strong message. The other added benefit is a high resolution image at species level. As many stakeholders know only a sub-set of their plant and animal species it provides a dual benefit by assisting identification of common characteristic species of native pastures.

Several respondents felt that the two key questions we presented in the introduction of the guide (1. What might changes in management mean for the plant composition of native pastures and their ecological function and animal species which they support? and 2. Can native pastures deliver enhanced farm profitability, maintenance of key natural resources as well as biodiversity conservation?) were the crux of the booklet and one suggested re-structuring the entire booklet based around those two questions. While we agreed that those two questions are important, we decided that throughout the booklet information would be presented that addressed them rather than structuring the content around them.

5.2 Summary of data analysis and interpretation

A summary of the research results is provided in Section 4 and described in more detail in both published and forthcoming research papers (see Appendix 1).

5.3 Acceptance or not of the tested hypotheses

5.3.1 Hypothesis 1

Plant diversity in pastures ***is*** *more strongly influenced by paddock management (e.g. grazing strategy, cultivation, fertilization, and tree cover) than landscape scale factors (e.g. native vegetation cover, rainfall).*

Our research has clearly supported the first hypothesis. Our initial analyses, based on the experimental design factors (see Dorrough et al, in preparation, Section 4), revealed that the diversity of native plants in pastures was most strongly influenced by paddock management, in particular fertilizer, grazing pressure and past tree clearing. However, we also detected some landscape scale effects that suggest that in paddocks with some tree cover more native plant species are supported when the cover of native vegetation across the landscape is high (>30%) (Dorrough *et al.* in preparation). This result, while intuitive, was not expected.

Implications for land managers

Clearly there is a trade-off between high levels of some elements of production and native plant diversity. High levels of diversity are observed in paddocks with low levels of available phosphorus (indicating little or no fertilizer) and light stocking rates (typically less 3-4 DSE/ha). Paddocks with a history of such management, and where paddock trees have been retained will be those most valuable for native plant diversity.

The results do suggest that managers could increase native plant diversity and abundance through reductions in stocking pressure and cessation of fertilizer inputs. However, dramatic improvement should not be expected. The rate at which diversity will increase is uncertain in most cases but will be determined by seed availability, competition with established plant species, rates of soil phosphorus adsorption and nitrate cycling dynamics. Climatic variability will also play an important role. These are issues that are in urgent need of increased research investment.

5.3.2 Hypothesis 2

*Bird diversity in pastures is **not** more strongly influenced by landscape factors than by paddock management*

The second hypothesis was not supported. Our results suggest that local habitat availability is of utmost importance to bird occupancy and foraging within native pastures. The retention of trees and woody debris appear to be most important. Some of our results suggest that some groups of birds may or may not be favoured by rotational grazing and additional research is required to investigate these patterns further.

Contrary to our initial expectations birds were the least sensitive group in response to variation in landscape scale remnant tree cover.

Implications for land managers

Retaining paddock trees, encouraging tree regeneration and maintaining or enhancing ground-layer litter, woody debris and shrub cover will benefit many bird species. Such activities will be important for birds regardless of the context of the farm within the broader landscape.

5.3.3 Hypothesis 3

*Reptile diversity in pastures is influenced **both** by landscape and local paddock management*

The final hypothesis was supported. There were definite biogeographic (landscape-scale) trends, reflected most clearly in the relationship between reptiles and latitude; reptile species composition clearly changed with the south-north environmental gradient — the reptile assemblage in the more mesic southern sites differed with that of drier northern sites. Reptile abundance, in wooded pastures, was also positively correlated with the amount of remnant woodland in the surrounding landscape. There were also site-scale differences, where local paddock management will have the most impact. Tree cover and woody debris were found to influence the occurrence of reptiles — most species responded positively to increased tree cover and debris loads, although others did not (e.g. Olive Legless Lizard *Delma inornata*).

