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Sustainable development of VRD grazing lands

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Abstract

As production costs rise faster than prices received pressure is building to intensify production on extensive northern pastoral beef enterprises. Creating smaller paddocks and installing more waters are expected to improve forage use but limit the incidence of overgrazed patches, offering the potential for a substantial increase in cattle numbers and financial returns. But intensification also presents financial and ecological risks so guidelines for appropriate development are required. Based on the early results from this project utilisation rates of 20-25% appear to be sustainable in terms of land condition and animal production where water points are well distributed. However, the longer term implications for biodiversity are still inconclusive, as are the relative advantages and disadvantages of achieving higher utilisation rates by only increasing the number of water points versus increasing the number of waters and reducing paddock size.

Executive Summary

On pastoral beef enterprises in northern Australia pressure is building to intensify production as production costs rise faster than prices received. Opportunities to benefit from intensification are most apparent in large enterprises that have historically had relatively poor water and fencing infrastructure development resulting in uneven use of the available landscapes by livestock. Creating smaller paddocks and installing more waters are expected to result in more uniform grazing distribution across the landscape which in turn may allow stock numbers to be increased without greatly increasing effective forage utilisation rates across individual paddocks.

Numerous factors will determine the optimal degree and type of infrastructure development for increasing landscape use but our understanding of these is poor. For example, we do not know whether more even grazing distribution can be achieved solely by adding water points to a paddock, avoiding the need to subdivide large paddocks. If subdivision is necessary it is not known what paddock size and distance from water is optimal in terms of cost and evenness of use. Also, given that the objective is to increase overall forage utilisation it is critical to know the thresholds of sustainable pasture use. Other benefits also exist. Another advantage of increased sub-division is better animal control, which presents opportunities to spell paddocks, use fire to overcome patch grazing, and facilitates mustering with the potential for cost savings.

Intensification therefore offers benefits in terms of improving productivity per unit area and increased flexibility to improve grazing management and land condition. However, there are also ecological and financial risks in intensification. These include the potential loss of biodiversity, the loss of landscape heterogeneity that may buffer against declines in animal productivity in times of drought, a decline in land condition through overgrazing and increased susceptibility to variation in prices or demand because of the higher cost structure.

The challenge therefore is to make the most of the opportunities intensification offers but avoid any negative consequences. To guide intensification this project investigated optimum rates of forage utilisation and alternative water point and paddock configurations, and assessed the effects on grazing distribution, forage and cattle production, and biodiversity. Options for maintaining biodiversity and the economic-environmental trade-offs were also examined. The objectives of the project were to:

1. Inform all producers in the Victoria River Downs (VRD) district (Northern Territory) of locally-derived relationships between pasture utilisation and pasture and animal parameters, including the impact of variable levels of utilisation on pasture dynamics, pasture condition trends and pasture sustainability.
2. Identify and understand the key factors and processes influencing sustainable grazing at the paddock scale in the VRD, in particular: optimal levels and systems of pasture utilisation; the distribution patterns of grazing cattle; the role of the development options of paddock design and water placement; and, the impact of pastoral development options on biodiversity conservation.
3. Identify management guidelines for sustainable and profitable pastoral development.
4. Inform north Australian beef producers of the relationship between grazing behaviour, land condition and animal production and provide the information and decision support tools to implement change on their properties to improve financial and land management performance.

This research was conducted at a commercial scale on a 320 sq. km site at Pigeon Hole Station, and was supplemented by studies of different forage utilisation rates in small paddocks at Mt Sanford Station. Utilisation treatments have been in place at Mt Sanford for five years, while grazing treatments at Pigeon Hole have been applied for only three years. Based on the longer term results from Mt Sanford some guidelines can be provided about safe utilisation rates.

However, the longer term implications for biodiversity are still inconclusive as are the relative advantages and disadvantages of achieving higher utilisation rates by only increasing the number of water points versus increasing the number of waters and reducing paddock size.

Indications from the utilisation study at Mt Sanford are that utilisation rates can be safely increased to 20-25% where infrastructure developments make it possible to achieve relatively uniform grazing distribution within paddocks. At these rates of utilisation no adverse effects were observed on pasture productivity, ground cover or livestock production. The combination of higher utilisation rates (36-43%) and a poor wet season appeared to degrade the land resource, which has adversely affected subsequent weaner production. Utilisation rates of 20-25% are twice the district average of about 10% (although on some properties rates of 20-25% might already be used). The utilisation studies at commercial scales at Pigeon Hole are yet to provide any evidence in support of, or contrary to, this recommendation.

At this point in the study it is reasonable to draw the following conclusions in relation to paddock size and water point configuration. Smaller paddocks (down to about 10 sq. km) result in greater use of the landscape as a whole, and are more effective in achieving even use than simply adding additional water points to large paddocks (>60 sq. km). Smaller paddocks therefore appear to be the most effective way to increase the use of pasture resources across the landscape. However, reducing paddock size does not overcome the problem of cattle grazing being concentrated on preferred areas within paddocks (e.g. red soil patches and riparian zones), with the risk that these areas will continue to be overgrazed and become degraded. We are not yet able to specify an optimum paddock size as this will also be a function of any benefits in livestock production, the cost of creating smaller paddocks, and the likely impact on pasture resources. Livestock production and pasture data are yet to show any strong trends in relation to paddock size, grazing radius and the number of water points, but this is not unexpected after only three years. It is expected many pastoralists will choose the cheaper option of installing more waters rather than subdividing large paddocks until there is clear evidence of benefits to livestock production, despite the other advantages offered by subdivision.

It is not yet possible to draw robust conclusions from this study on the implications for biodiversity of the various pastoral development options. Previous experience suggested that black-soil grassland systems are relatively resilient to grazing impacts and this study has confirmed that there are not significant short-term impacts on biota from relatively high levels of utilisation. In order to develop defensible management recommendations it will be necessary to continue monitoring the treatments into the medium-term.

An economic and environmental analysis of six scenarios with differing intensification options suggested that installing more water points is likely to generate the greatest gains in return on capital with the smallest environmental trade-off. Scenarios involving wet season spelling and cell grazing showed no improvement in return on capital compared with current practice, but the former produced a substantial environmental benefit through improvements in pastures and soils.

This project is expected to have a substantial impact on the extensive beef industry in northern Australia over the next five years. The project has begun to highlight the opportunities for, and ecological and economic limitations to, an expansion of the industry. Based on the results from Mt Sanford that suggest utilisation rates of up to 25% are sustainable, it is reasonable to conclude that there is potential for considerable expansion of the industry through developing properties to allow higher stocking rates. For development to occur wisely, robust guidelines based on a good understanding of development options and their ecological and economic effects in the longer term are required. At this stage it is too early for this study to provide those guidelines so the continuation of field studies at the Pigeon Hole site is strongly recommended.

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1 Background

1.1 The issues

Pastoral landscapes in northern Australia are undergoing rapid change as momentum builds to intensify production. There are a number of drivers of this push to intensify production. Like all other parts of agriculture, costs are rising faster than returns. During the 1980s and 1990s, improvements in herd management, supplementary feeding and infrastructure development provided the platform for the northern pastoral industry to intensify its production. Sustained good prices for cattle and beef from the late 1990s until the present time have provided the economic means to implement more intensified production. Farm cash incomes in northern Australia seem to have particularly benefited from these improved prices, with a noticeable gap in farm cash incomes emerging between beef properties in northern Australia and southern Australia in recent years (ABARE 2005). The main market for northern Australian beef is the live export trade into south-east Asia. Over recent years the demand for beef from this market has been stable and this has provided a base to the market and given the northern pastoral industry added confidence. Although northern Queensland has experienced more El Nińo climate events than normal over the last 25 years which has resulted in below average rainfall compared with long-term averages, much of the remaining northern Australian rangelands have had above average seasons during the same period. These favourable seasons are also influencing some of the plans to intensify production.

The benefits and risks of intensification have recently been discussed by Stokes *et al*. (2006). Opportunities to benefit from intensification are most apparent in large enterprises that have historically had relatively poor water and fencing infrastructure development resulting in uneven use of the available landscapes by livestock. Improving water distribution may allow stock numbers to be increased without greatly increasing effective utilisation rates across individual paddocks. Development of water points to lift animal numbers is now more cost effective than acquiring more land e.g. water infrastructure costs are in the order of $200-$500 per beast area compared with land which is currently over $2000 per beast area in the very extensive grazing lands. Key questions that need to be answered in developing more water-points are:

- Can more even grazing distribution be achieved with additional water points in a paddock without subdividing the paddock?
- If not, can animal behaviour be modified to achieve more even use e.g. rotating the use of different water points or use of fire and supplements?
- If subdivision is necessary what paddock size and distance from water is optimal in terms of cost and evenness of use?
- Given that the objective is to increase overall levels of utilisation, what are the thresholds of sustainable pasture use?

One advantage that increased sub-division provides is better animal control, which provides a number of opportunities:

- Better management of grazing pressure through rotational grazing systems. There is little opportunity to completely rest large paddocks but a larger number of smaller paddocks allows resting strategies such as wet season spelling to be introduced to improve land condition, though there can be increased management costs associated with more intensive grazing systems.

- More flexibility to successfully use fire to manage grazing pressure and overcome uneven grazing at patch scales (Andrew 1986).
- Lower mustering costs through reducing reliance on expensive helicopter mustering. This may have some additional benefits in terms of animal handling and temperament.

In summary the main benefits of intensification are in improving productivity per unit area and in having greater flexibility to improve grazing management and land condition.

However, there are also a number of risks with intensification. These include:

- Potential loss of biodiversity. The increased availability of water sources opens up previously ungrazed areas that may provide refugia for grazing-sensitive species (Woinarski and Fisher 2003). Also higher levels of utilisation at smaller spatial scales tend to homogenise the landscape and remove a more diverse grazing regime in both time and space that likely contributes to plant and animal species diversity.

- Loss of landscape heterogeneity. By reducing the spatial scale of grazing through paddock subdivision it is likely that diet choice is reduced. Large heterogeneous paddocks may provide some buffering against density dependent declines in animal productivity that occur with increasing stocking rate (Ash *et al*. 2004), especially in times of drought. In addition, the greater diet choice in larger paddocks may be of benefit during the dry season when protein in particular becomes a major limiting factor in the diet.

- Decline in land condition through overgrazing. While it is argued above that increased infrastructure provides increased flexibility to better manage grazing pressure it is likely that in intensified systems grazing pressures will, on the whole, be maintained closer to ecological thresholds. Early warning monitoring systems must be put in place to avoid the risk of crossing these thresholds when either mistakes in grazing management decisions occur or when unexpected events occur e.g. extended wet seasons preventing mustering, or unwanted fire.

- A system with more external inputs will be more susceptible to outside influences e.g. an intensively managed property may be more prone to fail if prices or demand fall (say mad cow disease occurs in Australia) as they have a higher cost structure and less capacity to adjust.

The challenge for pastoral management is to make the most of the opportunities intensification offers and to avoid any negative consequences. This challenge should not be underestimated because intensification involves a complex array of changes and decisions that interact and involve strong feedbacks. A systems approach combined with adaptive management is needed to successfully address these challenges of pastoral intensification.

To address these challenges, a partnership developed between Heytesbury Beef, MLA and key R&D agencies (NT Government, CSIRO, the University of Queensland) to undertake a major experimental study in the Victoria River Downs (VRD) district in the Northern Territory. The Northern Beef program became involved in the project by initiating underpinning research in three key areas:

1. Identifying optimum levels of pasture utilisation;
2. Enhanced understanding of grazing distribution at paddock scales for improved fencing, paddock design and water placement;
3. Implications of pastoral development options for biodiversity conservation.

The following sub-sections provide more detail to each of these activity areas. Also described is an economic and environmental analysis of a number of development scenarios.

1.2 Activity 1 - Identifying optimum levels of pasture utilisation

A 1997 survey in the VRD of 134 paddocks found paddock stocking rates averaged 11 AE/sq. km and ranged from 5-35 AE/sq. km (Dyer et al. 2003). Forty percent of paddocks were stocked at less than 10 AE/sq. km. Based on modelled pasture growth, 11 AE/sq. km is equivalent to a utilisation rate of 25% on red and 15% on black soils in a median rainfall year (Dyer et al. 2003). At the time of the survey however, this represented utilisation rates of just 13% on black soil or 21% utilisation on red soil (Dyer at al. 2003). (Note: one AE = one animal equivalent = one 450 kg dry Brahman cow.)

However, while average utilisation rates were low to moderate, paddock sizes are large and 40% of the VRD is greater than 4km from water (Fisher 2001), resulting in areas close to water being overgrazed, while far from water utilisation is very low. Cattle producers in the region recognise the potential for further development and in a recent survey of cattle producers in the Katherine region (Oxley 2006), producers estimated that carrying capacity could be increased by 25% in the next five years and 42% in the next 10 years with current development plans, with 80% of producers having immediate plans to develop further water points and subdivide paddocks.

However, there is currently little local information on sustainable carrying capacity of the region. This study will provide objective estimates of sustainable utilisation, and facilitate infrastructure development based on realistic production capacity estimates, which will hopefully avoid the over-development of the rangeland that has occurred in some parts of the eastern savannas (Stokes 2004).

Key Hypotheses:

1. Decreasing large paddock size and distance to water enables increases in average utilisation rates, animal production per hectare and profitability, whilst maintaining or improving land condition.
2. At the 2000 ha scale there is an optimum utilisation rate beyond which animal production and land condition decline.
3. In 2000 ha paddocks with a grazing radius of 3 km, evenness of grazing does not vary with utilisation rate.

1.3 Activity 2 – Enhanced understanding of grazing distribution for improved fencing, paddock design and water placement

In northern Australia cattle properties are typically very large and have poorly developed infrastructure (i.e. fences and water points). As a result paddocks are large and water points are widely separated. For example, paddocks in the Victoria River Downs (VRD) district are typically 100-150 sq. km in area and usually have only two or three water points. This situation limits the degree of control management has over livestock and thus their use of, and impact on, the landscape and vegetation. Because of the freedom afforded cattle in their use of the landscape, there is uneven use and high utilisation around water points and preferred areas so there is a need for using low stocking rates to limit the degree of utilisation in these heavily used parts of the landscape. Consequently, there is limited overall use of pasture by livestock because of uneven use of paddocks by cattle. Increasing the level of development offers the opportunity to increase outputs and profitability partly because more even use of the landscape that is expected will result in more effective use of pasture, less degradation of heavily used areas and therefore allow more stock to be carried – increasing the level of production.

Reducing paddock size or increasing the numbers of water points per paddock are considered potentially effective ways of improving grazing distribution. Reducing paddock size is the approach that was used in the early development of rangelands in southern Australia (Lange et al. 1984). Nearly all experimental programs have focussed on reducing paddock size. In such studies it is assumed that animal production will be improved compared with large paddocks that have limited waters, but this has rarely been quantified so the economic and ecological trade-offs can be assessed. Also, no work has been conducted to assess the relative effectiveness of these two strategies in improving landscape use and thus limiting the problems associated with large paddocks. For the VRD it is not known what is the optimum paddock configuration (i.e. size and number of water points) and how environmental factors such as topography, soil type, plant community and wind direction interact with infrastructure to influence landscape use by cattle.

There are several factors to be considered in the choice of options for managing grazing distribution. Reducing paddock size by fencing is far more costly than only increasing the numbers of waters in a large paddock. Also, reducing paddock size often reduces the diversity of landscapes and habitats within a paddock. Such diversity can be important in offering a wider dietary choice to livestock, which may allow buffering of declining animal productivity particularly during the dry season and droughts when protein is deficient. Maintenance of landscape diversity has been recognised as being important for large herbivores in natural grazing systems in Africa (Scoones 1995).

This issue of landscape diversity raises important questions. Does maintaining large paddock sizes that are diverse but have good water distribution have advantages over reduced paddock sizes through better landscape-animal interactions that improve animal performance? Does increasing waters even out grazing distribution as much as reducing paddock size, or do animals end up favouring particular water points at the expense of animal production and land condition? Can we better understand foraging behaviour and the effects of paddock size, water point number and landscape features (e.g. soil type, location of water, preferred plant communities and landscape elements such as riparian areas) to improve paddock design and location of water and supplement points? Understanding these issues is of critical importance to the management of extensive beef grazing systems since they will have implications for both the inputs (infrastructure costs) and outputs (animal performance and resource condition) of the beef enterprises.

Key Hypotheses:

1. There is an optimum maximum distance to water for evenness of use and land condition.
2. There is an optimum maximum distance to water for animal production.
3. Increasing spatial scale and landscape diversity reduces coupling between utilisation rate and animal production per head such that the usual linear decline in animal production per head with increasing utilisation rate observed at small spatial scales is dampened at large spatial scales.
4. Increasing landscape diversity will result in more uneven use and more land in poor condition (independent of distance to water).

1.4 Activity 3 - Implications of pastoral development options for biodiversity conservation

In northern Australian rangelands, pastoral lands play an important role in biodiversity conservation. Due to the lack of broad-scale land clearing and retention of native perennial pastures, many biodiversity values persist in the very extensive areas under pastoral management. Pastoral lands provide a linkage between conservation reserves and habitat for many mobile species. However, many land types of relatively high pastoral value are unrepresented or poorly represented in the conservation reserve system. A number of government conventions, strategies and other initiatives now recognise the very important role of “off-reserve” conservation in the maintenance of biodiversity in the Australian rangelands. There is also a general recognition within the pastoral sector that sustainable pastoral use includes the maintenance of regional biodiversity values and that demonstrating the ecological sustainability of pastoral use will form part of the development of an Environmental Management System or other form of environmental accreditation.

Sustainable pastoral management will ensure the maintenance of many biodiversity values. However, recent research suggests that in most rangeland regions (including Mitchell grasslands) there are grazing-sensitive species amongst many plant and animal groups that are only abundant in water-remote or lightly-grazed areas. The “best-practice” approach of increasing the number of stock watering points and spreading grazing load evenly across the landscape may in fact conflict with the ideal management approach for these native “decreaser” species, which would require portions of a pastoral region to be retained as water-remote or lightly grazed. This issue is likely to be of particular significance where there is an intensification of pastoral use at a property or regional scale. In this case, specific management actions may be required to safeguard biodiversity values, such as setting aside a portion of the property for conservation management. Currently, however, there is little specific data to inform decisions about how large such “conservation areas” should be, or how they should be managed. Additionally, further data is required for individual land types and species-groups on what the threshold of pasture utilisation is before declines in decreaser species are observed, and at what scales of evenness of use are impacts on biodiversity most pronounced.

There are a number of key questions that must be addressed in order to ensure that intensification of pastoral use can be managed in an ecologically sustainable manner:

- what is the response of biota to different levels of utilisation? Are there threshold levels of utilisation for biodiversity decline and do these vary between various components of biodiversity?
- does increased evenness of use lead to declines (or improvement) in biodiversity?
- what minimum area of high-quality habitat (e.g. with low or zero utilisation) is required for the persistence of various components of biodiversity? What management is appropriate within “conservation areas” to maintain biodiversity values?
- what are the economic and logistic costs of integrating biodiversity conservation with pastoral management?
- to what extent are the tools and indicators applied to pasture monitoring effective as indicators of biodiversity status? Are there effective “early-warning” indicators of biodiversity decline in this system? How can biodiversity monitoring be integrated with other monitoring protocols in a way that can guide adaptive management?

Key Hypotheses:

1. There is a threshold of pasture utilisation (at a paddock level), above which there are marked declines in biodiversity values.
2. It is practical and cost-effective to integrate "conservation areas" of high quality habitat into an intensified pastoral property that achieve desired biodiversity outcomes.
3. The size of conservation areas required to sustain local wildlife populations will vary between taxa, but appropriate minimum areas can be identified.
4. It is possible to develop biodiversity indicators that can be integrated with pasture/land condition monitoring to guide adaptive management.

1.5 Economic and environmental analysis

Any significant changes to property management are likely to have both environmental and financial impacts. This is particularly true of management changes that involve intensification of grazing and land development activities; and raises the question of what these impacts will be. It is unlikely that the environmental and financial impacts will always both be positive, and tradeoffs will be required to meet both environmental and financial objectives. To assist the task of making sound choices, the nature of these trade-offs and their magnitude need to be identified and assessed.

Most decisions on grazing land management are made and implemented at the property level, and assessments of ecological and economic trade-offs need to be made at this level. McIvor and MacLeod (2004) developed an assessment framework that calculates and compares the environmental and financial performance of a property under some proposed management change with that of the current operation. The comparison is of two static situations (before and after implementing the change), not of what happens during the period of change. In the first step in using the framework, the existing management on the property is defined and then assessed in both ecological and financial terms, and an assessment of tradeoffs is made. A review is made of possible management options to determine what is technically possible and what fits with property management. These are then incorporated into a new management scenario, and the assessment of the ecological and financial impacts and tradeoffs is repeated.

In a subsequent study (McIvor and MacLeod, in preparation), the assessment framework was revised to improve the assessment of impacts on biodiversity and another environmental attribute (fire regime) was added to give a total of ten environmental attributes. Seven of these (soils and hydrology, pastures, weeds, feral animals, riparian areas, atmosphere and fire regime) describe the maintenance of ecosystem function and stability, and the other three (native vegetation communities, native plant and animal species, and significant sites and habitats) describe conservation of biodiversity.

The likely impacts of management options on carrying capacity, breeding performance and annual liveweight gain are combined with the costs of the activities to assess the changes to financial performance of the property (gross margin, net profit, return to capital and capital value). These are presented as indices relative to the baseline operation. Likely impacts of the management activities on each of the 10 environmental attributes are described on a scale from –3 (large negative impact) to +3 (large positive impact).

2 Project Objectives

By completion of the project in October 2006:

1. One hundred percent of producers in the VRD will be aware of locally derived relationships between pasture utilisation and pasture and animal parameters, including the impact of variable levels of pasture utilisation on pasture dynamics, pasture condition trends and pasture sustainability.

2. The key factors and processes influencing sustainable grazing at the paddock scale in the VRD, Northern Territory will have been identified and understood, in particular: optimal levels and systems of pasture utilisation; the distribution patterns of grazing cattle; the role of pastoral development options of fencing, paddock design and water placement; and, the impact of pastoral development options on biodiversity conservation.

3. Management guidelines for achieving sustainable and profitable pastoral development will have been identified.

4. Twenty percent of beef producers in northern Australia will be aware of the relationship between grazing behaviour, land condition and animal production and have the information and decision support tools to implement change on their properties to improve financial and land management performance.

3 Methodology

3.1 Overview

This study involved major experimental sites at both Pigeon Hole and Mt Sanford Stations (Fig. 3.1). This research project was undertaken at an unprecedented scale either nationally or globally. The experiment involved nearly 40,000 ha of land and on average 5000 head of cattle so it was a major logistical undertaking in infrastructure development, ongoing management and data collection, analysis and interpretation.