The absence of more definitive evidence amongst the measured variables suggests that other (unmeasured) habitat characteristics are responsible or, the reptile assemblage in these landscapes is in transition (from variegated to more highly disturbed, relictual landscapes).

Implications for land managers

Stocking rates and patterns, and pasture improvement, do not seem to have a strong or direct effect on reptile occurrence in native pastures, although weak trends for these site variables suggest the indirect effects of greater microhabitat diversity (reflected in greater range of ground-layer vegetation and proportion of bare ground). Environmental characteristics that are not immediately affected by livestock or fertilizer, such as tree cover and coarse woody debris loads (and probably microhabitat heterogeneity) appear to be the main drivers of reptile occurrence in these landscapes. There is also a role for catchment management and state conservation agencies to develop incentives that make certain conservation activities are widely spread among regions to ensure a range of reptile species are retained.

5.3.4 Hypothesis 4

Biodiversity in native pastures is correlated with some elements of livestock production but less so with profitability

Part of this hypothesis was upheld.

Several measures of native plant and animal diversity have been shown to be either directly or indirectly negatively correlated with aspects of livestock production in native pastures. Such results suggest a lack of compatibility with production systems. However, our results also demonstrate that some aspects of diversity are not correlated with the profitability of these livestock production systems. Importantly however, live native perennial plant cover, which is directly related to many important ecosystem functions in these landscapes, showed a negative correlation with profitability.

Our project has also demonstrated that retention of paddock trees is critical to maintaining diversity in native pastures. Changes in fencing and grazing management can be used to reduce nutrient deposition beneath paddock trees and this may be important for extending the life-span of trees. However, the retention of paddock trees in the long-term will require some periods of de-stocking to facilitate natural regeneration or to enable replacement trees to be seeded or planted. Under continuous grazing management this may entail 5-15 years of de-stocking, and would no doubt reduce profitability (Dorrough, Vesk & Moll 2008). Anecdotal information suggests that some rotational grazing systems may provide sufficient rest to allow regeneration to occur. We did not detect any greater likelihood of regeneration under rotational grazing systems, but more research is required to better explore the effects of rotational grazing systems.

Implications for land managers

Approaches to increasing profitability based on increased inputs of fertilizer, higher stocking rates and pasture sowing will not be compatible with biodiversity. However, our results suggested that input costs vary markedly among properties. Reducing input costs, combined with good business and grazing management appears to also provide a pathway to profitability.

Long-term persistence of biodiversity is likely to require reductions in profitability if a producers goal is to increase native perennial ground cover and establish or replace existing paddock trees.

For many producers incentives may be necessary to encourage uptake of management strategies that could achieve these aims.

5.4 Development of management guidelines

A 30 page booklet incorporating project results and drawing on other research has been published. The booklet has had thorough review both by landholders, Catchment Management Authority extension staff, project funders and managers and peer review by other researchers.

Delivery of the booklet is largely beyond the scope of the current project although the following delivery plan is suggested:

(a) Media release – August 2008.
(b) Delivery of hard copy to project primary producer contacts on south-west slopes and tablelands of NSW and inland slopes and uplands of central and north-east Victoria.
(c) Delivery of multiple hard copies to key producer and conservation management organisations e.g. Grasslands Society of Southern Australia, Stipa.
(d) Delivery of multiple hard copies to current contacts within seven CMA's (North Central, Goulburn Broken, North East, Murray, Murrumbidgee, Lachlan and Southern Rivers), Victorian and NSW DPI and Victorian DSE.
(e) MLA Prograzier Spring 2008 article
(f) Placement of pdf on FFI CRC, MLA, CSIRO SE and DSE websites.

A more thorough delivery plan can be developed if funding was to become available.

5.5 Development of scientific and conference papers.

Two science and one conference paper have been published and a further four science publications are in preparation, two of which are nearing submission. See Appendix 1 for details.