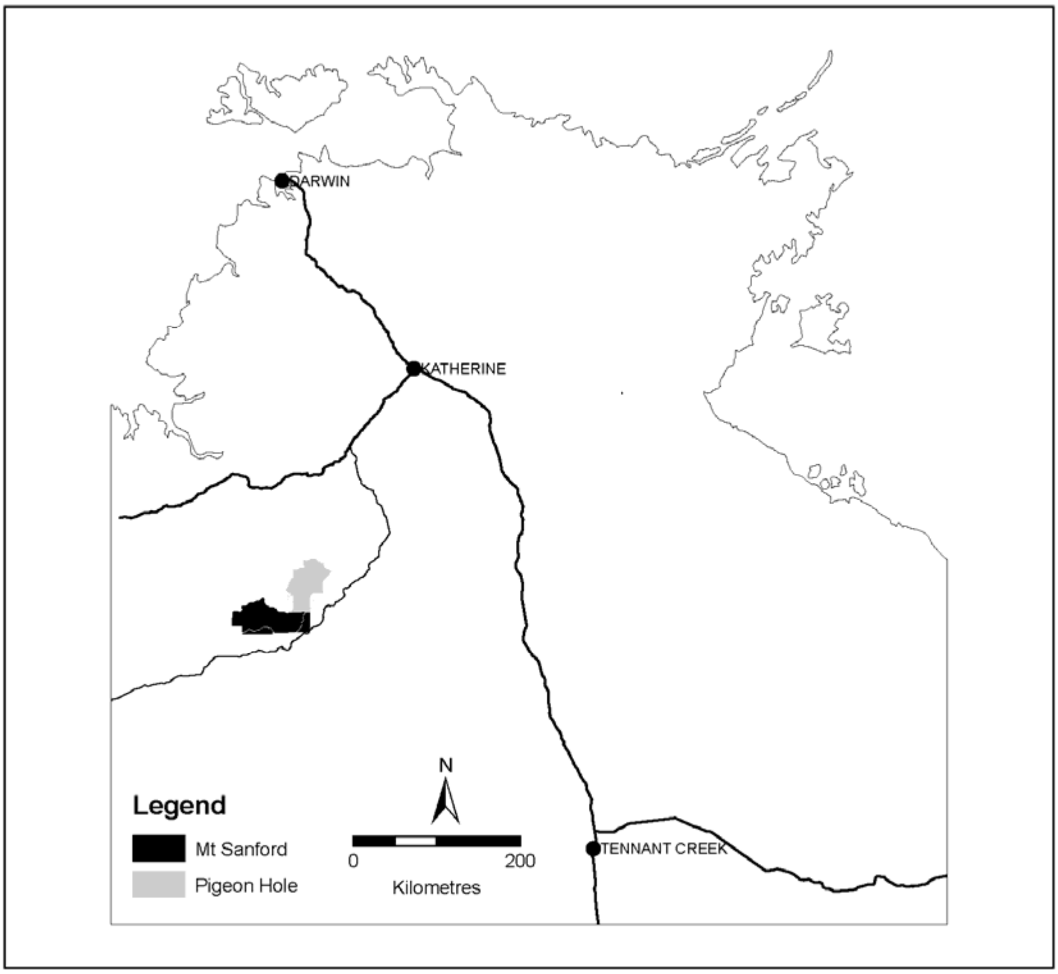


Figure 3.1. Locality map of Mt Sanford and Pigeon Hole Stations, Victoria River District, Northern Territory.

The Mt Sanford paddocks were in place because of their previous use as a stocking rate demonstration site and so utilisation treatments commenced there at the outset of the project. Major fencing and water infrastructure was required at Pigeon Hole Station. It was originally planned to have all treatment paddocks at Pigeon Hole ready for stocking by the first round mustering in May 2003. However, there were some delays in putting in fences and water points so treatment paddocks were not ready for stocking until September 2003. The experiment was stocked according to treatments following second round mustering in October 2003.

In October 2002, pasture and biodiversity sampling exercises were undertaken to test sampling methodologies in preparation for the start of the experiment in 2003. There was a considerable challenge in developing sampling methodologies that were both practical in terms of the research budget and human resources available and which yielded useful information at the paddock scale for treatment comparison and some understanding of spatial patterning within paddocks, a key area of interest in this study where spatial interactions are important.

3.2 Activity 1 - Identifying optimum levels of pasture utilisation

3.2.1 Experimental design

The most appropriate experimental approach was to derive a response curve relating animal production and a number of pasture variables to a range of utilisation levels. For the purposes of this study utilisation was defined as the amount of pasture consumed in a year as a percentage of total standing biomass at the end of the wet season. The utilisation rates used needed to cover the range from conservative levels (c. 10%) up to levels that were not expected to be sustainable in the long-term (c. 45%), but which may offer high levels of animal production per unit area in the short-term. There needed to be at least five utilisation rate treatments so that a reasonable response curve could be derived.

Two experimental scales were adopted to meet the needs of this utilisation study.

3.2.1.1 Mt Sanford

Experiment one involved using the Mt Sanford stocking rate site that was established in 1994 to investigate pasture, animal and biodiversity responses to stocking rate. The stocking rate treatments were converted to utilisation rate treatments in 2001. The change in stocking treatment for the current experiment was from constant stocking to constant utilisation i.e. animal numbers were altered each year to achieve the desired utilisation rate. Variable stock numbers in treatment paddocks were achieved by adding or removing spayed cows to the base population of breeders.

The utilisation rates were 11%, 16%, 22%, 28%, 35%, 45% (see Table 3.1, Fig. 3.2). The six years of stocking treatments from 1994-2000 provided an opportunity to gain a longer term view of the impacts of different levels of stocking on pasture and animal performance i.e. by 2006 there were 13 year's data on stocking/utilisation rates at Mt Sanford. However, the Mt Sanford treatment paddocks were at sub-commercial scale, with paddock sizes ranging from 4 to 8 sq km.

Table 3.1. Summary of treatment paddocks and animals used in the Mt Sanford utilisation study. Note: One animal equivalent = 450 kg dry Brahman cow.

Paddock Name	Area (ha)	Average Stocking rate May 2001 – May 2006 (animal equivalents per km^2)	Target and (average adjusted) utilisation rate May 2001 – May 2006
Parrot Creek	758	12	12 (12)%
Pigeon	587	17	16 (19)%
Budgie	431	18	22 (21)%
Wedgetail	497	22	28 (28)%
Quarrion	803	27	35 (36)%
Larry Mac	481	38	45 (43)%

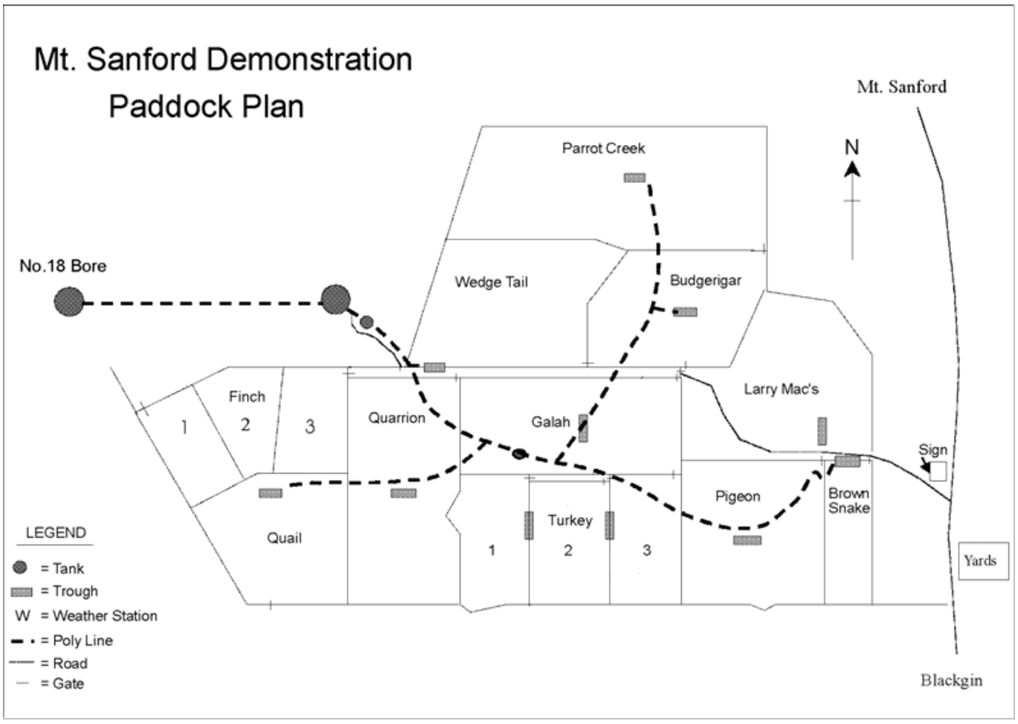


Figure 3.2. Layout of the Mt Sanford study site.

3.2.1.2 Pigeon Hole

In experiment two, the animal and pasture response to increasing utilisation at commercial scales was explored on Pigeon Hole Station. Paddock sizes were 20-22 sq km and five utilisation treatments were established: 15%, 20%, 25%, 30% and 40% (Fig. 3.3, Table 3.2). As with the Mt Sanford utilisation treatments stock numbers were adjusted each year based on standing pasture biomass at the end of the wet season. Paddocks were stocked largely with breeders, but 25 or 26 steers were also included in each treatment to give a reliable measure of liveweight change in growing animals. Stock numbers were altered to achieve desired utilisation rates through the use of spayed cows and/or young heifers as “dummy” animals. No data was collected on the dummy animals.

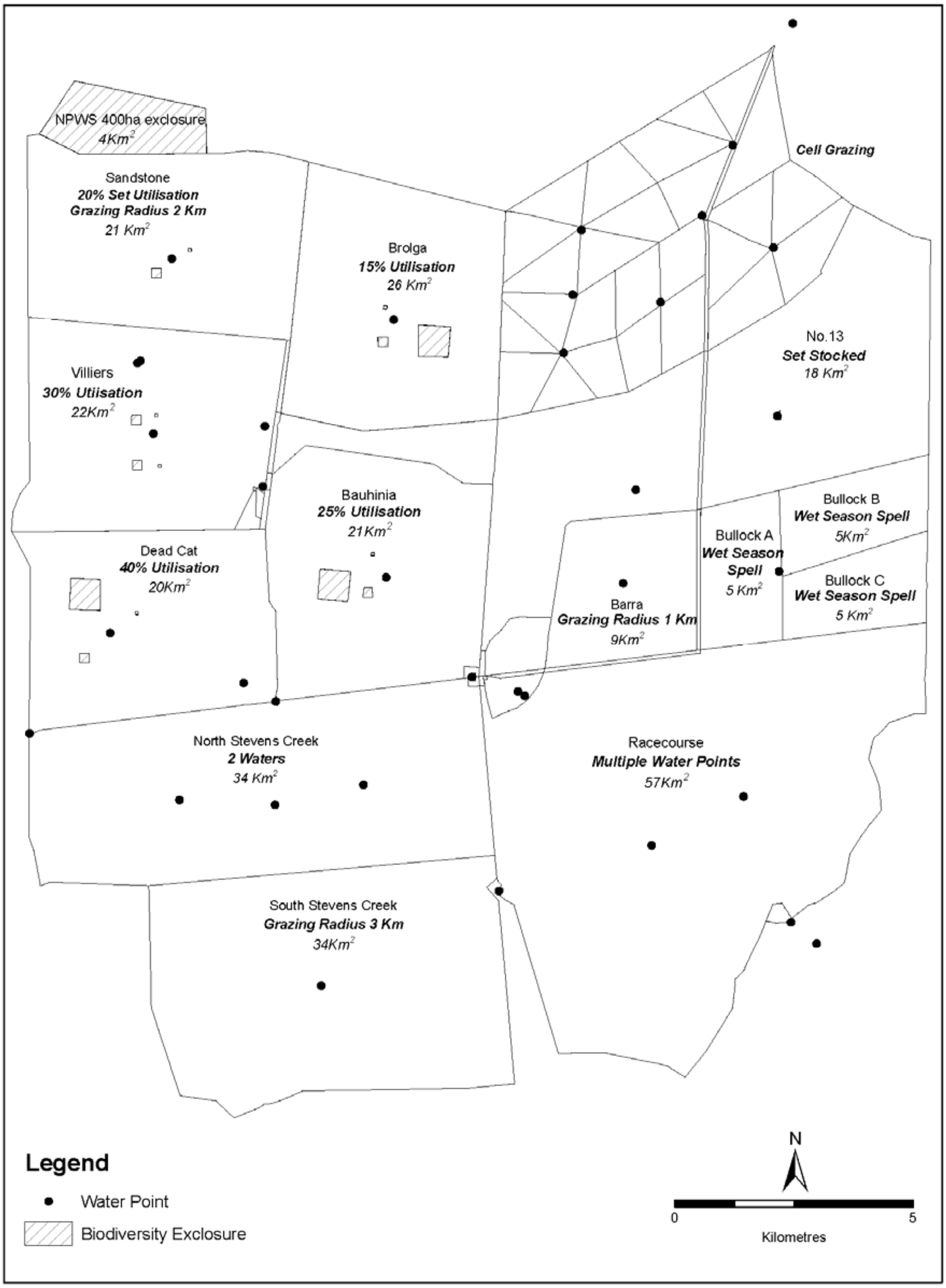


Figure 3.3. Layout of the Pigeon Hole experimental site and treatment paddocks.

Table 3.2. Summary of treatment paddocks and animals used in the Pigeon Hole utilisation study. Note: one animal equivalent = 450 kg dry Brahman cow.

Paddock name	Utilisation Rate %	Paddock size (sq. km)	Average AEs* per sq. km 2003-2006
Brolga	15	21	8.3
Sandstone	20	21	10.6
Bauhinia	25	21	10.5
Villiers	30	22	12.2
Dead Cat	40	20	15.1

3.2.2 Data collection

3.2.2.1 Mt Sanford

Pasture/vegetation understorey sampling

Sampling design

Pastures were monitored from 10 permanent transects marked with a star picket. Transects were placed at a range of distances from water, with sites representing the proportion of land types found within the paddock. The first two observers walked left and right of the picket (Fig. 3.4). The next two paced out 10 m in the direction away from the trough before walking a transect set at 90^o either left or right. Each observer assessed the pasture in a 1m^2 quadrat dropped directly in front of them every 7 paces, recording 15 quadrats per transect.

Pasture was assessed at the end of April and end of October each year, except where access to the site was not possible due to rain.

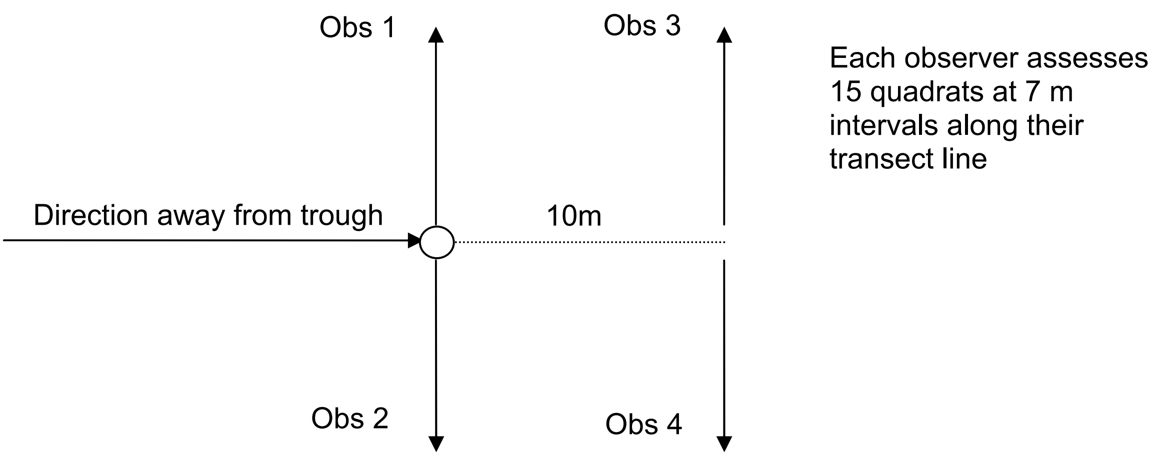


Figure 3.4. Layout of pasture measurements at each transect.

Variables

A modified Botanal method (Tothill *et al*. 1992) was used to monitor the pasture. Observations were recorded onto HP palmtop computers and included:

- Total biomass of understorey pasture ranked on a scale of 0-60;

- The six pasture species making the greatest contribution to pasture biomass. Some species were functionally grouped, such as native legumes, and some grasses were grouped according to genera.
- The percent biomass contributed by each of the top four species;
- The percentage of bare ground;
- Defoliation score, where 0 = no grazing, 1 = slight grazing, 2 = moderate grazing, 3 = heavy grazing, 4 = very heavy grazing, 5 = severe grazing, 6 = no remaining pasture.

At the end of each day of observations, biomass estimates were calibrated using 10 quadrats encompassing the full range of biomass yields on offer. These were harvested, dried at 80C for 48 hours and weighed. Data files were checked for errors prior to analysis.

Photographs were taken looking right and left of each transect point (picket).

Utilisation rates

Utilisation rates were calculated as estimated consumption divided by estimated pasture growth. Pasture growth was calculated as the standing dry matter (DM) at the end of the wet, plus estimated intake over the wet. Intake was assumed to be 7.21kg DM/AE/day, where an AE is a 450 kg non-lactating non-pregnant Brahman breeder at maintenance. The average of the calculated utilisation rates across all years for each treatment paddock was used for analysis and these rates are referred to in the text.

<u>Livestock performance</u>

Breeding herd management

Breeders were mustered twice annually, at the end of the wet season and late in the dry season. Breeders were culled on barrenness (non-pregnant and non-lactating), temperament, injury or age (10 years) and were continuously mated at 4%. All breeding stock was vaccinated against C & D botulism strains at the May muster and a booster vibriosis vaccination was given to bulls at the October muster.

A minimum weaning weight of 120 kg was used at both weaning rounds in all years. Calves (progeny <120 kg) were generally castrated, branded and dehorned prior to being returned to the breeding herd.

Supplementation was provided all year round by water medication.

Procedure

Two musters were completed annually, usually in the months May and October with all herds being processed within a week of each other. Month of pregnancy, lactation status, body condition and liveweight were recorded for all breeders at each muster. Liveweight and sex were recorded for all progeny.

Month of pregnancy was determined by a trained operator via rectal palpation. To determine lactation status of breeders, udders were visually assessed and teats were stripped and the colouration of the fluid obtained examined. The body condition of the animal was visually assessed and scored accordingly against a nine point system where 1 is emaciated and 9 over-fat (Holroyd 1978).

Liveweights were recorded for all animals at the time of processing after being held overnight without feed, but *ad libitum* access to water. Weights were generally recorded electronically using Tru-test or Ruddweigh weigh beams fixed beneath a weigh box. Progeny remained on their mothers prior to their liveweights being recorded.

Planes of nutrition

In order to measure the relative planes of nutrition available to be grazed by the herds, 10-13 steers of similar age and liveweight were included in each paddock. Steers were added in May each year and replaced in May the following year. Inter-paddock differences in annual liveweight gain was used to indicate relative paddock quality.

3.2.2.2 Pigeon Hole

Pasture/vegetation understorey sampling

Pasture assessments were made twice a year, at the end of the wet (May) and dry (October) seasons, using a modified Botanal method. Botanal is a doubling-sampling visual estimation process (Friedel *et al*. 2000). Table 3.3 presents a list and brief explanation of the variables estimated for each quadrat sampled. Sampling locations formed a fixed 100 x 500 m grid across each paddock. These points were sampled as N-S transects 500 m apart and a 2 x 2 m ‘virtual’ quadrat (i.e. the quadrat perimeter estimated by eye) located at 100 m intervals along each transect. Navigation along transects was by GPS between permanent northern and southern waypoints. Quadrat locations were not permanently marked so that on different sampling occasions pasture assessments were made in the same approximate location to the extent possible with the accuracy permitted by GPS error (i.e. approximately ±5 m). Data were entered directly into hand-held computers.

Table 3.3. Pasture and related variables visually estimated for each quadrat in the modified Botanal procedure.

VARIABLE	Description	Comments
Species present	Top five species present in order of biomass (weight) rank in each quadrat	
Species composition	Percentage composition (by weight) of each of the top five species in quadrat	
Species defoliation	Percentage defoliation (i.e. cattle grazing) category of top five species according to percentage defoliation categories 0, 0-5, 5-25, 25-50, 50-75, 75-100%	
Overall quadrat defoliation	Overall defoliation for whole quadrat according to above defoliation categories	Incorporates defoliation of species not included in top five species
Herbage biomass	Total yield of dry standing herbage biomass (estimated as equivalent biomass in kg/ha)	Excludes any detached plant material
Perennial grass basal area	Basal area of perennial tussock grasses as a percentage of quadrat area according to percentage categories 0, <1, 1-3, 3-5, 5-7.5, 7.5-10%	
Total projected vegetative cover	Total vegetative ground cover (herbage cover + litter) as a percentage of quadrat area	Manure included, rock cover excluded
Land (soil) type	Dominant land type within 10 m radius of quadrat; possible choices are black soil, red soil, intermediate, creek line, and riparian	Intermediate soils were in between red and black soils, and other soil types not fitting into the other categories. Creek line referred to quadrats actually located in rocky creek beds
Fire	Yes/no according to whether quadrat had been burnt since the last wet season	
Patch type	If quadrat was located within one of three patch types (riparian, new grazed, old grazed)	New grazed patches were areas with abundant palatable perennial grasses with >50% defoliation. Old grazed patches had lost most palatable perennial grasses, increased bare ground and forbs and short-lived species
Latitude and longitude	Location of quadrat recorded electronically from GPS appliance	

<u>Livestock performance and dietary quality</u>

Livestock performance was assessed on a paddock/treatment basis in terms of liveweight gain, branding percentage and mortality. These data were gathered at the two musters each year. Cattle dietary quality was assessed monthly using faecal near-infrared spectroscopy (NIRS; Coates 1999). For each paddock 20 separate faecal samples were collected from fresh cow pats near water points and bulked for analysis.

3.2.3 Data analysis

3.2.3.1 Mt Sanford

Pasture – testing effects of treatments

Each utilisation treatment was represented by a single paddock. Hence variables could vary significantly between paddocks as a result of inherent paddock differences. For this reason, it is the effect of utilisation treatment on change through time that was often of interest as a way of differentiating utilisation effects. This was assessed in terms of the significance of the time x utilisation interaction in repeated-measures Analysis of Variance tests.

Cattle production data

Because animal data often have no replication within a treatment, where the nature of relationships appeared to be linear the effect of utilisation was tested using linear regression on production data averaged over all years, and data year by year. Regressions were compared over time. Univariate tests of significance were also used to test for effects of utilisation and time. Further analysis of the data is planned.

3.2.3.2 Pigeon Hole

Pasture – preliminary data processing

Extensive error checking was carried out on each data set. Yield estimates were calibrated using harvested calibration standards (dried at 80C for 48 hours). Cover estimates were standardised across observers by rescaling estimates according to the mean estimated cover of all observations. This assumes observers were spread relatively uniformly across the study paddocks and treatments (which was achieved as well as possible).

To allow for analyses based on distance from water, the distance of each sampling point (i.e. quadrat) to the closet water point was calculated in ArcView using a combination of cost-distance and Euclidean distance methods where appropriate.

Pasture – testing effects of treatments

Each utilisation treatment was represented by a single paddock. Hence variables could vary significantly between paddocks as a result of inherent paddock differences. For this reason, it is the effect of utilisation treatment on change through time that was often of interest as a way of differentiating utilisation effects. This was assessed in terms of the significance of the time x utilisation interaction in repeated-measures Analysis of Variance tests.

The effect of utilisation on evenness of pasture utilisation is yet to be investigated, but will be for future reports. In particular the effect of utilisation on the development of piospheres will be examined, and pasture variables will be related to distance to water using regression. Regressions will be compared between treatments and over time.

Cattle production data

Because animal data often have no replication within a treatment, and the nature of relationships appeared to be linear, the effect of utilisation was tested using linear regression on data averaged over all years, and data year by year. Regressions were compared over time. Additional analyses will be done for the final report and publications.

3.3 Activity 2 – Enhanced understanding of grazing distribution for improved fencing, paddock design and water placement

3.3.1 Experimental design

Two separate but related studies were conducted. Specific details of each study follow.

Experiment 1 considered the effect of paddock size, grazing radius and the number of cattle per water point on landscape use by cattle, and associated pasture and livestock production response. This study (referred to as the grazing radius study) involved three paddocks (9, 21 and 34 sq. km. in area, referred to as GR1, GR2 and GR3, respectively) each with a single watering point. Each paddock was stocked with the appropriate number of cattle to achieve an annual forage utilisation rate of 20% based on standing herbage biomass available at the end of the growing (i.e. wet) season.

Experiment 2 examined the effects of landscape diversity, water distribution and paddock size on grazing distribution, livestock performance and range condition. For this study (referred to later as the grazing distribution study) it was assumed that larger paddocks encompass greater landscape diversity. Three paddocks that differed in size (9, 34 and 57 sq. km) and the availability of water, but that had similar grazing radii (2.5 km) were used. The smallest paddock contained one water point, the intermediate size paddock two water points and the 57 sq. km paddock had five water points in order to achieve approximately similar grazing radii for all water points (Table 3.4, Fig. 3.3). As with experiment 1, each paddock was stocked with the appropriate number of cattle to achieve an annual utilisation rate of 20%.

Table 3.4. Treatments in the two grazing distribution studies.

Experiment	Number of water points	Grazing radius (km) (nominal)	Paddock size (sq. km)	Paddock name	Treatment designation	Average animal equivalents* per sq. km 2003-2006
1, 2	1	1.0	9	Barra	GR1; One water	8.7
1	1	2.0	21	Sandstone	GR2	10.7
1	1	3.0	34	South Stevens Creek	GR3	9.0
2	2	2.5?	34	North Stevens Creek	Two waters	8.7
2	5	2.5?	57	Racecourse	Multiple waters	7.4

* 1 animal equivalent = 450 kg dry Brahman cow.

The effectiveness of these paddock configurations in altering the way cattle used the landscape and achieving more even grazing, and any associated impacts on vegetation and land condition, were assessed in two ways. Firstly, the spatial patterns of defoliation, plant species composition and pasture productivity were regularly assessed by ground-based pasture sampling. Secondly, the distribution of cattle activity within the different paddocks was monitored using collars fitted with global positioning system (GPS) receivers on cattle grazing in the paddocks. The collar data and pasture data were also used together to develop a better understanding of the factors that influence cattle grazing distribution. The effects on dietary quality, liveweight gain and branding percentage were also monitored.

3.3.2 Data collection

3.3.2.1 Pasture/vegetation understorey sampling

Pasture assessments were conducted using the same approach as for the utilisation rate activity (described in section 3.2.2.2 above).

3.3.2.2 Cattle distribution and grazing behaviour

To better understand cattle use of the landscape at large spatial scales and the factors influencing this, a sample of cows were fitted with GPS collars. These collars allow the logging of a cow's location and grazing, resting and travelling activities at regular intervals over extended periods.

Lotek 2200LR and 3300LR collars containing two-axis activity sensors and a temperature sensor were used. For most of the study a GPS fix interval of one hour and activity sensor sampling period of 5 minutes were used. In addition to recording the location of the cow at every GPS fix the collars record the time and date of fix, an activity sensor count averaged over sub-samples during the fix interval, the temperature (approximating ambient temperature), and information relating to satellite identity and performance. This information is written to memory at each fix for later downloading.

Collars were fitted to and retrieved from cattle when each paddock was mustered as part of normal herd management. Musters occurred twice a year (usually in April and September) and the collars remained on the cattle for the entire period between musters. Upon retrieving the collars the data were downloaded, the collars fitted with charged batteries and reinitialised and fitted to different cattle. The cattle were then returned to their respective paddocks. Thus we obtained data on grazing behaviour for entire years partitioned approximately into the wet and dry seasons. Collars were fitted only to cows which were selected randomly within the constraints of meeting the pregnancy status and body condition score expected by the station managers at that time. When possible, up to four cows per paddock were fitted with collars on each occasion. This was not always possible due to collars being damaged by the cattle and requiring servicing.

Collars were initially deployed to the three paddocks that constituted the paddock size and landscape diversity study (experiment 2). Currently, collars are deployed in the grazing radius paddocks that comprise experiment 1, and also in a typical commercial paddock that has no additional infrastructure developments. This paddock forms the 'control' treatment. The results from these paddocks will be described in subsequent reports.

3.3.2.3 Livestock performance and dietary quality

Livestock performance was assessed in the same way as for the utilisation rate study (Activity 1). Performance was determined on a paddock/treatment basis in terms of liveweight gain, branding percentage and mortality. These data were gathered at the two musters each year. Cattle dietary quality was assessed monthly using faecal near-infrared spectroscopy (NIRS: Coates 1999). For each paddock 20 separate faecal samples were collected from fresh cow pats near water points and bulked for analysis. In Racecourse paddock (the largest paddock with multiple water-points) separate bulked samples were collected from several water points to assess the diversity in dietary quality across the paddock.

3.3.3 Data analysis

3.3.3.1 Pasture – preliminary data processing

Extensive error checking was carried out on each data set. Yield estimates were calibrated using harvested calibration standards (dried at 80C for 48 hours). Cover estimates were standardised across observers by rescaling estimates according to the mean estimated cover of all observations. This assumes observers were spread relatively uniformly across the study paddocks and treatments (which was achieved as well as possible).

To allow for analyses based on distance from water, the distance of each sampling point (i.e. quadrat) to the closet water point was calculated in ArcView using a combination of cost-distance and Euclidean distance methods where appropriate.

3.3.3.2 Pasture – testing effects of treatments

Because of the unreplicated nature of the study and there being considerable initial variability between paddocks the emergence of different trends in pasture variables (i.e. yield, composition, cover, perennial grass basal area and defoliation) over time between treatments (paddocks) provides the most robust assessment of the relative effects of the grazing treatments. Residual maximum likelihood (REML) generalised linear mixed models were used for these comparisons. Separate analyses were completed for the two experiments (i.e. grazing radius, grazing distribution). The REMLs were performed individually for each pasture sampling and also over end-of-wet (i.e. May) sampling data for the first three years (2003-2005) to test for a time effect in the development of treatment effects on the pasture. The May data has been used for each year as this is most likely to show differences that reflect more lasting change in land condition or productivity rather than contemporary short-term grazing impacts.

Multivariate analyses (including ordination and correspondence analysis) are being used to compare species composition between treatments and examine shifts in species composition over time. The analyses were performed with all species and with functional groupings of pasture species. These analyses are not yet complete so no results are presented in this interim report.

3.3.3.3 Spatial patterns

A number of methods are being used to assess the impact of different paddock configurations on the development of spatial patterning in the pasture due to grazing but these analyses are yet to be completed so no results are presented at this stage. The analyses will compare initial patterning at the start with that at the conclusion of the study. Semi-variograms are being used to assess the scale at which patterning occurred in pasture variables. The expectation is that there will be a difference in the scale at which patterning occurs amongst different paddock configurations over the life of the experiment as differences in the evenness of grazing and the incidence of patch grazing will become apparent over time in the different paddocks.

To assess the development of piospheres around water points pasture variables will be related to distance to water using linear regression at the end of the study. Regressions will be compared between treatments and over time.

3.3.3.4 Cattle location data – basic analyses

Complete data sets were not always obtained from the GPS collars for several reasons. Poor satellite signal reception and battery failure were the most common reasons. The data therefore required some editing to remove spurious GPS fixes, and some data have not been included in the analysis where the period over which data was collected was relatively short. Data from the first 24 hours following the return of collared cows to the paddock and the data from the day cattle were mustered were also excluded from the analyses.

Basic statistics calculated for each data-set (i.e. one cow for one mustering) included:

- inter-fix distance (i.e. distance travelled in one hour);
- cumulative distance travelled over the deployment period, and average distance travelled per day;
- mean distance from water;
- home range (using a 95% minimum convex polygon with fixed mean);
- the centre of activity (i.e. centroid) for individual cattle;
- proportion of paddock used (i.e. home range relative to paddock size).

ArcView GIS 3.2 and the Home Range extension (Rogers and Carr 1998) were used for these calculations (except for the centroids which were calculated in Genstat).

Some of these data are still being derived from the data. When complete they will be compared between paddocks to test the effect of the different paddock configurations on cattle behaviour and how this might influence use of the landscape by cattle. These data might also help to explain any observed differences in livestock production between treatments.

3.3.3.5 Classifying different behaviours

The two activity sensors in the GPS collars (which measure vertical and lateral movements of a cow's head) were used in combination with inter-fix distances to define when different animal activities occurred. By relating direct observations of collared cows in the paddock to activity sensor and distance data three activities were defined: grazing, travelling and resting. Using information on the various activities should allow the development of a more refined understanding of how cattle use the landscape and the factors that influence grazing distribution. This work is to be carried out over the next few weeks so no results are presented in this interim report.

Grazing, resting and travelling time per day are also to be compared between different paddock configurations.

3.3.3.6 Factors influencing patterns of use

Two sets of data were derived from the pasture and GPS collar data and other spatial data for use in developing an understanding of the factors that are potentially important in determining grazing distribution. Firstly, the distance of each GPS fix to the closest water point and distance to the closest creek were calculated in ARCGIS. Secondly, the proportion of fixes that occurred in different pasture communities and soil types was determined (ignoring all fixes within 250 m of water points). This data was derived by first developing separate spatial interpolations of several descriptors of the pasture data (e.g. different pasture community types, total pasture yield, palatable forage yield and perennial grass basal area). A soil data layer was also developed using a combination of the ground observations and an aerial photo interpretation of the site (K. Richardson, pers. comm). By then intersecting each GPS location fix with various data layers describing the spatial arrangement of particular land and pasture characteristics within a geographic information system secondary data was compiled on the proportion of GPS fixes in different habitat types.

The spatial interpolations were performed in ARCGIS using the inverse distance method. Each paddock was interpolated separately so that data from neighbouring paddocks did not influence the interpolation of the paddock of interest.

An initial examination of the factors most likely to influence the way cattle use the landscape within paddocks was achieved by plotting the proportion of fixes that occurred in different pasture communities and soil types. However, since these results can be influenced by the area of a paddock within a particular class, with larger classes more likely to have more fixes simply by chance, the data was adjusted by the proportion of a paddock within the particular classes of features. The data thus can be interpreted as a measure of selection for or avoidance of land or habitat of certain characteristics (or proportional habitat use).

Proportional habitat use (x) is interpreted as follows:

x = proportion of time/fixes in pasture class a/proportion of pasture class a in paddock

If x = 1 then no preference for that habitat class
If x>1 then selecting for that habitat class
If x<1 then avoiding that habitat class.

Generalised Linear Models are also to be used to assess the influence of environmental and pasture characteristics in determining the use of paddocks by cattle. Similar models will also be used to assess the effect of paddock size and water point number on a range of land condition/pasture variables. A similar approach is to be used to relate dietary quality to paddock size and diversity, and livestock production. These analyses are yet to be completed.

3.4 Activity 3 - Implications of pastoral development options for biodiversity conservation

3.4.1 Experimental design

There were two separate, related studies within the biodiversity component:

1. examining the effects of the various grazing treatments implemented in the trial;
2. examining the value for biodiversity conservation of small, ungrazed areas within the grazed paddocks.

The general approach was repeated sampling of biodiversity at a large number of fixed sites within most of the grazing treatments, and within a set of exclosures of varying size. Sampling at fixed sites was used because of the logistic requirement to establish permanent pit-traps (for sampling reptiles and small mammals), and the difficulty of sampling (for all biota) an adequate number of random sites to separate local variation from treatment effects.

The total number of sites sampled, and the allocation of sites to treatments, had a trade-off between the need for adequate replication and constraints on time and effort of sampling. A maximum of 100 sites could be sampled (requiring c. 160 person-days of fieldwork annually). Consequently, the “multiple-watering point” and “set-stocked” paddocks within the project were not sampled, and the biodiversity studies concentrated on the “utilisation”, “grazing radius” and “alternative grazing system” treatments (as well as the “conservation areas”).

The aim was also to sample as broad a range of biota as practicable, including vascular plants, ants, birds, reptiles and small mammals. Key attributes of biodiversity for this study are species richness, species composition (particularly the balance between increaser and decreaser species), the relative abundance of individual species (particularly decreaser species and species useful as indicators) and vegetation structure (including attributes related to landscape function).

The distribution of sample sites amongst treatments is shown in Table 3.5 and Fig 3.5. There were between 6 and 10 sites within each level of each treatment. Two sites were placed on drainage lines in each paddock within the utilisation experiment (and one in the largest exclosure) because these riparian zones have a distinct flora and fauna, and are also likely to experience a different pattern of grazing effects. Within the utilisation, grazing radius and wet-season spelling paddocks, two sites were placed within 500 m of the new watering point and the remainder were placed about 1.5 km from the water-point. Sites within the cell grazing paddocks are 0.5-1 km from the troughs. Within the limitations of the paddock layout, all sites were placed to avoid unusual vegetation patches or landscape features, or areas that were in obviously poor prior condition. The distance of all sites from current and previous water-points was quantified as one indicator of prior and current grazing pressure.

A total of 16 exclosures were established within the five paddocks of the utilisation experiment (Table 3.5, Fig 3.6). Exclosures were of four sizes – 0.4 ha, 4 ha, 40 ha, and 400 ha – with 6, 6, 3 and 1 representatives, respectively, of each size. Exclosures of the three smaller sizes were all placed within 500 m of water-points, in an attempt to ensure they were surrounded by an area of at least moderate grazing pressure. The location of the largest exclosure was chosen to minimise disruption to pastoral management while containing a comparable landscape to the utilisation paddocks. There were between one and six biodiversity sampling sites within each exclosure, depending on size. The adjacent Gregory National Park also contains thousands of hectares of country comparable to that within the grazing treatments, which have been fenced from the pastoral lease since about 1990 (although this area is still grazed by variable numbers of wild and/or fugitive cattle, as well as donkeys). Five biodiversity sampling sites were located within Gregory National Park adjacent to North Stevens Creek paddock.

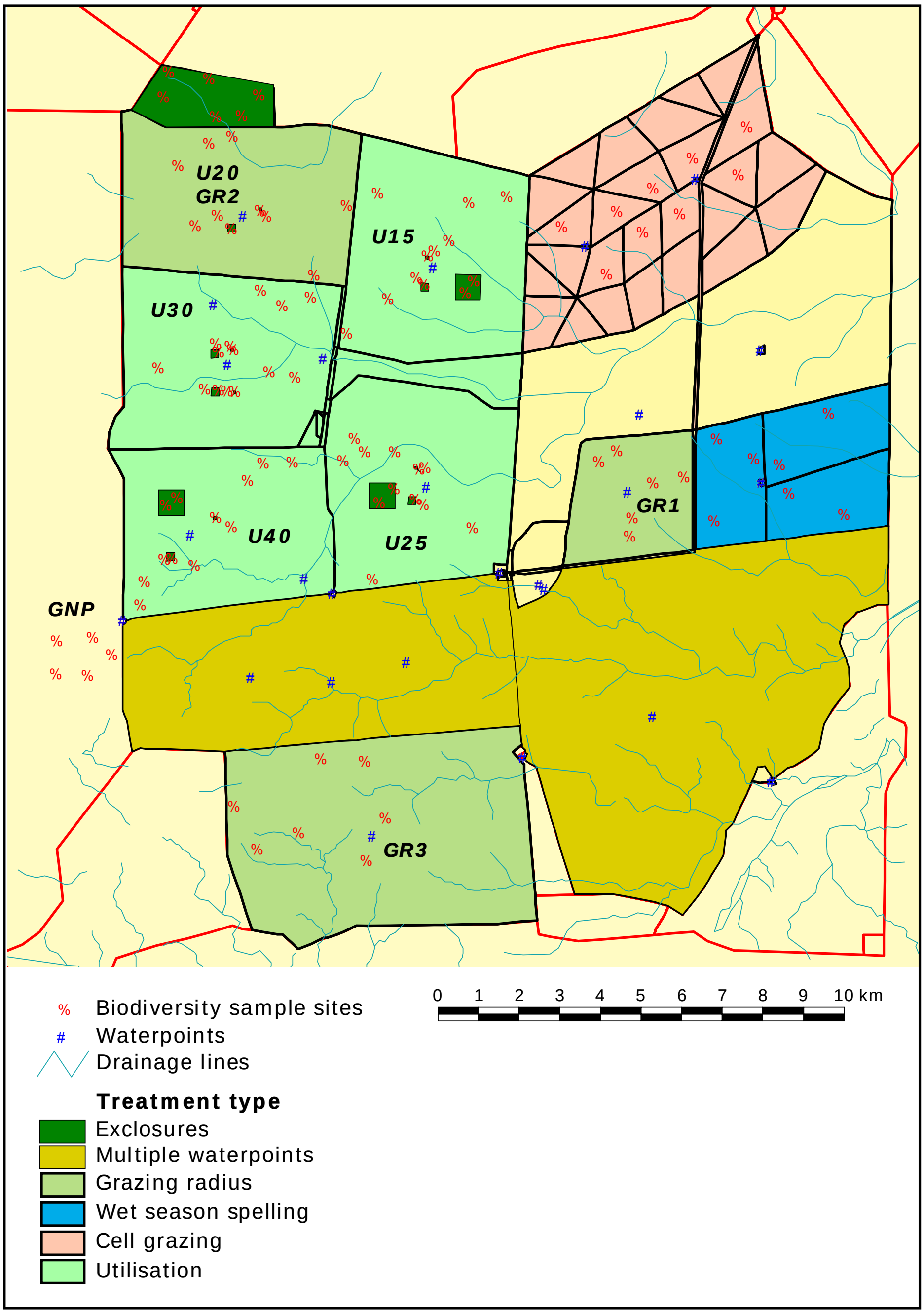


Figure 3.5. Layout of the Pigeon Hole Project area, showing location of biodiversity sample sites. The levels of the utilisation (U15-40) and grazing radius (GR1-3) treatments are labelled, as well as Gregory National Park (GNP).

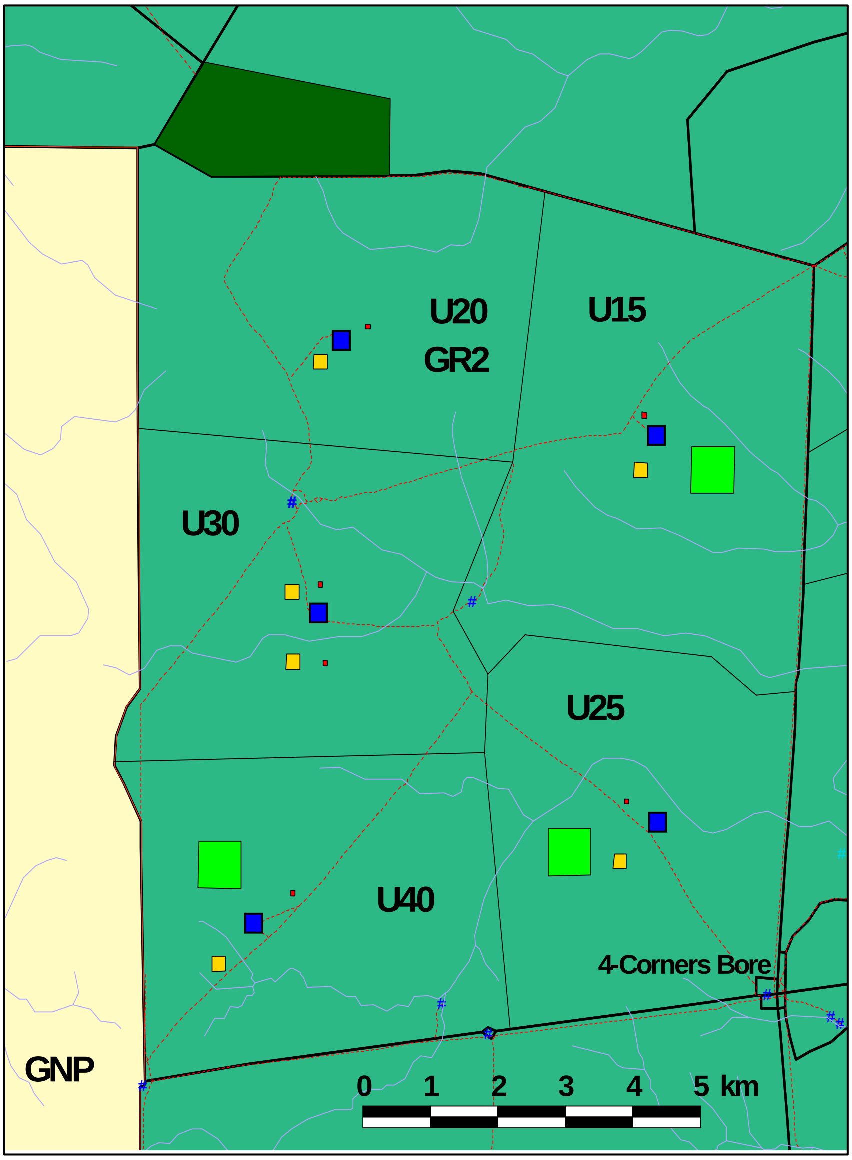


Figure 3.6. Layout of exclosures within the utilisation paddocks. Red=0.4 ha; yellow=4 ha; light green=40 ha; dark green=400 ha. Cattle watering points are blue squares.

Table 3.5. Distribution of biodiversity sampling sites between treatments. Sites on drainage lines are indicated separately.