6 Impact on Meat and Livestock Industry

6.1 High input trade-offs

6.1.1 Fertilizer inputs and biodiversity

There is a clear trade-off between high input production systems and maintaining biodiversity (plants, birds and reptiles) in pastures. There is also a trade-off between high input systems and indicators of ecosystem function (e.g. perennial plant cover). Production systems that are driven by a need to maintain high levels of soil fertility (>20 mg kg^{-1} Colwell P) and high total stocking rates (>4-5 dse/ha) will tend to be species-poor and dominated by annual plants. Such systems will also fail to provide long-term habitat for fauna due to their requirement for tree and shrub persistence. Persistence and recruitment of such woody plants is either absent or extremely limited in high input pastures (see Dorrough & Moxham 2005). While these pastures are often productive, they will be more vulnerable to climatic variability and soil erosion owing to the vulnerability of perennial plants under conditions of high fertility combined with high grazing pressure.

The implication of this trade-off is that high levels of stock production obtained through the maintenance of high soil phosphorus, is not compatible with biodiversity maintenance within a single paddock. Maintaining plant and animal diversity on a grazing property will require at least part of the property to be managed using low input production systems – that is with no or very little phosphorus input and low total stocking rates. A discussion of proportions of different land uses that are required for biodiversity persistence in grazed landscapes can be found in McIntyre et al. (2002). It is worth noting the apparent dependence of native pasture plants on the maintenance of extensive low input land use at the landscape scale, identified in this project.

There would appear to be strong financial incentives to continue high input pasture management even at the cost of soil protection. No property that had <20 mg/kg P had a gross margin of over $200 per ha (see Fig. 17 Section 4.4). Only two properties had live plant cover over 50% (see Fig. 16 Section 4.4). With only a single exception a gross margin of more than $100 per ha was only achieved on properties that had less than 30% plant cover (see Fig 16 Section 4.4). While these low levels of cover can be rationalized because of drought conditions, minimum plant cover values of 60 - 70% are recommended to protect an irreplaceable natural resource, and this is required irrespective of season.

6.1.2 Adopting low input native pasture systems

Adoption of low-input extensive grazing systems are likely to have benefits for maintaining native plant diversity and perennial cover in pastures. If such systems are also accompanied by increased habitat complexity, through increased woody debris, variable ground layer tussock structure and tree regeneration, benefits to reptile and bird diversity are also expected.

We note that there is growing uptake of low input production systems amongst a subset of land managers. The uptake of low input systems is partly driven by higher input costs but also by perceived NRM and farm business benefits. An increasingly important vehicle for the adoption of these systems is the education and promotion of planned grazing systems (rotational grazing), which tend to emphasise low inputs and a greater focus on feed prediction and utilisation. These systems are often being actively supported by Catchment Management Authorities who see their adoption as playing an important role in contributing to catchment targets in relation to pasture, soils and water.

Managers using these production systems often claim significant increases in carrying capacity owing to paddock sub-division and more even livestock distribution and less nutrient concentration in camps. Such systems are also accompanied by a reduction in fertilizer use, as training emphasises direction of inputs towards management systems that improve utilisation i.e. fencing and water. Just over 50% of producers involved in this research project no longer fertilize their native pastures and of these most used rotational grazing systems. Although not statistically significant, owing to considerable variation in observed gross margins, results tend to suggest that adopting rotational grazing sy … ease being realised th … fertilizers most are u …

While ther … thout high fertilizer in … ion of high input syste … easons for the meat … and their rationalizat …

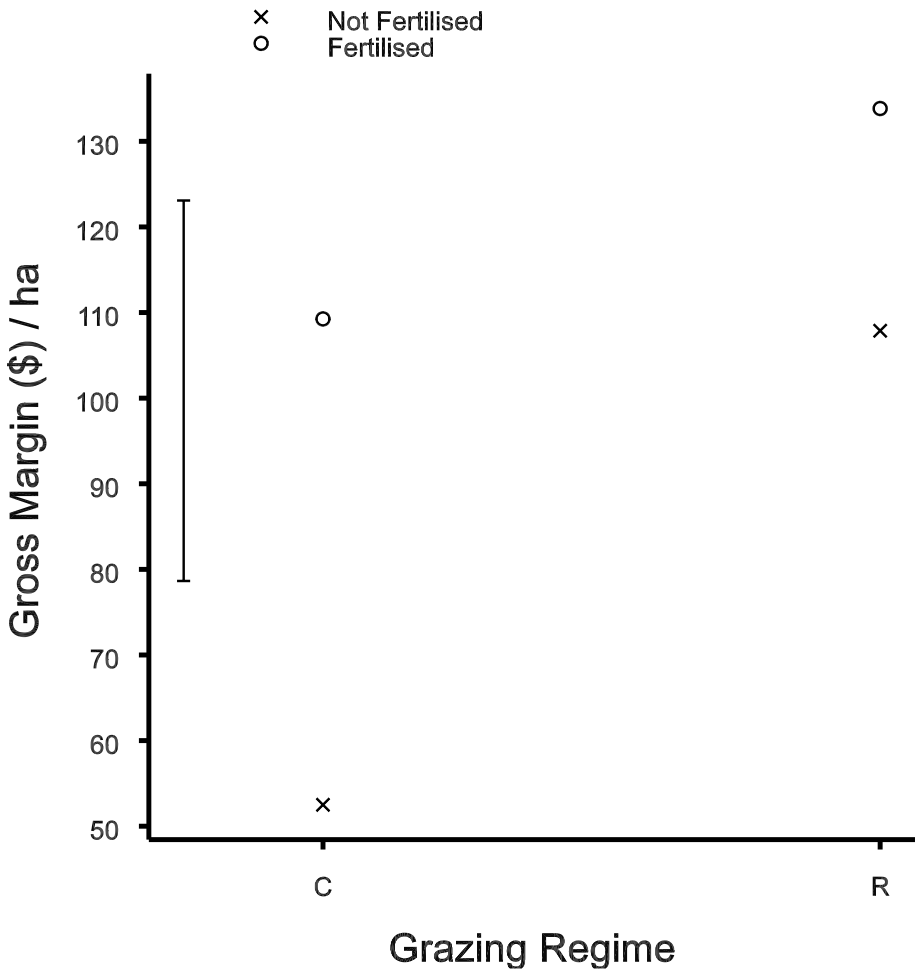

Figure 20 The average gross margin per hectare for continuous (C) and rotationally (R) grazed paddocks that are fertilized or not fertilized. Data based on 24 farms.

6.1.3 Promoting rotational grazing systems

While our results did not suggest a positive effect of rotational grazing systems for biodiversity, such systems are potentially quite compatible with high levels of diversity. No doubt there are groups of species that will not be favoured by such grazing systems (in particular note the negative response of birds to rotational grazing), but other species may be favoured in the longer term. However, what seems to be most important from the perspective of biodiversity management is, regardless of the grazing system imposed, best outcomes will be achieved under a low input system. Low input rotational grazing systems appear to provide a profitable pathway for management of native pastures. Greater adoption of these systems is predicted to have biodiversity benefits but as a virtue of the low levels of fertilizer inputs. Such systems may also improve perennial and total ground cover in these often erodible and high recharge landscapes.

6.2 Contribution to MLA key priorities and targets

The MLA Livestock Production Research and Development Strategic Plan for 2006-2011 lists a number of relevant priorities and key targets. Below we discuss what we see as the implication of our results for these.

This research project contributes to three of the five key areas identified in the plan:

- Healthy environments;
- Improved productivity;
- Building knowledge and capacity.

6.2.1 Healthy environments

This research project has developed new knowledge that contributes to a better understanding of how the meat and livestock industry can contribute to the management of biodiversity and remnant vegetation, reduce soil loss and recharge, improve water use and water quality and increase pasture resilience to climatic variability, in particular drought. The project team also actively engaged with industry (most notably landholders) through participation in seven field days, seven workshops and four conferences for land managers. There were also extensive consultations and interactions with stakeholders during the development and conduct of the project (including nine specific interventions, see Table 6).