Treatments	Level	Paddock	Normal sites	Riparian sites
Utilisation	15%	Brolga	6	2
	20%[a]	Sandstone	6	2
	25%	Bauhinia	6	2
	30%	Villiers	8	2
	40%	Dead Cat	6	2
Grazing Radius	1km	Barra	6	
	2km[a]	Sandstone	6	2
	3km	South Stevens	7	
Wet-season Spelling	-	Bullock	7	
Cell-Grazing	-	26 paddocks in one cell	9	
Conservation	0.4ha	6 exclosures	6	
	4ha	6 exclosures	6	
	40ha	3 exclosures	6	
	400ha	1 exclosure	5	1
	Gregory National Park		5	

[a] these levels are shared between the two experiments, so these 8 sites are duplicates

3.4.2 Data collection

Sites were established in 2003, although only 62 sites were located in time for sampling in May 2003 (due to delays in finalising the layout of cell grazing and wet-season spelling paddocks, and selecting exclosure locations). There were two periods of sampling in each year. Floristics, birds and ants were sampled early in the dry season (April-May). Birds, reptiles and small mammals, understorey yield and cover, and grazing impact were sampled late in the dry season (Sept-Oct). The sampling methods for various taxa/attributes are summarised in Table 3.6.

Table 3.6. Summary of sampling methods for biota and habitat attributes.

Taxon/Attribute	Methods	Timing
General habitat attributes	Standard NRETA habitat description (including location, landscape position, slope, aspect, soil type, land unit, rockiness, distance to water)	Once only
Vegetation – overstorey structure & composition	Canopy height, cover, basal area and size class distribution of trees and shrubs using Bitterlich variable-radius technique from 4 corners of 0.25 ha quadrat	Once only
Vegetation - floristics and structure	0.25 ha quadrat: composition and ground-layer structure sub-sampled in 20 x 0.5 m^2 plots + timed search in quadrat for additional spp.	Annually Early dry season
Groundcover	Cover of bare ground, rocks, litter, ground-layer vegetation (by functional group) and perennial grass basal area, in 0.25 ha quadrat as per floristic sampling	Annually Early dry season
"Pasture assessment"	Yield, cover, dominant species composition, perennial grass basal area and fire recorded in 5 x 4 m^2 plots within each 0.25 ha quadrat using modified Botanal procedure	Annually Late dry season
Birds	5 x instantaneous counts within 1 ha quadrat 2 x 1 km walked transect adjacent to quadrat	Twice annually Early & late dry season
Reptiles & small mammals	4 x 20 m drift fences in 1 ha quadrat, each fence with 2 x 20 l buckets. Open for 4 days.	Annually Late dry season
Ants	15 x 7 cm diameter pits in 20 x 40 m array. Open for 3 days.	Bi-annually Early dry season

All data are stored in purpose-built Access databases. Separate databases are maintained for vegetation/groundcover and fauna from each sample period, although these are combined across sample periods as required for analysis. Site photographs are labelled with site name and date and stored in directories by sample period. A library of other photographs (plants and animals, researchers, activities) is also maintained.

3.4.3 Data analysis

The raw data from the biodiversity study are essentially the presence and relative abundance of each plant and animal species at each site in each year, plus a number of 'habitat attributes' (understorey cover by life-form, bare ground, etc). Relative abundance of plant species in a site is represented by both mean cover and frequency. In addition to the abundance of individual species, a set of summary variables were derived for each site, including:

- total species richness, broken down by taxonomic and functional groups;
- total relative abundance, broken down by taxonomic and functional groups;
- diversity indices (e.g. Shannon-Wiener), broken down by taxonomic and functional groups;
- perennial grass frequency, broken down by cover class.

While some functional groups are well defined (e.g. bird foraging guilds; ant functional groups; palatable perennial grasses), other synthetic variables appropriate to this context are being developed through exploratory analyses.

In addition to univariate analyses of these single response variables, multivariate analyses - ordination and ANOSIM (Clarke and Gorley 2001) - are used to compare species composition between sites and over time. Composition is also broken down by taxonomic and functional groups and transformation/standardisation used to vary the relative contribution of rare or abundant species.

3.4.3.1 Comparison between grazing treatments

The primary treatments within the grazing trial are unreplicated and there is inevitably substantial within-treatment variability. Initial analyses using ordination and ANOSIM demonstrated that, for all major taxonomic groups, there was significant pre-treatment difference in composition between paddocks. Additionally, the relative abundance of many species varies substantially between years independently of grazing effects. Consequently, simple comparisons between paddocks (e.g. of mean site richness) are relatively uninformative. The general analytical approach was therefore to examine whether trends over time (in composition, summary variables or abundance of individual species) differ significantly between treatments.

For <u>composition</u> this involves:

i) comparison of the trajectories of sites in different treatments through ordination space;
ii) testing whether changes over time in the similarity of sites within a treatment differs between treatments.

For <u>individual variables</u> this involves:

i) comparison between treatments using generalised linear mixed models, specifically testing for a time x treatment interaction;
ii) implementing this in a repeated-measures context, to control for pre-treatment differences between sites.

3.4.3.2 Conservation areas

Comparison of composition and simple response variables between sites within conservation areas and those in grazed paddocks is a special case of the comparison between treatments described above. This comparison can be drawn with all (non-riparian) sites within each grazing treatment, or with selected sites close to each conservation area in a paired-site model. Similarly, comparisons between conservation areas of different size are made by considering size as a treatment with five levels. In this case, the question is whether the trajectories of sites in ordination space are dependent on exclosure size; or whether there is a significant time x size interaction for simple response variables.

3.4.3.3 Comparison between individual sites

While the Pigeon Hole project is designed to test the difference between treatments (paddocks), it is also useful to explore additional predictors that explain differences between sites. This is especially so where grazing distribution/effects still vary substantially between sites within a paddock, and there is some site-based estimate of grazing pressure.

In a multivariate context, the association between predictor variables (which include indices of grazing pressure, prior condition and habitat attributes) and the pattern between sites of species composition is analysed using vector fitting (Kantvilas & Minchin 1989) or the BIO-ENV procedure (Clarke & Gorley 2001). In a univariate context, generalised linear modelling is used to test the association between predictor variables (as above) and biodiversity response variables.

The full suite of analyses described above has not yet been attempted for all biodiversity data. Results presented in this report use primarily plant (frequency) data.

3.5 Economic and environmental analysis

3.5.1 Property description

Pigeon Hole Station encompasses a land area of 1,833 km^2. The CSIRO Ord-Victoria survey (Anonymous 1970) recognised two major land types on Pigeon Hole (Wave Hill and Antrim) and four less common land types (Wickham, Ivanhoe, Gordon and Humbert). The most widespread land system, Wave Hill, occupies 56% of Pigeon Hole. This land system comprises cracking clay soils on undulating basalt plains supporting Mitchell grass and other grasses.

For the purpose of conducting the economic study, 6 scenarios have been developed to evaluate different grazing systems (continuous, wet-season spelling and cell grazing), different levels of utilisation, different paddock sizes, and increased numbers of water points.

In all cases, the scenarios have been applied only to the southern end of Pigeon Hole (Fig. 3.7), an area of approximately 384 km^2 or 21% of the total area of the property. The analysis treats this sub-area as if it were run as a single management entity, and the economic summary measures relate to that entity, rather than the actual property itself. The area is almost all comprised of the Wave Hill land system, and much of the area is currently used for the experiment.

Pigeon Hole is a breeding operation selling steers and heifers (i.e. heifers surplus to requirements for replacement breeders) at 18 months of age (weights of 340-360 kg). The total breeder herd on the property is approximately 8,000 head, with individual animals first entering the herd at 1.5 years and progressively culled from 8 years until all have been sold by 14 years. The bull percentage is 4% and branding percentage across the various age cohorts is approximately 85%. For the economic analysis, involving the 384 km^2 sub-property, the baseline breeding herd is assumed to number around 3000 breeders, plus bulls and their progeny to market age giving a total number of livestock carried at 4680 adult equivalents (AE).

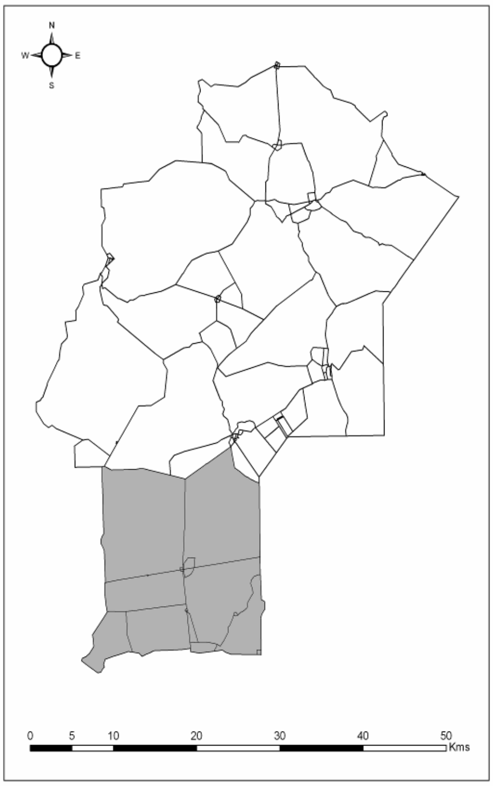


Figure 3.7. Pigeon Hole Station showing the area (shaded grey) where the scenarios were applied.

3.5.2 Scenario 1 (Current management)

Scenario 1 (the base line under current management) is structured to approximately represent the management regime and land use on that part of Pigeon Hole before the present experiment was initiated. For this analysis, some small paddocks that existed on the holding have been ignored and the area is configured as comprising only 5 paddocks:

A - the original Villiers Paddock
B - the original No. 13 Paddock
C - the existing North Stevens Creek, South Stevens Creek and Drought Paddocks
D - Racecourse Paddock and the small Delivery and Delivery Holding Paddocks
E - Depot Paddock

Water points are:

- Villiers Bore and trough supplying Paddock A;
- 4 Corners Turkeys Nest with troughs supplying Paddocks A, B, C and D;
- No. 8 Bore and troughs supplying Paddocks C and D;
- Racecourse Turkeys Nest and trough supplying D;
- No. 13 Bore and trough supplying Paddock B;
- No. 12 Bore and trough supplying Paddock B;
- A waterhole in the most easterly portion of Depot Paddock.

Cattle can walk up to 10 km from water and pasture use declines exponentially with distance from water as shown below. The “effective grazing area” in each paddock (Table 3.8) was calculated using total paddock area, the number and location of water points in the paddock, and the percentage use values with distance from water presented in Table3.7.

Table 3.7. Percentage use values with distance from water.

Distance from water (km)	Use (%)
0-1	100
1-2	80
2-3	65
3-4	50
4-5	40
5-6	30
6-7	22
7-8	15
8-9	10
9-10	5
>10	0

Table 3.8. Effective grazing area in each paddock and overall.

Paddock	Actual area (km^2)	"Effective area" (km^2)
A	110.7	54.9
B	94.5	53.1
C	90.8	29.6
D	63.3	37.9
E	24.3	13.1
Total	383.6	188.6

Thus the paddocks can be considered to be 49.2% effective. The area carries 4680 AE, so the baseline stocking rate for the area that actually can be grazed is assumed to be 4.0 ha/AE, while the nominal stocking rate across the property is 8.0 ha/AE.

3.5.3 Scenario 2 (Increased water points)

The availability of water supplies will generally determine where and when cattle can graze in the landscape. In extensive range situations where paddocks are large and permanent water is limiting, there are decreasing levels of grazing with distance from water points. Installing new water points can provide extra grazing opportunity by:

(a) allowing animals to access previously inaccessible areas that were too far distant from existing water supplies for animals to reach them; and
(b) decrease the distance from water within previously accessible areas so that grazing on these areas increases.

In this scenario, additional water points are installed with the aim that little or no land is more than 5 km from a water point. The new water points were assumed to have been installed on fence-lines, where possible, so they could serve two paddocks. An additional 5 water points were installed without changing fences and paddock layout With this water point distribution, 98.5% of the existing paddock area is assumed to lie within 5 km of a water point.

The five new water points were located as follows:

On the fence between paddocks A and B towards the northern end
On the fence between A and C towards the western end
On the fence between B and D towards the eastern end
In the south-west portion of paddock D
In the south-west portion of paddock E.

This scenario reduces the distance to water and increases the effective grazing area from 188.6 km^2 to 252 km^2 or 65.7% of the total. Cattle numbers were, accordingly, increased (from 4680 AE to 6240 AE) to keep the stocking rate per effective area constant at 4.0 ha/AE, but with no change assumed to per head animal production rates.

3.5.3.1 Capital costs

Provision of new water points involves a source of water (dams, bores), pumps (windmill, motor, electrical, solar), tanks, pipe, fittings and troughs, plus labour to install. For this scenario, we have assumed that the necessary tanks, troughs and associated facilities required to establish a new watering point can be provided through connection to existing bores. No allowance is made for the drilling and equipping of additional bores. There is no additional fencing associated with this scenario. The estimated cost per watering point is $20,000.

3.5.3.2 Annual operating costs

All items in the supply of water require maintenance and repairs. A depreciation charge on the new watering points of 7.5% of the installation cost has been applied to cover maintenance of this equipment.

3.5.4 Scenario 3 (Reduced paddock size)

The 5 large paddocks from the baseline case were subdivided, so that paddocks were generally between 20 and 30 km^2 in area. This involved sub-dividing Paddock A into 4 new paddocks, B into 3 paddocks, and D into 2 paddocks. The distance of new fencing required to effect this scenario was assumed to be 37.5 km. An extra 3 water points were also installed to ensure that all paddocks have at least one watering point. As is the case with Scenario 2, these additional watering points have been placed on fence-lines so they can water more than one paddock. Using the same water to grazing distance ratios as for Scenario 1, these changes increased the effective area to 277.9 km^2 or 56.8% of the total. Cattle numbers were increased (from 4680 AE to 5400 AE) in order to keep the stocking rate per effective area constant, but with no change to per animal productivity rates.

We have chosen to assume that fencing has no direct impacts on animal production *per se*. This is not strictly correct, but impacts of installing fencing will depend on the land types and areas that are excluded from, or added to, a grazing area. Since responses may be positive or negative, and are so dependent on the actual situation, it is difficult to describe a general situation.

3.5.4.1 Capital costs

The installation of fences and water points involves the purchase of materials and labour to erect the fence and install water points. The estimated cost per watering point is $20,000, and 1 km of new stock fencing erected on the property is $2400 per km.

3.5.4.2 Annual operating costs
Both fences and water points require maintenance and some repairs. Depreciation charges on the new watering points and fencing of 7.5% and 5% respectively of the installation cost has been applied to cover maintenance of these items.

3.5.5 Scenario 4 (Grazing systems – wet season spelling)

In this scenario 25% of the area is assumed to be rested from grazing during the wet season each year. During this time all of the animals graze on the remaining 75% of the area, increasing the grazing pressure on the remainder for this period. The area being rested is rotated around the paddocks, so that all paddocks are spelled once in four years. There are no changes to water points or paddock numbers, so the effective area is unchanged from Scenario 1.

There have been many claims for increases in animal production with new grazing systems and much research and experience showing no or only small responses when the only change that has been made is a change of grazing system. Given this diversity, we have chosen to set no changes to liveweight gain. However, grazing systems may be important for maintaining or improving pasture composition and condition that will influence long-term carrying capacity. This has been modelled by increasing carrying capacity (i.e. number of animals per unit of effective area) by 10% (from 4680 AE to 5190 AE) with this scenario.

3.5.5.1 Capital costs
More intensive grazing systems will usually require additional fencing and watering points, but none have been specifically included in this scenario, as these costs will depend strongly on the individual situation.

3.5.5.2 Annual operating costs
An extra muster is required to collect the animals from the paddock(s) to be spelled and to distribute them to the other paddocks. We assume the animals are returned to the paddock during the normal post-wet season muster.

3.5.6 Scenario 5 (Grazing systems – cell grazing)

This scenario has been based on having 200 paddocks of approximately 200 ha each, with 8 paddocks being watered from each water point. Assuming each of the 7 existing water points can each serve 8 paddocks, this required an extra 18 water points. With this layout almost all of the area is within 2 km of water and the effective grazing area is increased to 80.8%.

There is continuing debate about the impacts of cell grazing on animal production but we have chosen to increase carrying capacity on the effective grazing area by 10% and annual liveweight gain by 10 kg with no change to branding percentage. Cattle numbers were increased (from 4680 AE to 8530 AE) to allow for the dual effect of both the increase in effective grazing area and the stocking rate across that area.

3.5.6.1 Capital costs
This scenario assumes the need to install approximately 4km of new fencing per paddock, to give a total fencing requirement of 800 km (200 x 4 km). The actual costs of constructing the cells is hard to estimate with any accuracy, as the task will vary considerably with the actual layout, laneways and siting of existing fence-lines. There will also be a requirement to augment the watering facilities with 18 new watering points. We have assumed that 4 of the new watering points will require the drilling and fitting of 4 new bores, while the remaining 14 watering points will be drawing water from existing bores.

3.5.6.2 Annual operating costs

Additional labour to manage the cell grazing systems has been costed at one full time adult worker employed at an annual cost of $40,000. An additional 4WD vehicle has been employed at a replacement cost of $60,000. Depreciation charges on the new watering points, additional fencing and 4WD vehicle of 7.5%, 5% and 15% respectively of the installation or acquisition cost has been applied to cover maintenance of these items.

3.5.7 Scenario 6 (Increased utilisation)

In this scenario animal numbers are increased by 50% (from 4680 to 7000 AE) over Scenario 1, but with no changes to water points or paddock numbers so the effective grazing area remains unchanged.

As stocking rate increases, liveweight gain per animal decreases. Jones and Sandland (1974) have shown the relationship is approximately linear for a particular system, but the rate of decline varies between systems. There is insufficient data to provide to provide an accurate value for the changes, but we have assumed annual liveweight gain per animal declines by 20 kg, and the average branding percentage across the breeding herd declines by 5% with the 50% increase in animal numbers.

3.5.7.1 Capital costs

No additional capital costs have been included for changes in stocking rates. We have assumed that increased numbers come from stock bred on the property, and the larger herd size is reflected in the capital value of the property and hence affects return on capital.

3.5.7.2 Annual operating costs

No specific additional or reduced operating costs have been included, but these situations are covered in the financial model where operating costs are directly related to herd numbers. If numbers increase, the variable costs also increase commensurately, and vice versa.

3.5.8 Economic assessment

As noted in the Introduction, for the purposes of conducting the economic assessment, the portion of Pigeon Hole on which the experiments were largely sited has been assumed to represent a stand alone property. The financial performance of this property under the 6 scenarios was assessed using an economic model of a beef enterprise (MacLeod and McIvor 2006) that was calibrated for the Pigeon Hole case. The production and financial impacts were described in terms of:

- (i) animal numbers - carrying capacity/stocking rate
- (ii) animal performance - annual liveweight gain, branding percentage and mortality of breeders and dry stock
- (iii) costs
  - (a) initial capital costs
  - (b) annual operating costs (including treatment reinforcement etc)
- (iv) returns – based on animal performance [(ii) above] and market prices.

The impact of adopting the management change associated with each Scenario on enterprise profitability is assessed in terms of changes to gross margins, return to capital etc. The initial capital costs associated with a given management option were added to the capital value of the property – they do not normally influence the running costs of the property, but are reflected in returns to capital investment. However, for the present analysis, an annual operating cost that is based on the initial capital outlay has been included in the enterprise overhead costs as an incremental depreciation charge.

3.5.9 Ecological health assessment

The current status of ecological health was assessed against 10 attributes (Table 3.9) using methods described in McIvor and MacLeod (in preparation). Briefly each of the ten attributes was given a score between -3 (very poor condition for that attribute) and +3 (very good condition for that attribute). The summed values for Component A and Component B were expressed as percentages of their maximum values to provide ratings for the two components.

Table 3.9. Components and attributes of ecological health.

Component A: Maintenance of ecosystem function and stability	
Attribute A1	Soils and hydrology
Attribute A2	Pastures (cover and composition, perennial grasses)
Attribute A3	Weeds (species, density/cover)
Attribute A4	Feral animals (species, density)
Attribute A5	Riparian areas
Attribute A6	Atmosphere (greenhouse gas emissions)
Attribute A7	Fire regime
Component B: Conservation of biodiversity	
Attribute B1	Native vegetation communities
Attribute B2	Native plant and animal species
Attribute B3	Significant sites and habitats

The impacts of the revised management scenarios on the ecological health of the affected area were predicted using the same ten attributes. The impact of the management change of an attribute was given a value between -3 (large negative impact) and +3 (large positive impact) where 0 = no impact. The management impact score was then added to the initial value to give a revised value for the particular scenario with the restriction that the final score remains between -3 and +3.

3.5.10 Trade-off assessment

The ecological and economic assessments were considered together for each scenario.

4 Results and Discussion

4.1 Activity 1 – Identifying optimum levels of pasture utilisation

4.1.1 Mt Sanford

Paddocks at Mt Sanford have now been stocked for six years at the target utilisation rates of 11, 16, 22, 28, 35 and 45%.

4.1.1.1 Seasonal conditions

Total rainfall was average to well above average during the trial (Fig. 4.1). However, there was very poor growth in 2003 due to most of the rain falling towards the end of the growing season in February (Fig. 4.2). This is also evident in the yield measured in May, which is indicative of the relative pasture growth between years (Fig. 4.3).

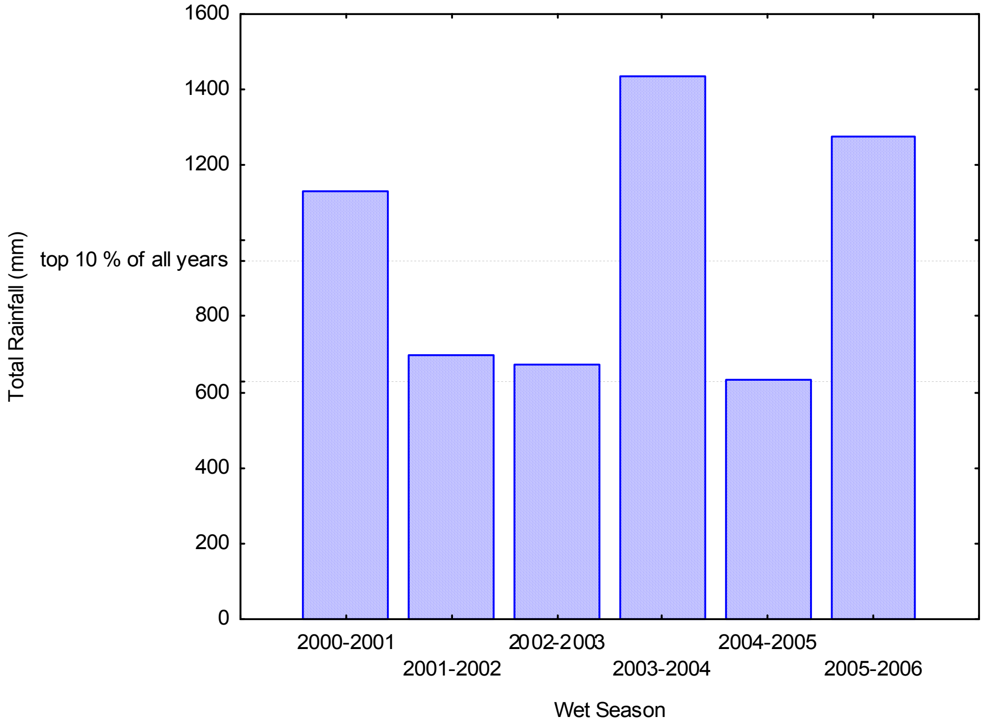


Figure 4.1. July to June rainfall at Mt Sanford during the study.