The project has encountered and documented some excellent examples of environmental stewardship during the research. It is important to note that producers were not selected on their environmental credentials, or for their previous involvement in research or NRM programs. While there was evidence of concern for natural resources on most properties, evidenced either through action or from interviews and discussions (i.e. a positive environmental stewardship philosophy), the relationship between fertility, stocking rates and loss of biodiversity has yet to be assimilated by the broader population of producers and industry stakeholders. This is partially due to lack of information but also the difficulty acknowledging the existence of trade-offs, and that the solution to balancing conservation and production is going to be a constant sum game. That is, there is a fixed amount of natural capital that needs to be apportioned to production and natural resource conservation.

Our initial consultations and later field days and workshops identified a segment of the farming population with strong interests in biodiversity and broader natural resource management who have already decided to take less in terms of production, and are hungry for detailed information on biodiversity. A contrasting segment are those determined that there is a win-win outcome to be had.

6.2.2 Improving productivity

We have established that high input systems are compatible with biodiversity persistence only if limited in extent across landscapes. Within a lower input framework, a key path to improved productivity is through grazing management and reduction in costs of production. Native pastures appear to provide a valuable resource in this regard. Many producers are opting to take a low input, low cost approach to their management of native pastures. Our results and anecdotal testaments by several of the producers have revealed that management of native pastures using a low input approach can be profitable. These results are supported by previous Land Water and Wool Research on pastures in central Victoria (Moll, Dorrough & Crosthwaite 2005; Crosthwaite *et al.* 2006; Dorrough, Moll & Crosthwaite 2007; Crosthwaite *et al.* 2008), New England Tablelands of NSW and South Australia. Our unavoidable conclusion is that improving productivity for its own sake will pose major risks for the health and diversity of our grazed landscapes.

6.2.3 Building knowledge and capacity

In addition to extensive stakeholder consultation and communication (see 6.2.1) the project team has developed a producer management guide, for ongoing communication. In addition to landholders, we have strong relationships developed with catchment management authorities in NSW and Victoria. These organisations are developing extensive on-ground networks, several with strong focus on native pastures and grazing management systems. Several (e.g. the Lachlan CMA in NSW and Goulburn Broken CMA in Victoria) are providing both funding and networking support for alternative grazing management systems.

Workshops with on-ground CMA staff and NSW DPI pasture extension staff were seen as important approaches to extend research to those that will have more lasting contact with end-users than this research project. The secondary significance of the development of these links has been in developing a network of individuals and organisations prepared to promote and distribute the project management guidelines.

Our research results point strongly to the need for incentives for biodiversity stewardship in production landscapes where pressures to increase inputs and productivity can be strong. Our relationships with land management agencies has enabled appropriate information to be provided for the development of incentive schemes.

6.2.4 Profitable and sustainable producers – targets

Reduce cost of production (by 5%) : Native pastures can provide producers with an option for low input production systems. They have considerable potential to contributing to industry wide reductions in the cost of production, particularly in terms of fertilizer use.

Increase awareness of environmental risks and encourage relevant management practices by 20%: Knowledge developed in this project contributes to better understanding of the environmental outcomes of different native pastures management practices.

Key risks facing the industry in the landscapes supporting native pastures include biodiversity loss, paddock tree decline, management in face of climatic variability, soil loss, salinity and soil acidity. Management strategies to maintain diverse perennial native pastures are likely to provide producers with a low risk system, resilient to varying climatic conditions and maintenance of native biodiversity.