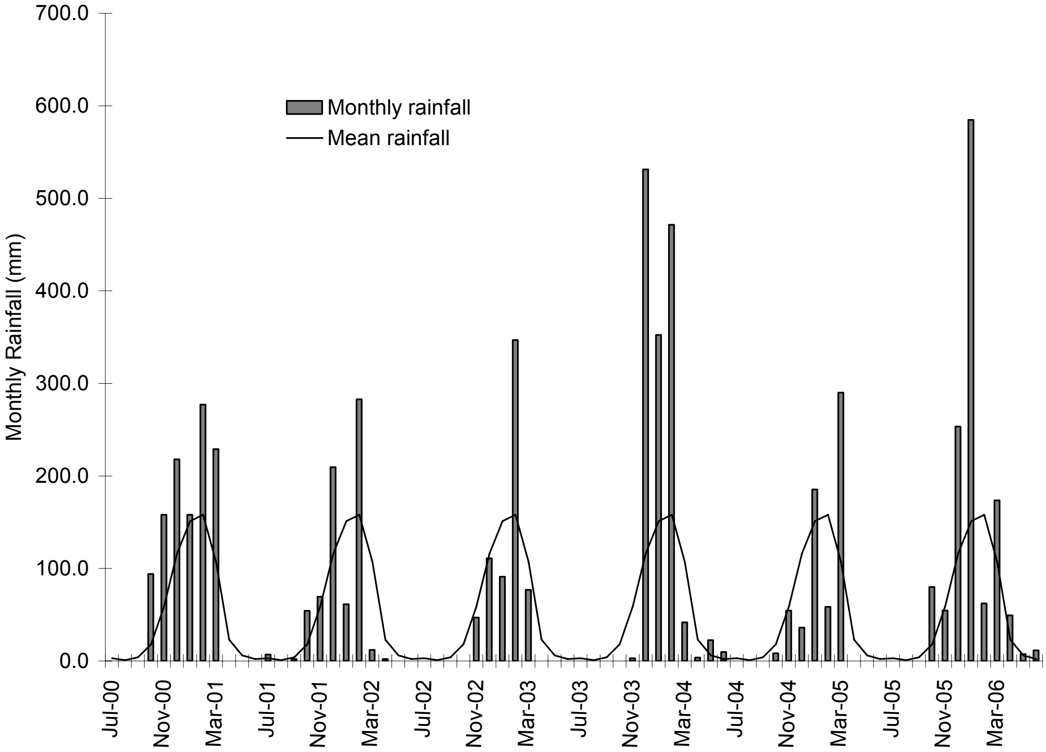


Figure 4.2. Monthly rainfall at Mt Sanford.

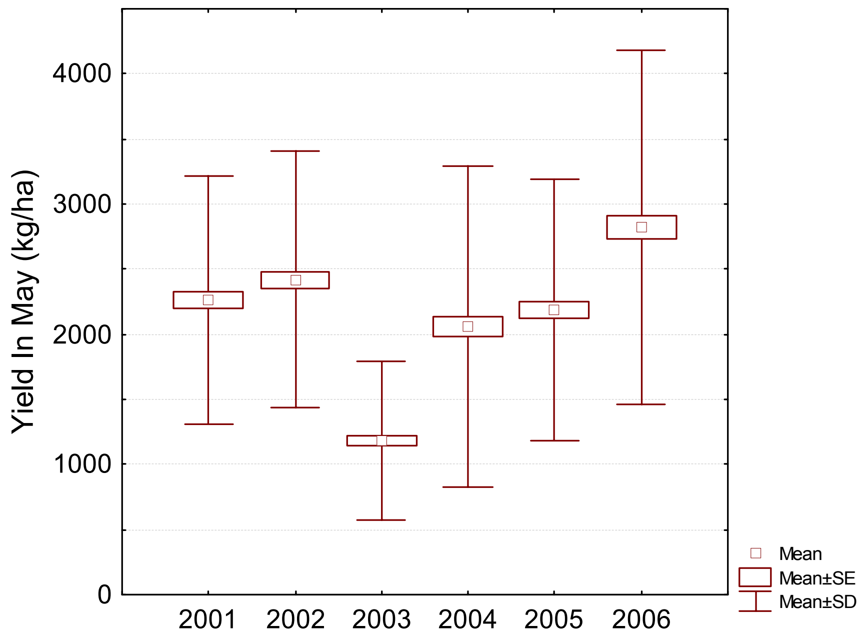


Figure 4.3. Total standing dry matter in May through time at Mt Sanford (average of all treatments).

4.1.1.2 Cattle numbers

Stocking rates in the experimental paddocks have fluctuated with seasonal conditions during the trial (Figure 4.4), but there is no evidence that animal numbers are declining through time in the higher utilisation treatments (Table 4.1).

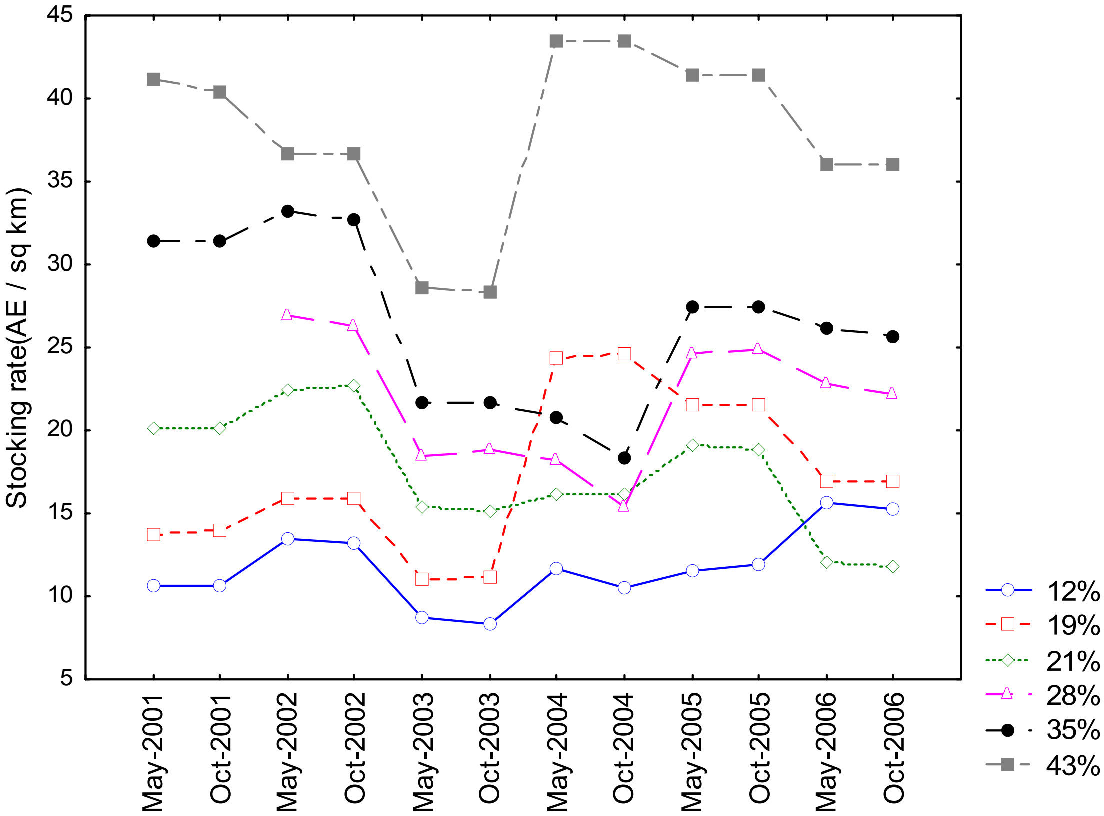


Figure 4.4. Stocking rate in utilisation treatment paddocks at Mt Sanford grazing trial 2001-2006. Utilisation rates are average actual achieved rates.

Table 4.1. Stocking rate (AE/ sq. km) for treatment paddocks and actual utilisation rates at Mt Sanford.

Muster Date	Parrot Creek	Pigeon	Budgie	Wedgetail	Quarrion	Larry Macs
Utilisation Rate	12%	19%	21%	28%	36%	43%
16/05/2001	10.6	13.7	20.2		31.4	41.1
10/10/2001	10.6	14.0	20.2		31.4	40.4
15/05/2002	13.4	15.9	22.4	26.9	33.2	36.7
10/10/2002	13.3	15.9	22.8	26.3	32.7	36.7
15/05/2003	8.7	11.0	15.5	18.5	21.6	28.6
08/10/2003	8.3	11.2	15.1	18.8	21.6	28.3
12/05/2004	11.7	24.3	16.1	18.2	20.8	43.5
06/10/2004	10.5	24.6	16.1	15.5	18.3	43.5
11/05/2005	11.5	21.6	19.2	24.6	27.4	41.4
13/10/2005	11.9	21.6	18.8	24.9	27.4	41.4
08/05/2006	15.6	17.0	12.1	22.9	26.2	36.0
13/10/2006	15.3	17.0	11.7	22.2	25.7	36.0

4.1.1.3 Utilisation rates

The average utilisation rates over the trial were equal or close to targeted utilisations, except for in 2003 where there was a spike in utilisation due to a very poor wet season. Utilisation rates in Pigeon and Budgie Paddocks appeared to have been swapped for the last two years, due to incorrect animal numbers being placed in paddocks (Fig. 4.5).

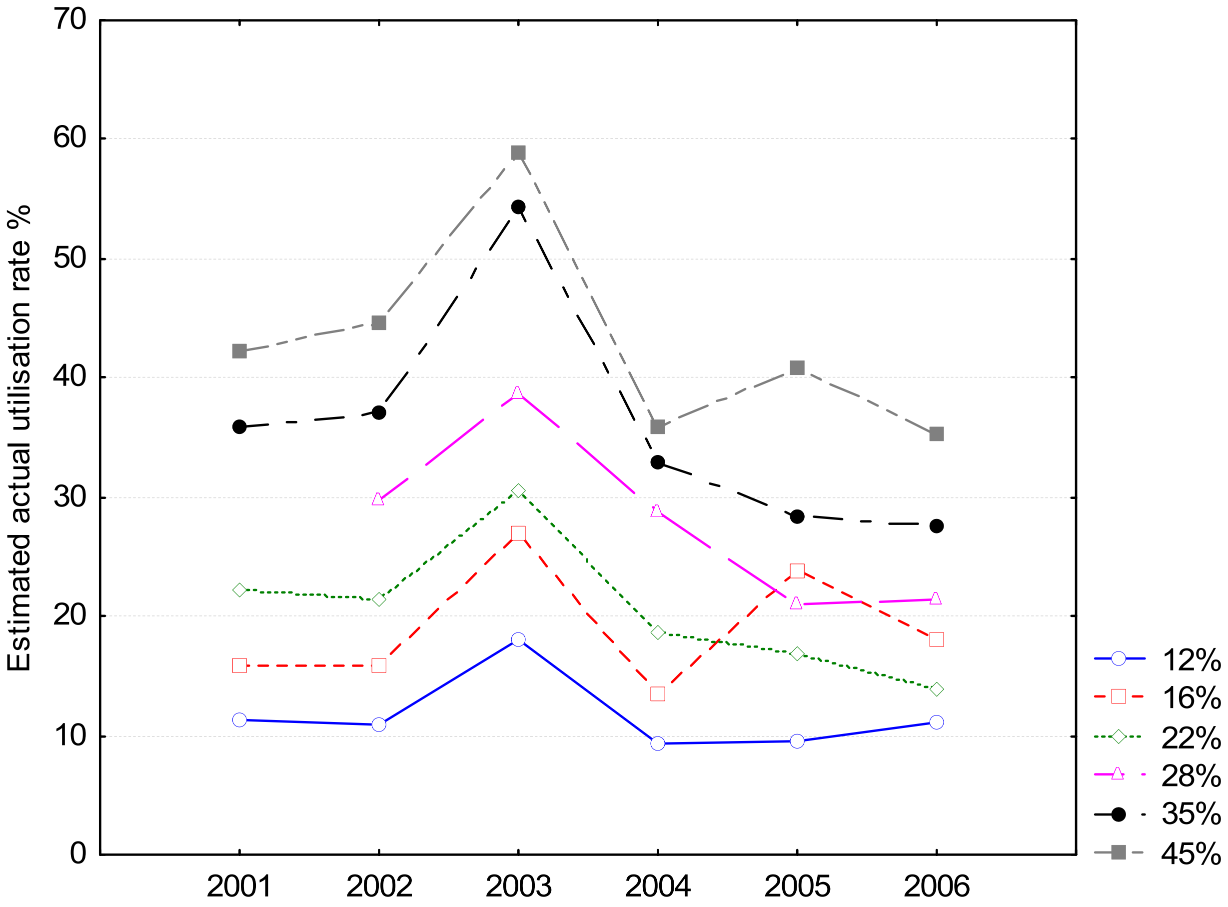


Figure 4.5. Actual utilisation rates achieved for each target utilisation rate for treatment paddocks at Mt Sanford 2001-2006.

4.1.1.4 Pasture

<u>Growth</u>

Where 'growth' was calculated as the yield in May plus the estimated intake from the beginning of the wet season, there was significantly less growth during the wet season in higher utilisation treatments (Fig. 4.6). For every 10% increase in utilisation, there was a decline in estimated growth of about 500 kg/ha. This calculation ignores the effect of utilisation on trampling and detachment. Future work will be done using GRASP to model the effects of utilisation on growth. This is scheduled for February 2007 at a GRASP workshop to be held in Katherine by QDNRM.

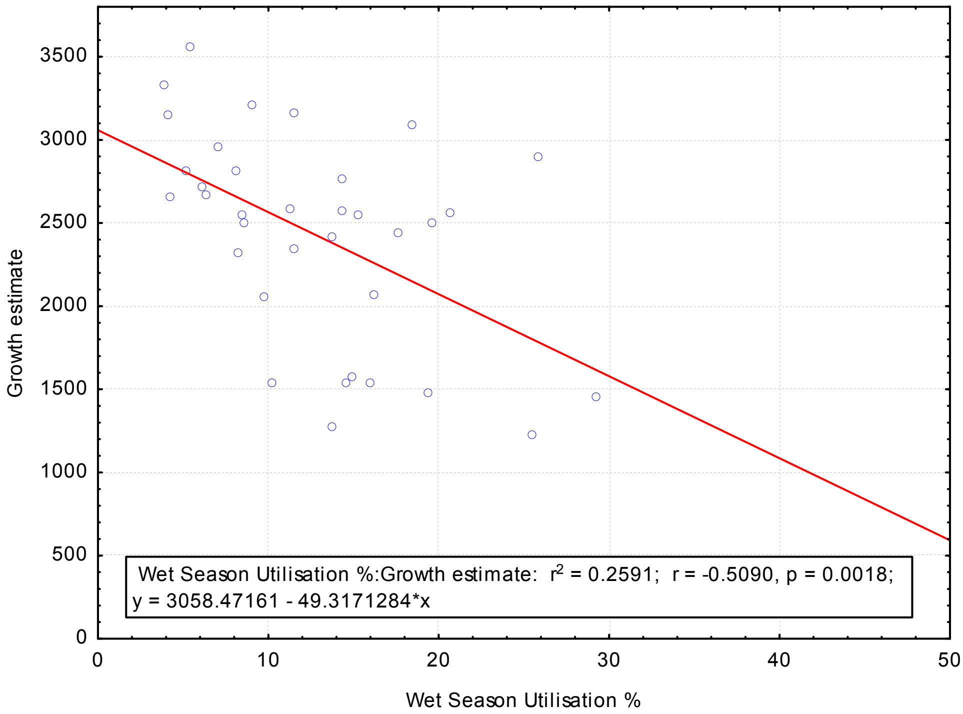


Figure 4.6. Change in growth estimate with wet season utilisation rate at Mt Sanford.

<u>Yield</u>

Yield in May fluctuated through time for all treatments, reflecting seasonal effects ($F_{5,275}$=178.91, P<0.0001) (Fig. 4.7). While higher utilisations tended to have lower yields in May, there was no overall significant effect of utilisation on yields ($F_{5,55}$=1.83, P=0.12). There was a significant time by utilisation effect ($F_{25,275}$=5.59, P<0.0001). Yield in May recovered more slowly following the 2003 wet season in the higher utilisation treatments.

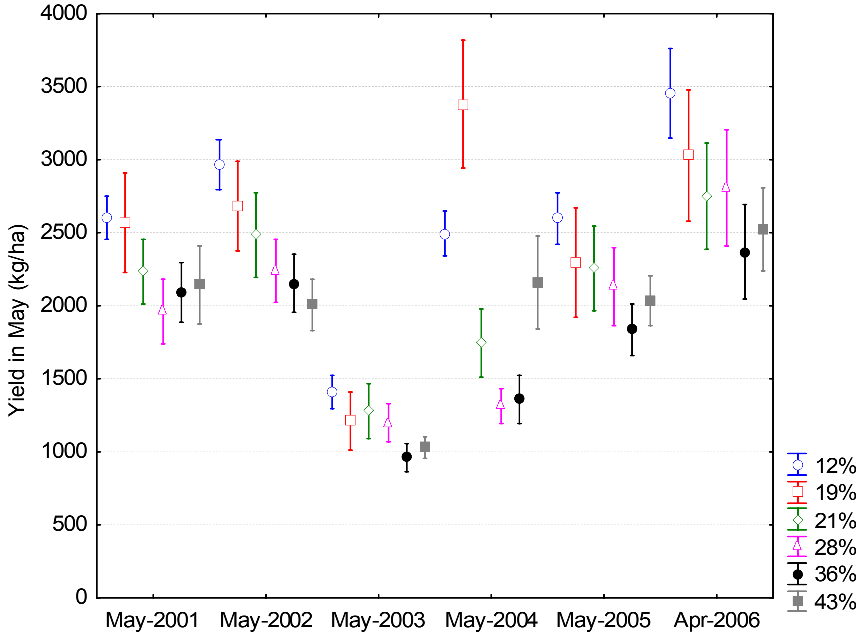


Figure 4.7. Yield in May of different utilisation rates through time at Mt Sanford. Bars denote standard errors.

Yield in October did vary significantly with utilisation ($F_{5,55}$=2.803, P=0.025; Fig. 4.8). Yield in October at 43% utilisation was significantly lower than yield at 12% utilisation (Bonferonni's test P=0.02). The average yields in October at 36 and 43% utilisations were low at around 1000 kg/ha. This is less than recommended to carry a continuous fire (McGuffog *et al*. 2001), and could influence fire frequency across a region if applied over the longer term.

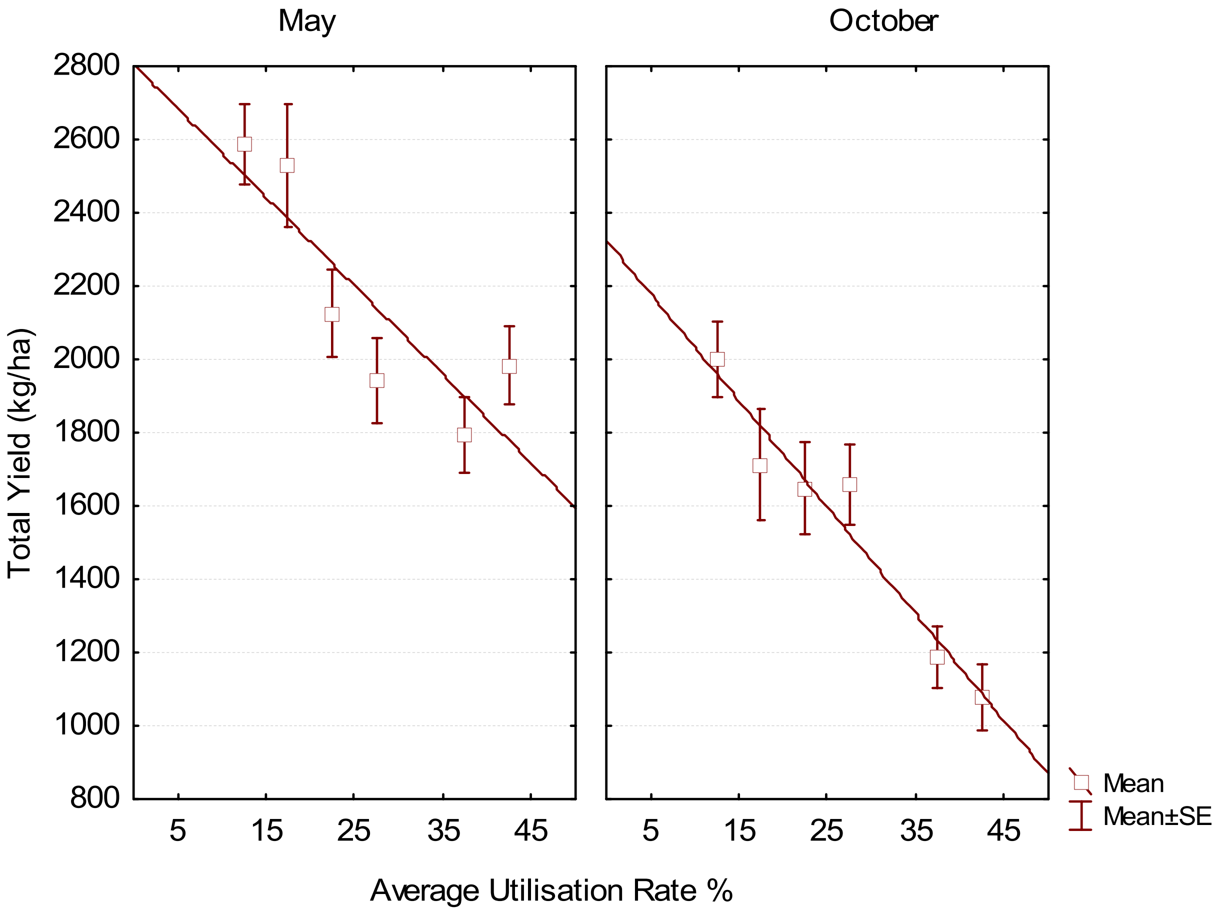


Figure 4.8. Average yield in May and October at Mt Sanford.