Increase skills, knowledge and confidence of producers (by 10%): Our extensive interactions with producers have included a) consultation which has acknowledged their role in providing information on production systems, pasture response and input into experimental design and layout; b) significant information dissemination regarding the influence of grazing management on biodiversity both during the project and subsequently through the availability of the information booklet. Our most direct contact was with the 24 producers on whose properties the research was undertaken. In relation to biodiversity and native pastures, we estimate that half of these producers would have substantially increased their knowledge, confidence and skills as a result of involvement in this project. Another 25% have probably received a small increase in knowledge and confidence, while the remainder are more aware, but knowledge, skills and confidence are largely unchanged. We estimate the project has had some contact with another 200-400 producers in the study region. The majority of these may only be aware of the research but a proportion (50-60 producers) have gained some knowledge or skills from the information disseminated.

7 Conclusions and Recommendations

7.1 *Diversity responses to woodland cover*

We looked at the response of native plants, reptiles and birds to pasture management variables (soil fertility, grazing management, retention of woodland) and the extent of native tree cover in the surrounding landscape. While the groups varied in their response to grazing and fertility, they all showed increased diversity or abundance when woodland was present in the paddock and in the wider landscape. **Conclusion:** The presence of woodland is critical to biodiversity in grazed landscapes, both in the paddock and in the wider landscape. Property and catchment planning needs to implement minimum tree cover targets through protection, regeneration and if necessary planting.

7.2 *Diversity responses to pasture fertilization*

Plants and reptiles responded negatively to increasing soil phosphorus, while birds did not respond. However, as bird richness and abundance was highly dependent on trees, and tree population health is adversely affected by fertilization, it can be inferred that all biodiversity groups studied are adversely affected by fertilization, if only indirectly. Of the factors analysed, available phosphorus was the strongest factor reducing native plant diversity. **Conclusion:** High input pasture management is not compatible with maintaining native plant diversity and has a indirect negative influence on birds and reptiles. There needs to be an appropriate balance of high- and low-input management on farms to maintain biodiversity in regions.

7.3 *Diversity responses to grazing*

There was no difference between rotational and continuous grazing management in terms of the diversity of native plants and the abundance of reptiles. Bird richness and abundance were reduced under rotational grazing. Stocking rate had a variable effect, with high stocking rate reducing native plant richness, having no effect on bird diversity and increasing reptile abundance.

Conclusion: A range of grazing intensities should be provided within or between paddocks to create the variety of sward structure and defoliation intensities to cater for the range of species requirements. There is still some ambiguity about the role of rotational grazing, but it certainly cannot be assumed to enhance diversity, and using it to create highly uniform sward structure across all paddocks will be of doubtful value to biodiversity persistence.

7.4 *Pasture management and ecosystem function*

The loss of perennial grasses is considered a key factor in the deterioration of ecological condition, compromising the production base and increasing risk under conditions of drought. On the properties studied, the loss of native plant species invariably led to the replacement of perennials with exotic annuals. All the sites sampled had native plant cover of less than 50% and only two had total plant cover of over 50%. These are well below minimum levels required for the protection of soil and it can be concluded that the soil erosion risk is high. Higher gross margins were associated with lower levels of native and total plant cover.
Conclusion: As gross margins were higher on fertilized paddocks, it can be concluded that profitability in grazing enterprises has come at a cost to the ecological condition of properties through loss of native perennial cover and loss of total plant cover. While the observations were made during a drought, these mitigating circumstances do not make the systems less vulnerable to over-utilization. Droughts are the key periods when minimum cover levels need to be adhered to.

7.5 *Diversity and profitability*

There was no evidence that high diversity was associated with higher gross margins. This is consistent with the positive relationship between available phosphorus and gross margins, and explains the enduring success of pasture improvement technologies. However, the environmental cost of high input systems are being felt in a range of ways including loss of native species, soil degradation, watercourse deterioration and loss of landscape amenity.
Conclusion: Low-input production systems need to be further understood and promoted, even if there is cost to short-term profitability. The role of land management agencies is going to be important in providing a vision for the landscape and incentives for land stewardship.

In summary, the conclusions remain consistent looking at the results in a number of ways, and are in accord with previous research; i.e. there is a fundamental trade-off between higher levels of utilization and the amount of natural capital that is required to maintain the diversity and ecosystem function of the grassy eucalypt woodlands.