<u>Cover</u>

Cover levels fluctuated seasonally (Figs 4.9, 4.10), with cover of the different treatments varying less between utilisation treatments in the early dry than in October. Following the poor wet season in 2003, the average cover levels in October of paddocks with 28-43% utilisation remained low, averaging around 15-35% cover immediately preceding the wet. This is less than the critical threshold for cover levels of around 40% (Scanlan *et al*. 1996, McIvor *et al*. 1995) to reduce high runoff and sediment loss, and is not thought to be sustainable. This low cover level may also contribute to lower fire frequency (McGuffog *et al.* 2001) at high utilisation levels, especially combined with low fuel levels, which would reduce the ability to burn at the end of the dry season. At higher utilisation levels paddocks may need to be spelled to accumulate sufficient fuel and cover.

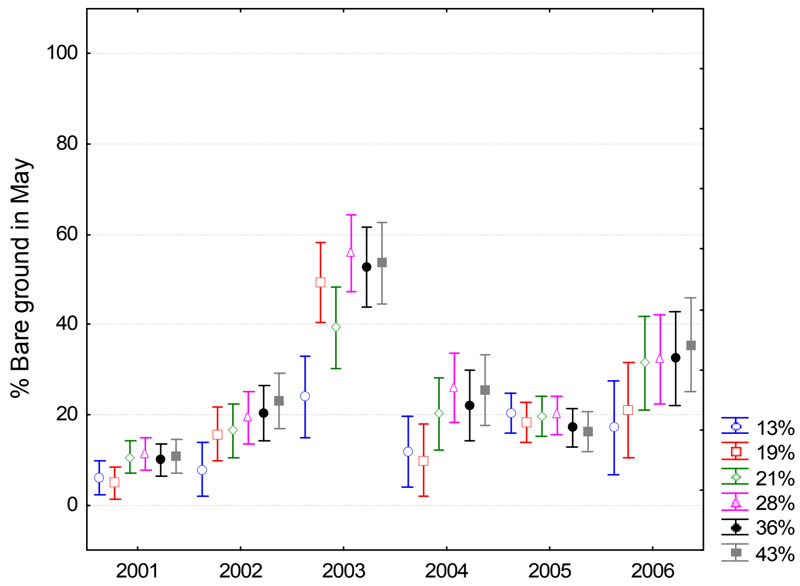


Figure 4.9. Percent bare ground for different utilisation rates through time at Mt Sanford in May. Bars denote 95% confidence intervals.

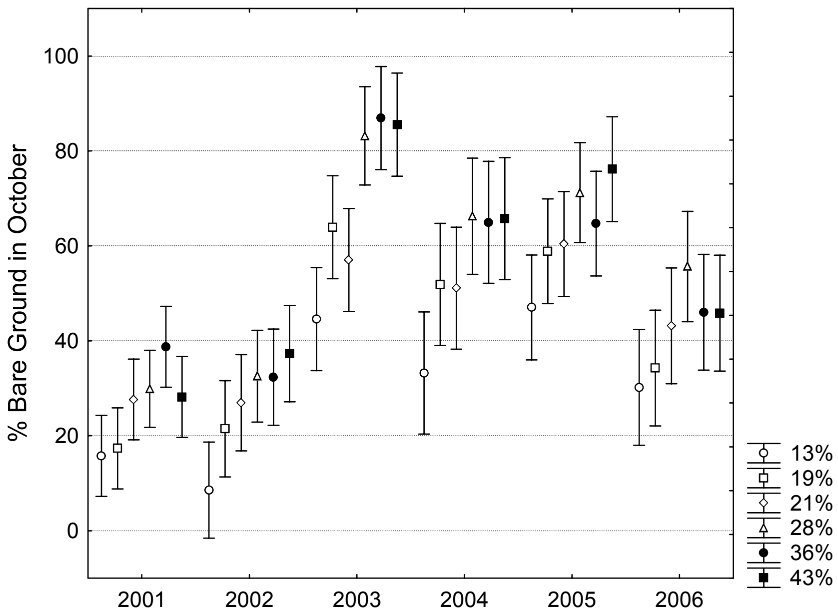


Figure 4.10. Percent bare ground for different utilisation rates through time at Mt Sanford in October. Bars denote 95% confidence intervals.

Palatable perennial yield

Palatable perennial yield was generally lower in the 36 and 43% treatments, although differences were not significant ($F_{5,55}$=2.112, P=0.077) (Fig. 4.11). Palatable yield significantly varied through time ($F_{5,275}$=33.069, P<0.0001) and there was a significant time by utilisation interaction effect on palatable yield. Palatable perennial yield increased through time in the lower utilisation rates ($F_{25,275}$=1.576, P=0.043).

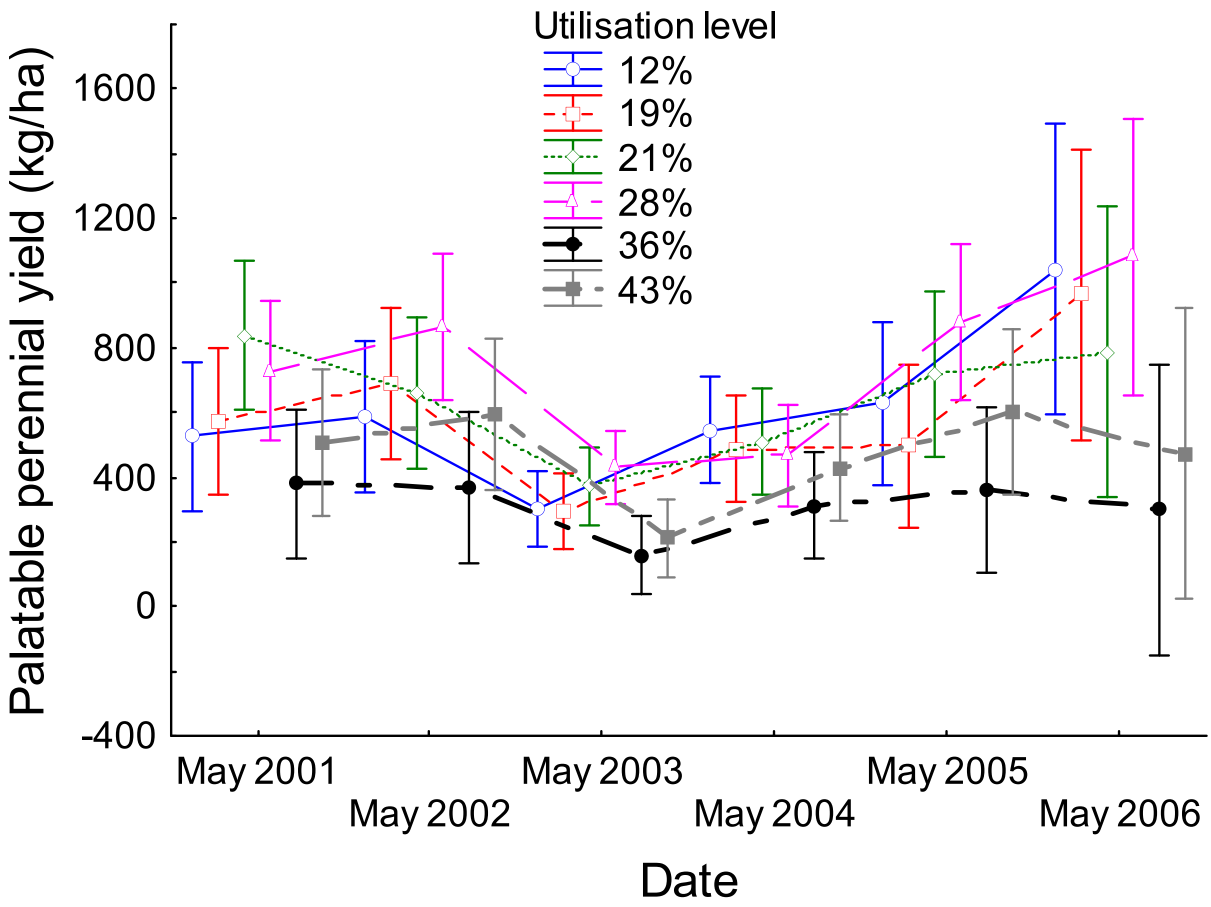


Figure 4.11. Palatable perennial yield in May through time at Mt Sanford. Bars denote 95% confidence intervals.

4.1.1.5 Biodiversity

From 2002 to 2003 the proportion of palatable plant species increased through time in the lowest utilisation treatments, but decreased through time in the two highest utilisation treatments (Table 4.2). Palatable species occurred at higher frequencies in the lowest utilisation rates, while unpalatable species had a higher frequency in the highest utilisation treatments (Table 4.3).

Table 4.2. Proportion of species with an average frequency of greater than 5% that are palatable for four utilisation treatments.

Utilisation %	2002	2003
12	0.64	0.67
21	0.66	0.74
36	0.61	0.54
43	0.66	0.63

Table 4.3. Effect of low versus high utilisation on species frequency in 2002 and 2003. Median frequencies shown in table. Mann-Whitney U Test. *P<0.05, **P<0.01, ***P<0.001.

	2002		2003	
Species	Low utilisation	High utilisation	Low utilisation	High utilisation
Increasers				
Brachyachne convergens			9.38	31.25*
Chrysopogon fallax			3.12	21.87*
Desmodium muelleri	0.00	6.25**		
Flemingia pauciflora	6.25	43.75**	6.25	31.25*
Glycine falcata			0.00	6.25**
Heliotropium plumosum			0.00	3.13*
Polymeria longifolia	0.00	12.50**	0.00	6.25*
Decreasers				
Ipomea nil	3.44	0.00*	6.25	0.00**
Iseilema vaginiflorum	43.75	18.75*	65.62	34.37*
Iseilema windersii			3.13	0.00*
Panicum decompositum			9.38	0.00*

The abundance of local ground nesting birds and Singing Bushlarks was negatively correlated with utilisation (Table 4.4).

Table 4.4. Effect of utilisation on bird species frequency at Mt Sanford. Spearman's correlation. n=24 *P<0.05.

Species / functional group	Date	Spearman R	P
Singing Bushlark	April 2002	-0.42	*
Singing Bushlark	October 2003	-0.46	*
Ground insectivore / granivore	April 2002	-0.42	*
Ground insectivore / granivore	October 2003	-0.46	*
Local ground nesters	April 2003	-0.42	*

The initial biodiversity results support the land condition and animal production evidence that 36 and 43% utilisation are not sustainable. Data collected in May and October 2006 will complement this dataset and give a longer term picture of utilisation treatment effects on plant and bird biodiversity.

4.1.1.6 Animal Production

Weaning percentage varied through time and between treatments (Fig. 4.12). At the beginning of the trial in 2002 and 2003 weaning percentage was initially high and didn't vary with utilisation rate. But following the very poor wet season of 2002/2003, weaning percentage generally dropped across all treatments. On average there was no difference between treatments in weaning percentage (Table 4.5).

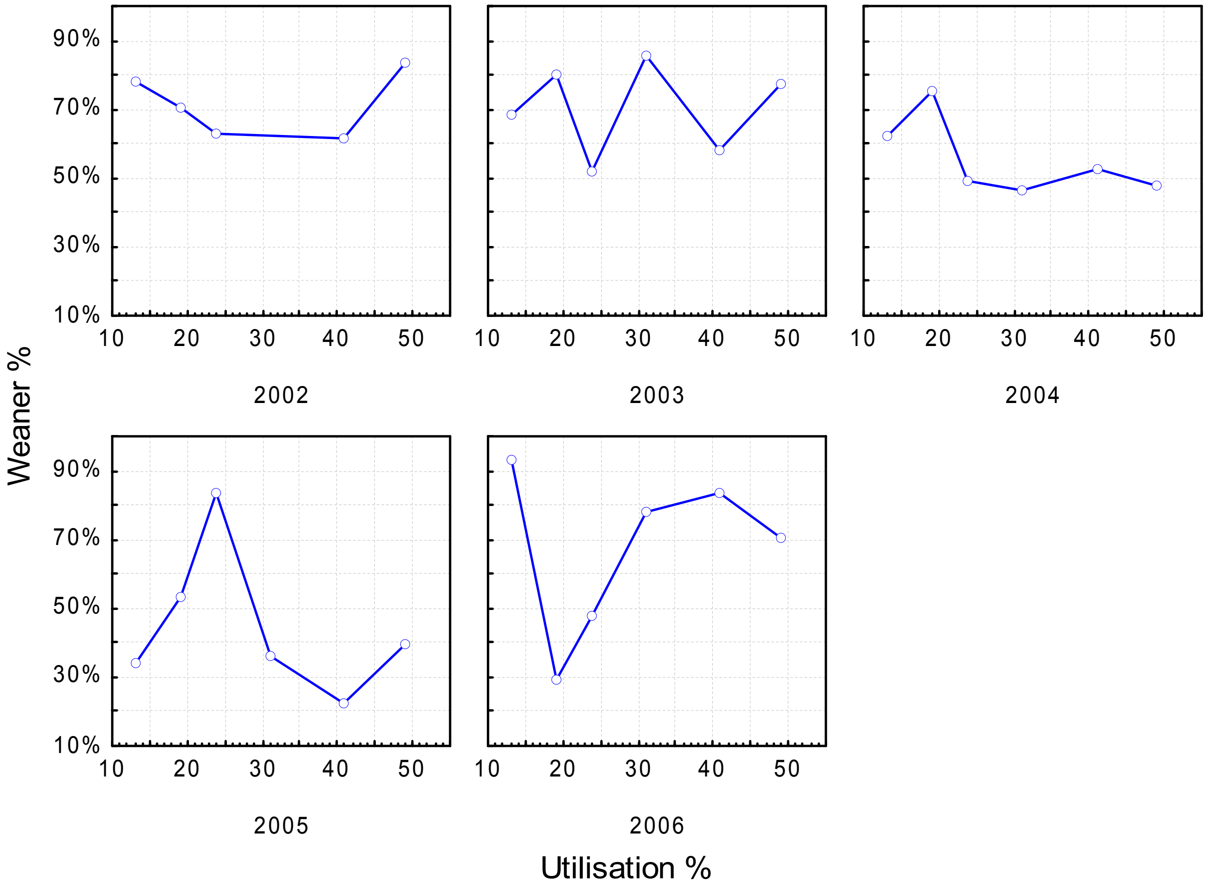


Figure 4.12. Effect of utilisation on weaning percentage through time at Mt Sanford.

Table 4.5. Average weaning percentage over all years at Mt Sanford.

Utilisation %	Average weaning %	Standard deviation
12	67%	22
19	62%	21
21	59%	15
28	61%	24
36	56%	22
43	64%	19

Calves weaned from breeders grazed at lower utilisation rates were generally heavier than those weaned from breeders grazing at higher utilisation rates (Fig. 4.13) (r^2=0.01, P<0.001, n=1139). At both weaning rounds, calves weaned from breeders which grazed at lower utilisation rates were heavier than those from high utilisation rates. (Weaning round 1, r^2=0.01, P<0.05, n=1139 and weaning round 2, r^2=0.02, P<0.01, n=1139).

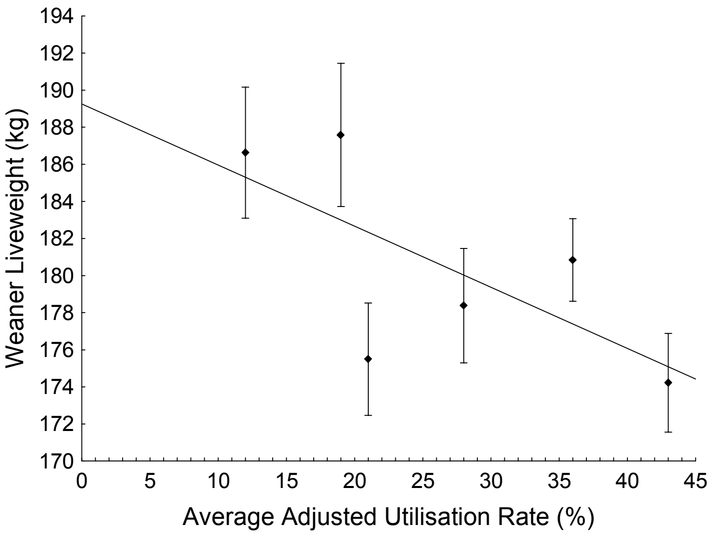


Figure 4.13. Effect of average adjusted utilisation rate (%) on average weaning weight (kg) 2003-2006. Bars denote s.e.

Weaner production per area was initially significantly higher with higher utilisation rates in 2001-2003 (Table 4.6, Fig. 4.14), but following the poor wet season of 2003, weaner production per area fell across all treatments, and by 2005 there was no additional weaner production per area with increasing utilisation rate. In 2006 weaner production increased for utilisation rates up to 36%, but not beyond. The slope of the fit for each year (B in Table 4.6) suggests that following a dry year the relative efficiency of production with the additional animals in the high utilisation paddocks was reduced compared to good years. This is due to a combination of a dampened weaning percentage and weaning weight at higher utilisation rates at different times following the dry 2002/2003 wet season.

Table 4.6. Summary of linear regression of weaner production versus utilisation for each year at Mt Sanford Station. B is the slope of the linear regression.

Year	N	B	Std. Err. of B	p-level
2002	6	62.63	6.12	0.0019
2003	6	44.14	7.96	0.0051
2004	6	24.08	6.29	0.0186
2005	6	4.67	22.11	0.8431
2006	6	59.49	16.59	0.0230
Average all years	6	38.76	4.84	0.0013

When averaged across all years weaner production was significantly higher at higher utilisation rates but variability in production between years greatly increased above 21% utilisation (Fig. 4.15).

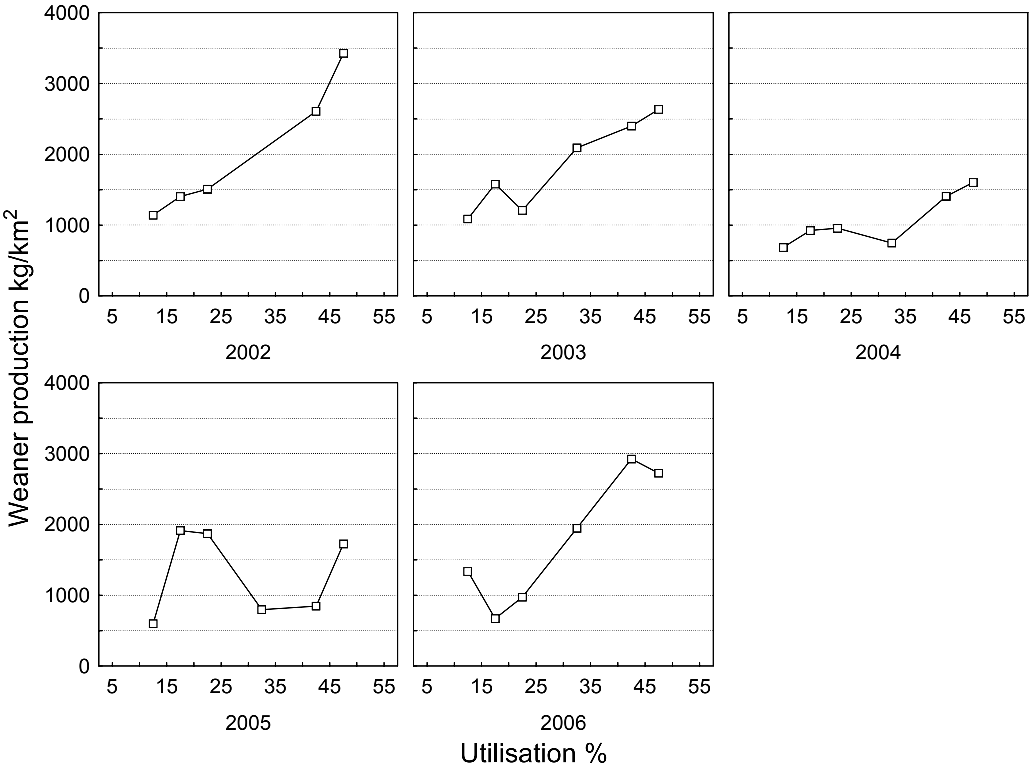


Figure 4.14. Effect of utilisation on weaner production through time at Mt Sanford.

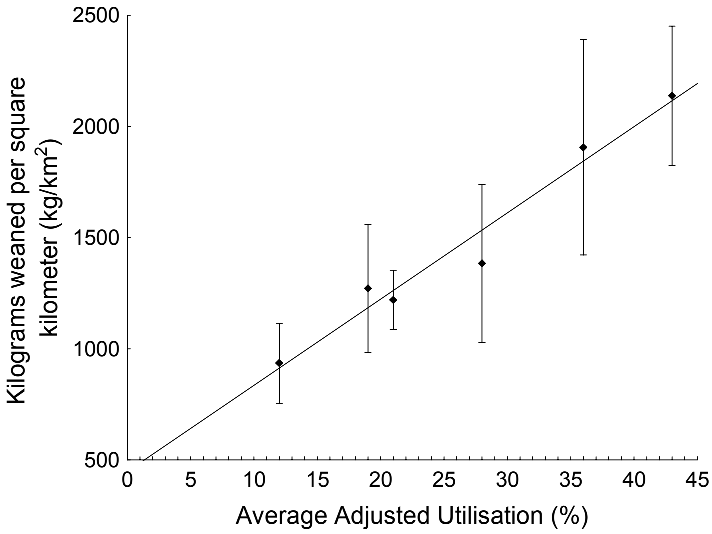


Figure 4.15. Effect of utilisation rate on average kilograms of weaner produced per square kilometre 2003-2006. Bars denote s.e.

4.1.2 Pigeon Hole

Utilisation treatments of 15, 20, 25, 35 and 40% have been in place for three years at Pigeon Hole.

4.1.2.1 Seasonal conditions

Since the study began rainfall has been above average in two years and below average for one year (Fig. 4.16). However the average used here (758 mm) is based on records from only the last 12 years and may not reflect the longer-term average. It is feasible that the long-term average is below 758 mm. Of importance in interpreting the results of this study is that the seasonal conditions experienced have not been extremes (either very low or very high), although rainfall in 2005-2006 was about 40% higher than the average. Timing of rainfall is also important and although rainfall in 2002-2003 was above average, since much of the rain arrived late in the season (February), pasture production for the wet season prior to the start of the study was poor (see later). Occasional wildfires started by lightning occurred on parts of the study site and have had an influence on the results of some grazing treatments. In particular, a large fire burnt about half of the study site in late 2002.

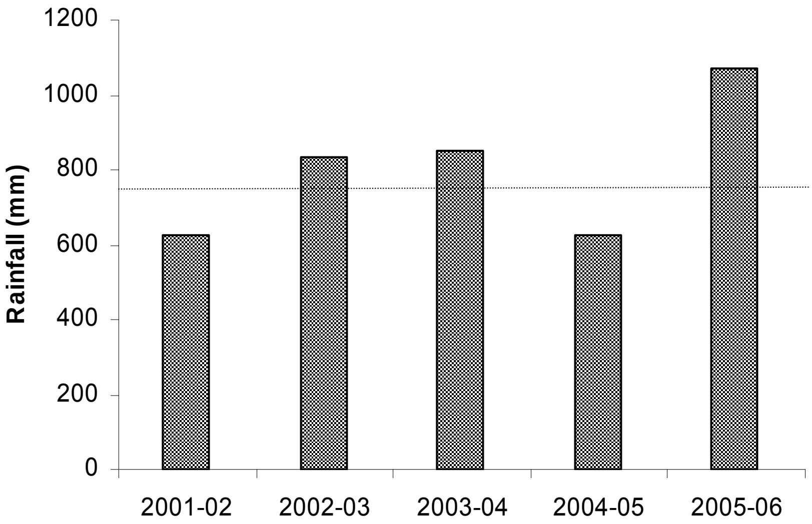


Figure 4.16. Annual rainfall (July to June) at Pigeon Hole for the two years prior to and during the study. The grazing treatments began in October 2003. The dotted line represents the 12-year average (758 mm).

4.1.2.2 Cattle numbers

Following the poor season of 2003, animal numbers increased substantially for 2004 (Table 4.7). Cattle numbers were reduced again for 2005 due to the combination of lower rainfall and fires in Villiers and Dead Cat paddocks. However, following a good wet season in 2005-2006, animal numbers were high again in 2006, with no trend of decreasing capacity through time in the higher utilisation treatments.

Table 4.7. Stocking rates (AE/sq. km) to achieve targeted utilisation rates in treatment paddocks at Pigeon Hole Station 2003-2006.

Paddock	Utilisation Rate	2003	2004	2005	2006	Avg
Brolga	15%	7.2	9.9	7.7	8.5	8.3
Sandstone	20%	6.6	13.4	10.6	12.0	10.6
Bauhinia	25%	3.5	14.1	11.3	13.4	10.5
Villiers	30%	5.8	16.9	9.9	16.2	12.2
Dead Cat	40%	10.5	20.4	7.7	21.8	15.1

4.1.2.3 Pasture

Yield

Yields in May 2004 were two to three times higher than yields in May 2003 reflecting the favourable seasonal conditions (Fig. 4.17). The 15 and 20% utilisation paddocks had significantly higher mean yields than the 25, 30 and 40% utilisation treatments in May 2003 and May 2004 (t-test, P=0.016, P=0.009 respectively). However average yield was not correlated with utilisation rate, initially due to the large inherent differences between paddocks. However, by May 2006, the range in average pasture yield between utilisation paddocks was only 176 kg/ha. This suggests little effect of higher utilisation treatments on pasture growth at this stage of the study.

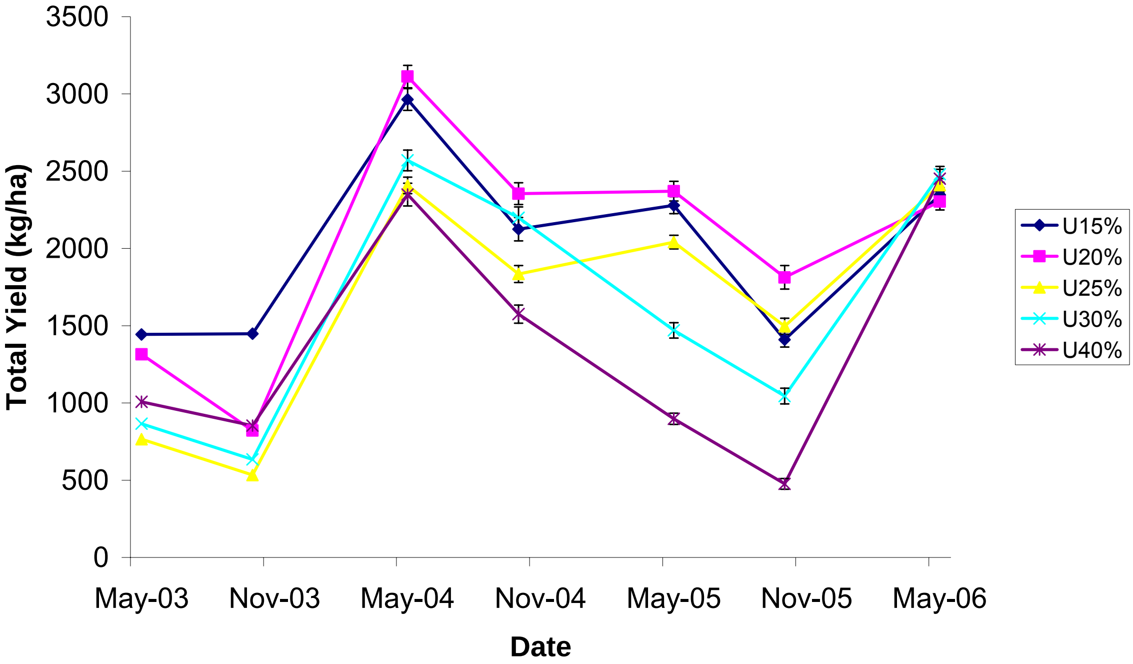


Figure 4.17. Average total yield in utilisation paddocks through time at Pigeon Hole. Bars denote standard errors.

Palatable Yield

The variation in plant functional groups between treatments such as palatable yield demonstrates the inherent site differences in utilisation paddocks (Fig. 4.18). There is no apparent separation of the treatments through time that resembles a treatment response yet for palatable yield.

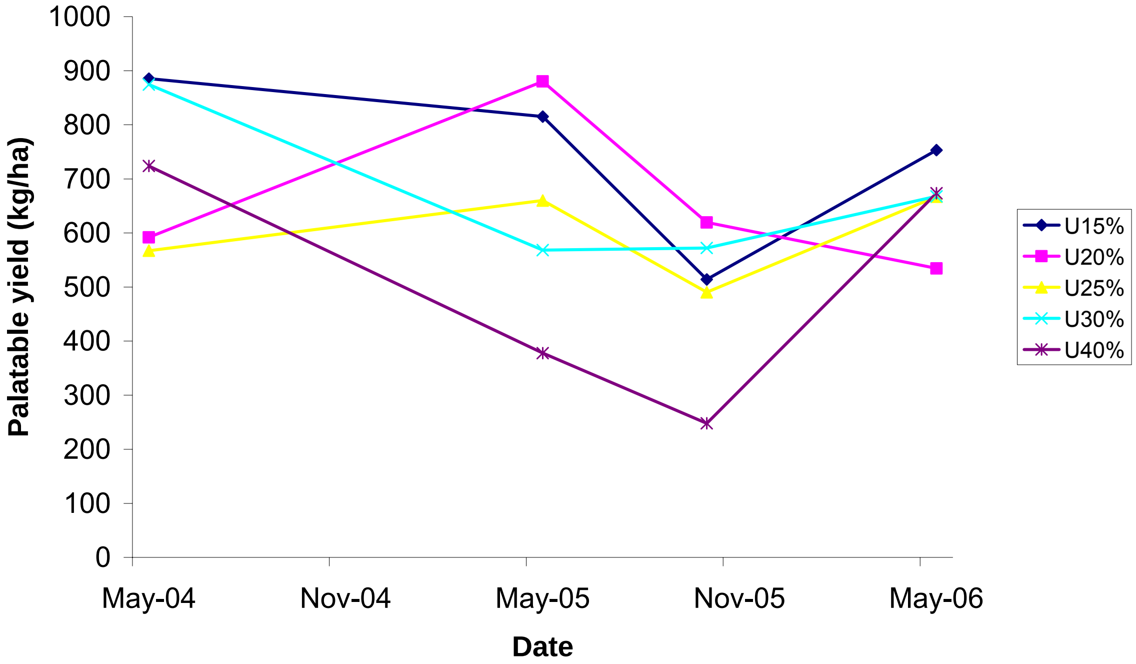


Figure 4.18. Average palatable yield in utilisation paddocks through time at Pigeon Hole.

Cover

Cover fluctuated seasonally (Fig. 4.19). Although cover is not significantly correlated with utilisation, the treatments are starting to separate out over time in October samplings. Of note is the very low average cover in the 40% utilisation treatment in October 2005, (29%) which is less than recommended for preventing soil and water loss (McIvor *et al*. 1995). However cover levels in October were probably low in part due to the fire at the site in February 2005.

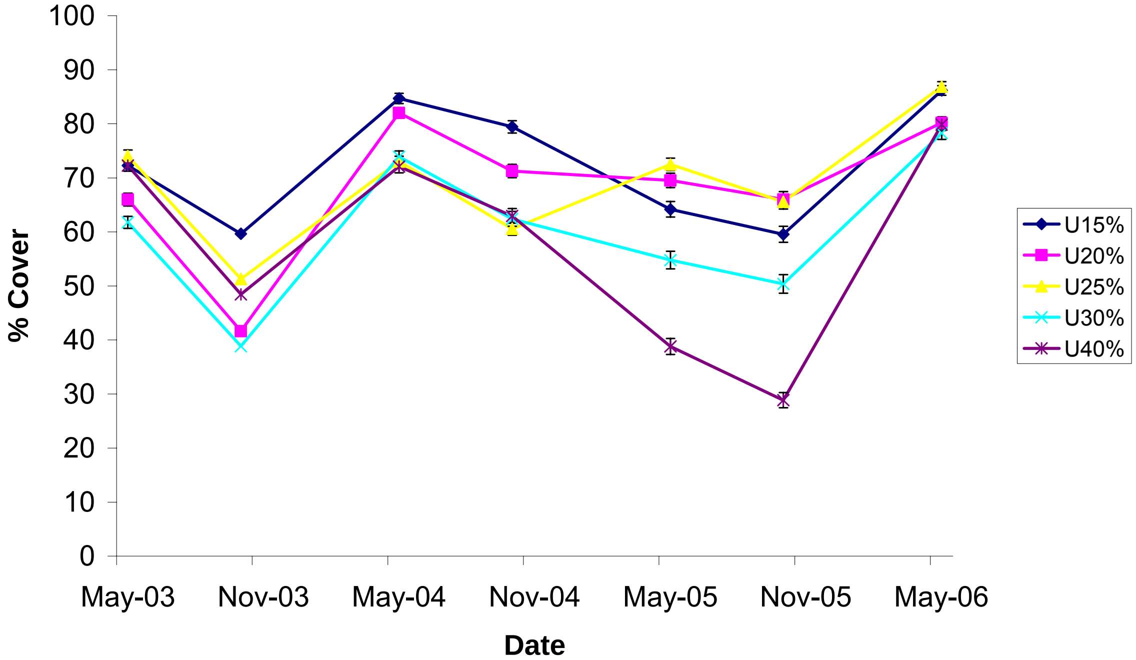


Figure 4.19. Average percent understorey cover in utilisation paddocks through time at Pigeon Hole. Bars denote standard errors.

Perennial grass basal area

There is no correlation between utilisation and perennial grass basal area (PGBA) (Fig. 4.20). The lowest PGBA is in the lightest stocked paddock. Perennial grass basal area is generally low across the study site, reflecting the high proportion of annual sorghum. Only the 20% utilisation treatment has not had a decline in PGBA through time.

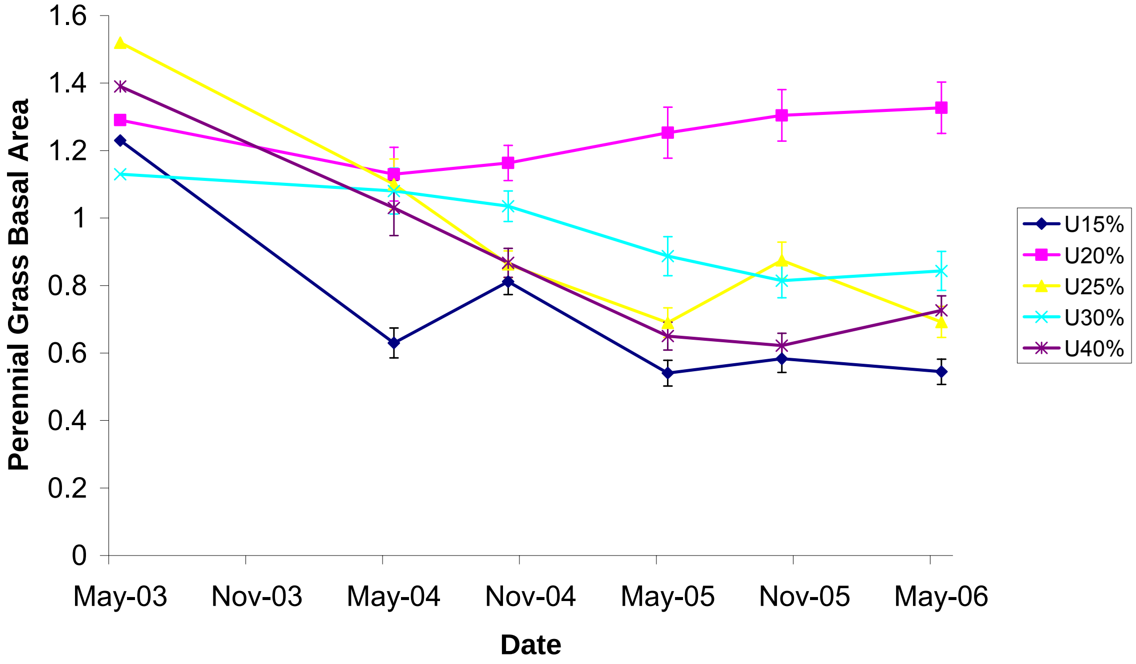


Figure 4.20. Average perennial grass basal area with utilisation treatment through time at Pigeon Hole. Bars denote standard errors.

4.1.2.4 Animal Production

Animal production is not yet reflecting utilisation at Pigeon Hole. Branding percentage is relatively stable across all utilisation treatments (Fig. 4.21).

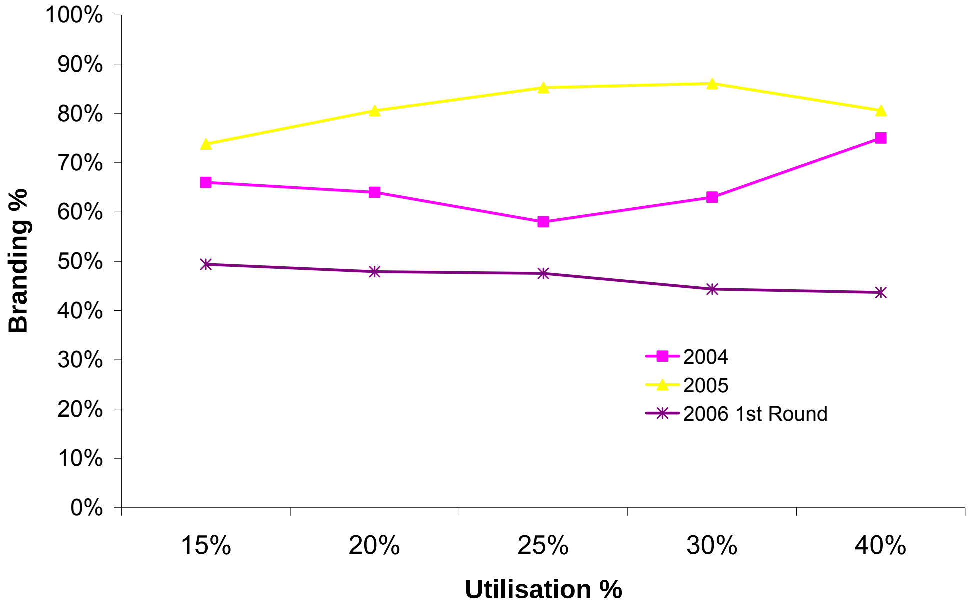


Figure 4.21. Branding percentage at Pigeon Hole Station for the utilisation treatments for 2004 to 2006.

Weight gain

Weight gain of indicator steers was higher with higher utilisation rates in 2005, although not during the wet season (Table 4.8, Fig. 4.22). The higher weight gain at higher utilisation rates in the 2005 dry season is unexpected and may be due to the fires in the 30 and 40% utilisation paddocks in February 2005, having an effect on pasture nutrition. Average crude protein was slightly higher in these paddocks in 2005 (approximately 5% compared with approximately 4% in the 25% and lower paddocks) (Fig. 4.23). Stocking rates were greatly reduced in the 30 and 40% paddocks due to low forage availability following the fires. The combination of the low stocking rates and high crude protein may have facilitated the greater individual gain in these paddocks.

On an area basis, the wet season of 2005 - 2006 had a different trend than the previous year, with average weight gain per area lowest at 40% utilisation. It will be interesting to see if this trend continues through the dry season of 2006.

Table 4.8. Average weight gain (kg) of indicator steers at Pigeon Hole Station in 2005 and 2006 for the utilisation treatments.

Paddock	Utilisation Rate	Wet 04/05	Dry 05	all 2005	Wet 05/06
Brolga	15%	109	1	110	146
Sandstone	20%	81	24	105	103
Bauhinia	25%	86	24	111	79
Villiers	30%	57	52	109	112
Dead Cat	40%	53	87	140	87

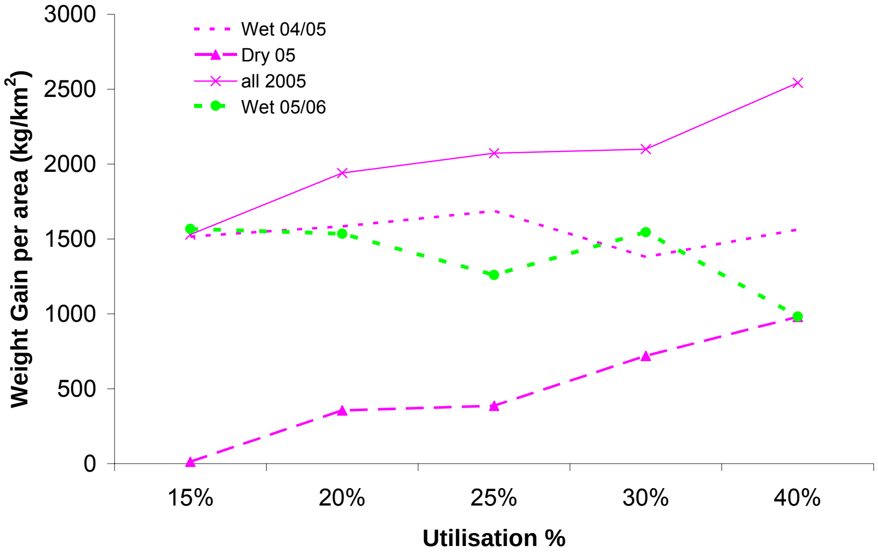


Figure 4.22. Weight gain of indicator steers per unit area at Pigeon Hole Station in 2005 and 2006 for the utilisation treatments.

Crude protein varied between sampling periods, but didn't vary with utilisation rate at Pigeon Hole (Fig. 4.23).

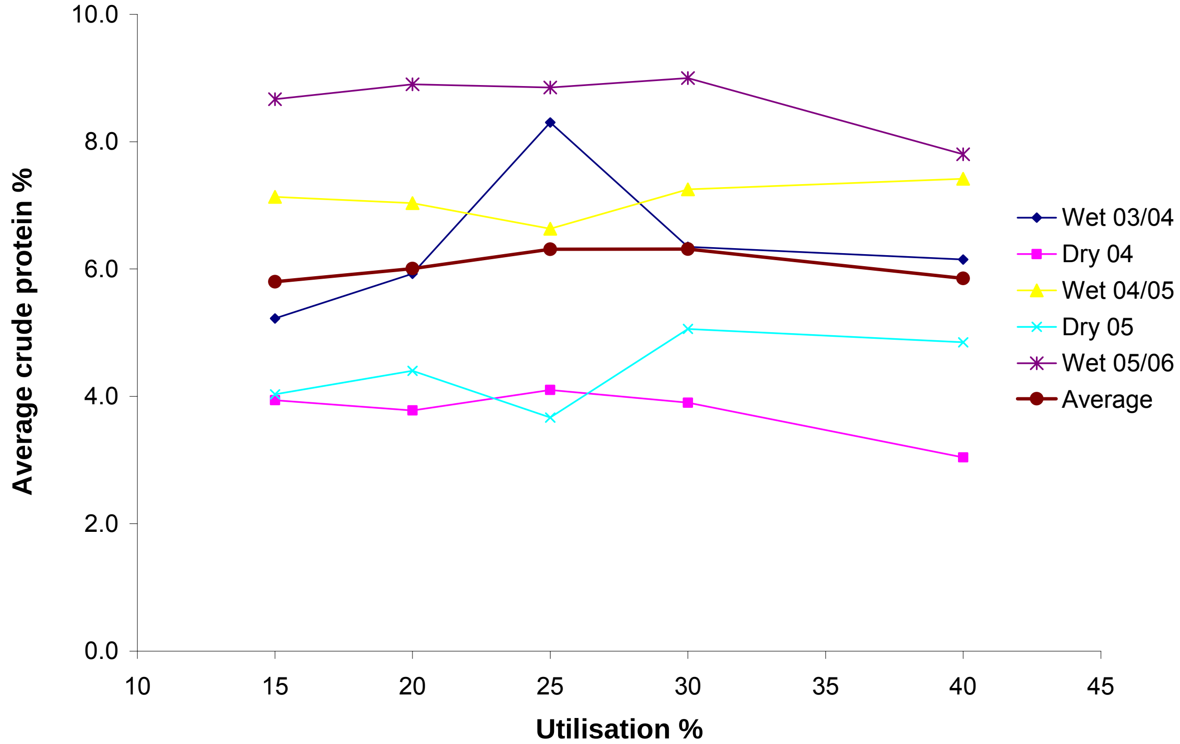


Figure 4.23. Average crude protein in different utilisation treatments through time at Pigeon Hole.

4.2 Activity 2 - Enhanced understanding of grazing distribution for improved fencing, paddock design and water placement

4.2.1 Experiment 1 – Grazing radius

4.2.1.1 Pasture

As might be expected given the relatively short time the study has been underway, there have been no clear and consistent effects of paddock configuration on pasture variables in the different paddocks. However, the statistical analysis suggests that overall some differences are emerging between the treatments for a number of pasture variables.

It might be expected that paddocks with a larger grazing radius would have more forage overall than paddocks with smaller grazing radii (despite similar imposed utilisation rates) since more of the paddock is further from water in the former case and cattle might be less likely to travel to distant areas. This would suggest that more of the forage is being unused because it is inaccessible to cattle. A trend of lower pasture yield in the paddock with the smallest (1 km) grazing radius does appear to be emerging (Fig. 4.24).