There is clearly scope for individual action, as evidenced in the variation across the properties studied. A number of paddocks did have retained woodland, reasonable diversity and/or low phosphorus, and recorded moderately high gross margins at the same time. Better profits overall from low-input systems are undoubtedly achievable with the right research focus and producer commitment. In addition, we met some highly motivated individuals who were actively managing for lower production as an acceptable trade-off to achieve lower risk, the enjoyment of wildlife, and improved resource condition. Some forms of rotational grazing appear to provide an appropriate tool and philosophical structure to assist many such individuals in meeting these goals.

In the absence of larger holdings or alternative incomes, many producers will not feel in a position, or be willing to change their management philosophy.

Indeed, high-input systems will continue to require improvement and have a role. Our constraint needs to be in the type, location and extent of these intensive land uses, taking a whole property and landscape perspective. This concept has been well articulated through publication and promotion for over five years but has failed to gain acceptance, primarily due to the unaccustomed notion of restricted production. This is the challenge facing MLA.

8 Acknowledgements

This work was conducted as part of the Future Farm Industries CRC (previously the CRC for Plant-based Management of Dryland Salinity). We would particularly like to thank and acknowledge the following for their significant contributions to this research project: Austin Brown, Department of Primary Industries, Victoria; Vivienne Turner, Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, Victoria; Alex Drew, Judith Harvey, Mason Campbell and Margaret Cawsey CSIRO Sustainable Ecosystems, Jim Moll (formerly Goulburn Broken CMA) and Cameron Allan and Warren Mason, Meat and Livestock Australia. We would also like to thank the great range of individuals and organisations that assisted in finding field research sites, participated in or organised field days and provided feedback on our work, including property owners and land managers; non-government farm and business consultants and agronomists; the Murray, Murrumbidgee, Lachlan, Goulburn-Broken and North-east Catchment Management Authorities; Department of Primary Industries, Victoria and NSW; NSW Department of Environment and Climate Change; Grassy Box Woodlands Conservation Management Network; CSIRO Entomology; Australian Superfine Wool Growers Association; Stipa Native Grasses Association; Grasslands Society of Southern Australia; Principle Focus; The Farm Business Gym; Charles Sturt University; University of Melbourne. We would like to thank Chris Hunt, Nick Goldie, Garry Johnson, Max Bowran, Phil Diprose, Rosemary Hook, Tony Nott, Greg Lawrence and John Powell for their inputs into communication aspects. Special thanks to the producers on whose properties this research was carried out.

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10 Appendices

10.1 Project Publications

10.1.1 Management Guidelines

Dorrough, J., Stol, J. & McIntyre, S. (2008) *Biodiversity in the Paddock: a land managers guide* Future Farm Industries Co-operative Research Centre.

10.1.2 Producer Articles

Dorrough, J. & Filmer, M. (2007) Grazing strategies give farmers an edge in biodiversity. *Farming Ahead*, **188**, 56-58.

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10.1.3 Research Papers

Dorrough, J., Stol, J. & McIntyre, S. (2007). Drought, grazing management and habitat structure in native pastures. *Native grasses for a thirsty landscape. Proceedings of the 5th Stipa National Native Grasses Conference on the Management of Native Grasses and Pastures, 7th - 10th October 2007. Mudgee, NSW* (ed C. O'Dwyer), pp. 71-77. FLFR University of Melbourne, Dookie.

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Dorrough, J., McIntyre, S., Barrett, G., Brown, G.W. & Stol, J. (in preparation) Differential response of plants, reptiles and birds to grazing practices in grassy woodlands *To be submitted to Oikos*.

Barrett, G., Dorrough, J., McIntyre, S., Drew, A. & Stol, J. (in preparation) Livestock grazing and ground-foraging birds *To be submitted to Wildlife Research*.

Dorrough, J., Martin, T.G., Scroggie, M.S. & McIntyre, S. (in preparation) Use of plant traits as informative priors predicts plant response to agricultural intensification.