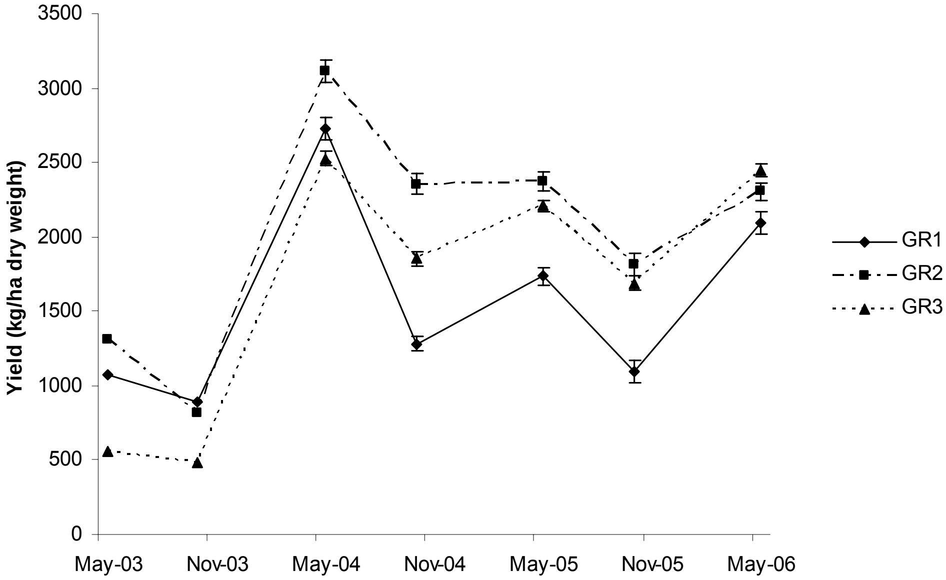


Figure 4.24. Pasture yield (mean ± SE) for the three grazing radius paddocks for the duration of the study. GR1, GR2 and GR3 = grazing radius of 1, 2 and 3 km, respectively.

However, this observation is not consistent with data on palatable yield (Fig. 4.25), where the smallest grazing radius often had larger quantities of palatable forage than the other paddocks. In this case palatable yield was comprised of those pasture species usually considered to be palatable and preferred by cattle. Thus the perennial grasses *Astrebla spp.*, *Chrysopogon fallax*, *Dichanthium fecundum*, and the annual grasses *Iseilema* spp. and *Brachyachne convergens* were in this group.

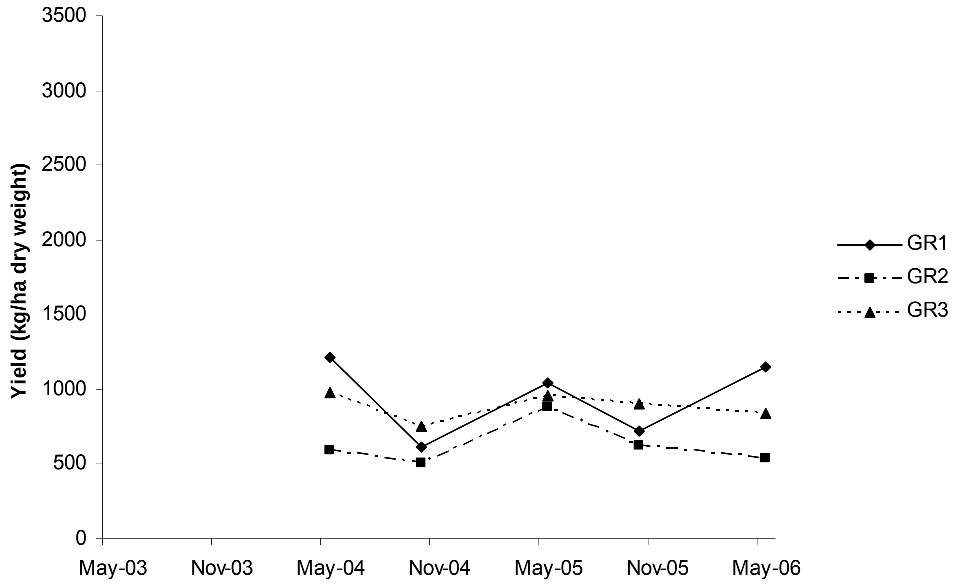


Figure 4.25. Yield of palatable forage for the three grazing radius paddocks for the duration of the study. GR1, GR2 and GR3 = grazing radius of 1, 2 and 3 km, respectively.

It is notable that the yield of palatable forage in GR1 was lower at the end of the dry season than for GR3, suggesting cattle were having a greater impact in consuming this component of the understorey in the smaller paddock. However, this difference was subtle and at this stage no statistical analysis of the palatable yield data has been completed. In addition, the palatable forage yield in GR2 was always less than the other two paddocks (possibly because of inherent paddock differences), complicating the picture.

Evidence for cattle having a greater impact on the pasture in GR1 is apparent in the defoliation data with the percentage defoliation consistently being higher over the dry season in this treatment (Fig. 4.26).

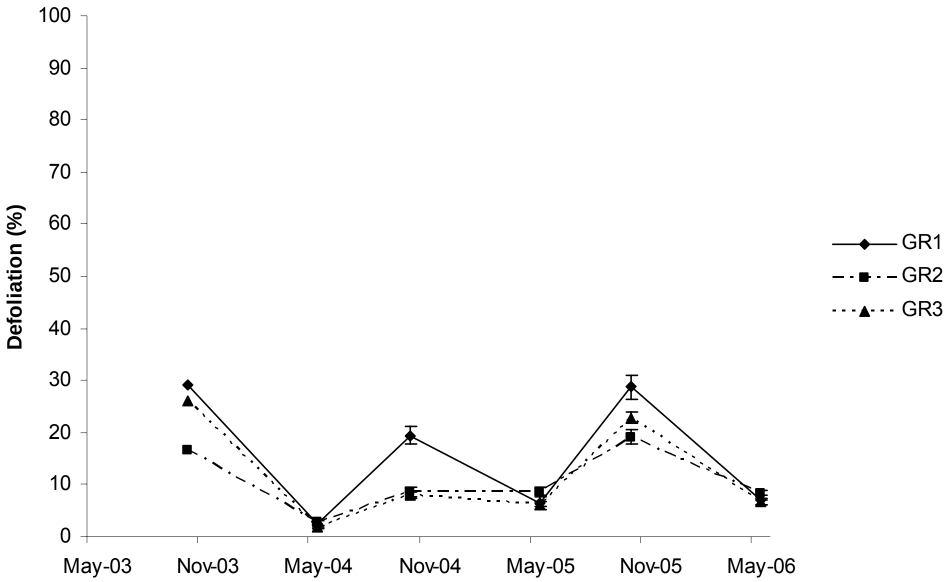


Figure 4.26. Defoliation (mean ± SE) for the three grazing radius paddocks for the duration of the study. GR1, GR2 and GR3 = grazing radius of 1, 2 and 3 km, respectively.

Perennial grass basal area (PGBA: an indicator of range condition) has shown no response to the treatments (Fig. 4.27). This is not to say that there have been no impacts of the treatments on PGBA since declines in the basal area of desirable (or decreaser) species may be masked by increases in undesirable (or increaser) species such as *Aristida latifolia*. At this stage of the study this is unlikely because this variable often tends to be slow to change and the treatments we have applied could be considered to be relatively subtle. This conclusion is supported by the observation that the initial differences in this variable between paddocks are still apparent.

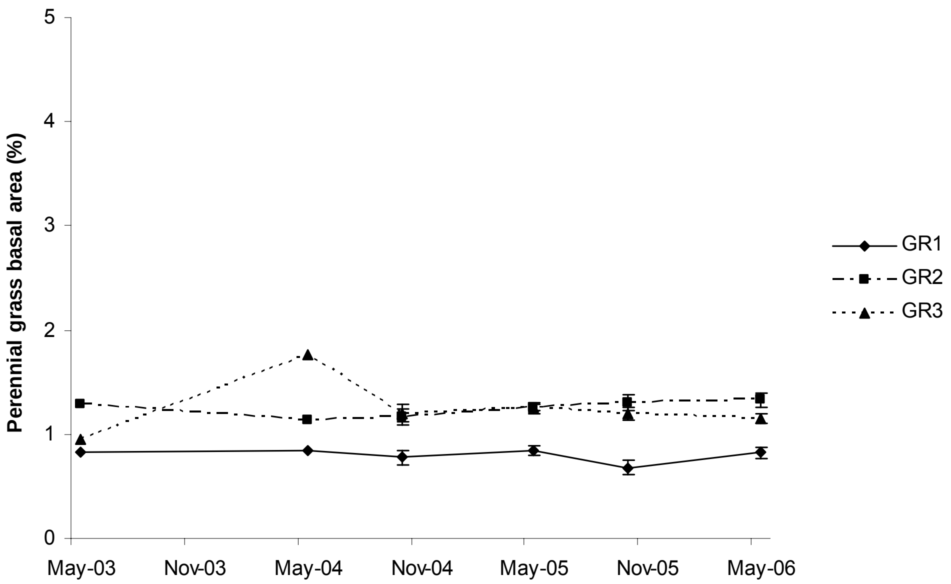


Figure 4.27. Perennial grass basal area (mean ± SE) for the three grazing radius paddocks for the duration of the study. GR1, GR2 and GR3 = grazing radius of 1, 2 and 3 km, respectively.

Total projected foliar cover also does not show a distinct separation in response to the treatments (Fig. 4.28) although, as for total yield, there does appear to be a decrease for GR1 relative to the other treatments. GR3 also shows a trend of increasing cover. This provides further (albeit weak) support for the tentative conclusion that cattle are having a greater impact where the grazing radius is smaller. It should be noted, however, that the statistical analysis did indicate an overall significant treatment*year effect for cover, suggesting a difference between treatments was emerging.

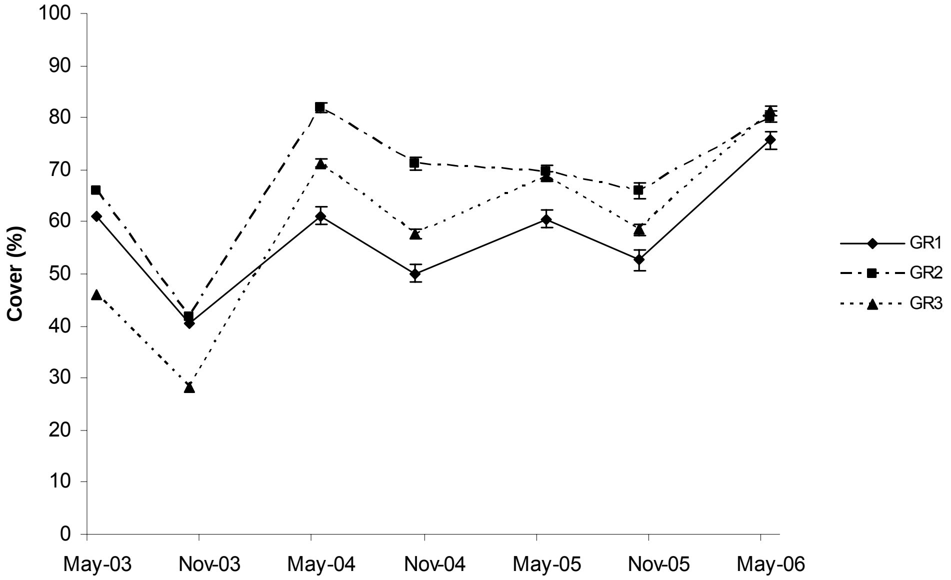


Figure 4.28. Total projected foliar cover (mean ± SE) for the three grazing radius paddocks for the duration of the study. GR1, GR2 and GR3 = grazing radius of 1, 2 and 3 km, respectively.

The statistical analysis indicated that for most variables there were overall significant treatment effects (i.e. differences between paddocks), a significant year effect and a significant interaction between treatment and year for the grazing radius treatments (Table 4.9). However, there were differences between paddocks before the treatments were imposed, which makes the treatment*year interaction especially important in assessing treatment effects. Since this effect is significant for all variables (although only weakly for perennial grass basal area) the effect of the treatments depends on the year, suggesting that some treatments are having differential effects on pasture variables. These results therefore support the above conclusions.

Table 4.9. Results of the REML Generalised Linear Mixed Model analysis for the grazing radius treatments for May pasture data from 2003-2005.

Effect	Variables			
	Yield	**Defoliation**	**Perennial Grass Basal Area**	**Cover**
Treatment	***	**	***	***
Year	***	***	NS	***
Treatment*Year	***	***	*	***

*** = P<0.001, ** = P<0.01, * = P<0.05, NS = not sig.

At this stage of the study the data suggest that despite similar utilisation rates in each paddock, those with a larger grazing radius might be experiencing more uneven grazing, with areas more distant from water being grazed less. Thus much of the available forage would not be utilised although in areas closer to water the forage is more likely to be depleted. These factors are possibly leading to overall differences in pasture variables between the paddocks. However, further analysis of the data particularly in terms of spatial impacts and grazing distribution is required to confirm these observations. For example, we might expect a stronger distance to water effect in paddocks with large grazing radii. GPS collars have only recently been deployed to these paddocks so no data on grazing distribution is yet available.

4.2.1.2 Livestock performance and dietary quality

The branding percentage (Fig. 4.29) and weight gain per animal (Fig. 4.30) data do not show any trends in relation to the treatments, although we only have full-year data for two years.

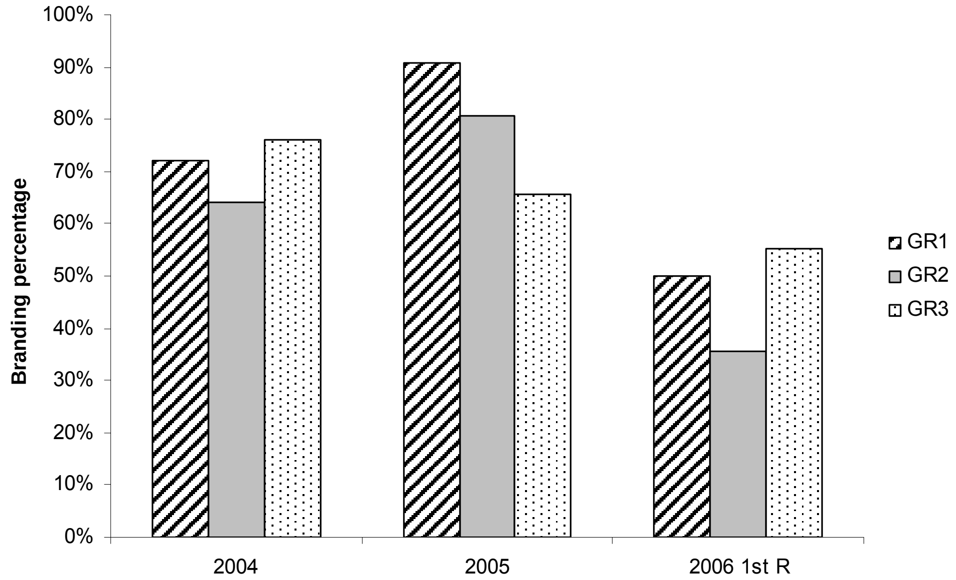


Figure 4.29. Branding percentage for the grazing radius paddocks. GR1, GR2 and GR3 = grazing radius of 1, 2 and 3 km, respectively.

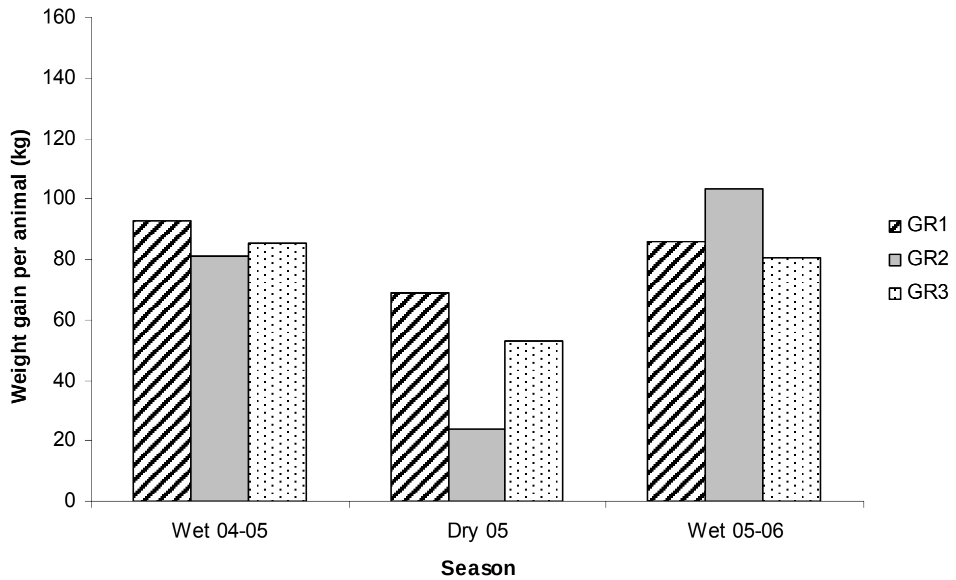


Figure 4.30. Liveweight gain (kg/animal) for the grazing radius paddocks. GR1, GR2 and GR3 = grazing radius of 1, 2 and 3 km, respectively.

A potentially weak trend is emerging in the percentage of crude protein in the diet. Specifically, protein has been marginally lower in the GR3 treatment than the other treatments since the 2004-2005 wet season (Fig. 4.31) despite this treatment showing higher dietary protein levels earlier in the study.

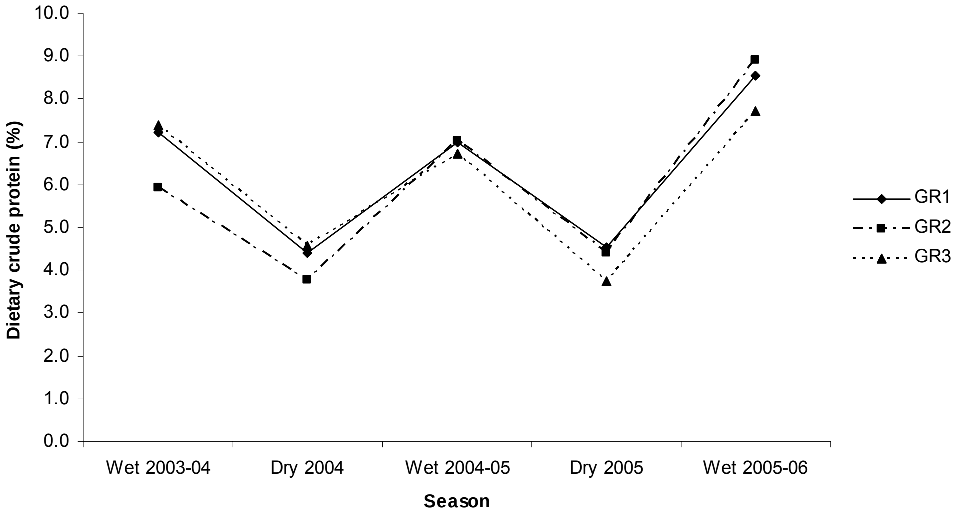


Figure 4.31. Percentage of crude protein in the diet for the grazing radius paddocks. GR1, GR2 and GR3 = grazing radius of 1, 2 and 3 km, respectively.

In conclusion, the data suggest there might be an effect of poor grazing distribution on pasture variables and perhaps diet quality in the largest grazing radius paddock resulting in differences compared to paddocks with smaller grazing radii. Cattle appear to be having a greater overall impact on the pasture in the smallest grazing radius paddock where the whole paddock appears to be more fully utilised, but there is no evidence that this is flowing through in any way to livestock production. It remains to be seen what the long-term consequences will be for range condition and livestock production from the apparent greater grazing impact in GR1. Because of the weak trends that have emerged, however, it is impossible at this stage to draw reliable conclusions concerning the impact of the grazing radius treatments on pasture variables and livestock production.

4.2.2 Experiment 2 – Grazing distribution

4.2.2.1 Pasture

In contrast to the grazing radius paddocks, it might be expected that little difference would emerge over time between the three grazing distribution treatments because each paddock has the same utilisation rate and grazing radii are similar for each paddock since larger paddocks have more waters. Grazing pressure is therefore expected to be more evenly distributed over each paddock, potentially leading to similar overall impacts on the vegetation.

No strong and consistent trends have emerged in the pasture variables amongst the three grazing distribution paddocks although the statistical analysis (on the May data only) does suggest differences are emerging for some variables. Of course a failure to detect strong effects might be due to hysteresis in the ecological system, the lack of extreme seasonal conditions and/or the relatively short time treatments have been in place rather than the absence of any effect.

Pasture yield appears to be showing some reduction in the One Water treatment compared with the other treatments (Fig. 4.32), although this treatment recorded a slightly higher yield at the recent sampling in May 2006 than the Multiple Water treatment. The statistical analysis on the May data over the first three years indicated significant treatment, year and treatment*year effects for pasture yield (Table 4.10).

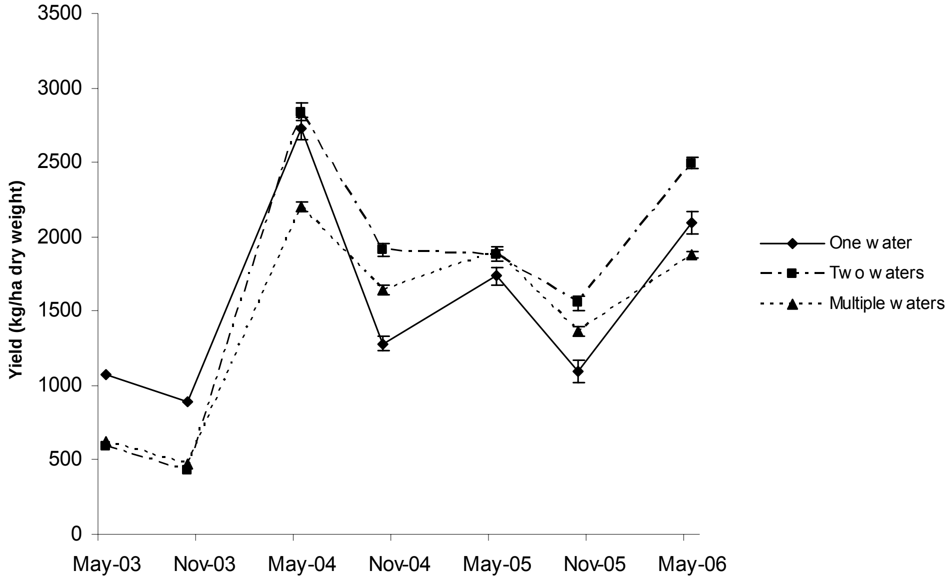


Figure 4.32. Pasture yield (mean ± SE) for the three grazing distribution paddocks for the duration of the study.

There appear to be no markedly different trends between the treatments in terms of yield of palatable forage (Fig. 4.33), defoliation of the pasture (Fig. 4.34) and perennial grass basal area (Fig. 4.35). These conclusions are supported by the statistical analysis for the latter two variables which showed treatment was not significant (Table 4.10), although a weakly significant treatment*year interaction is indicated for defoliation.

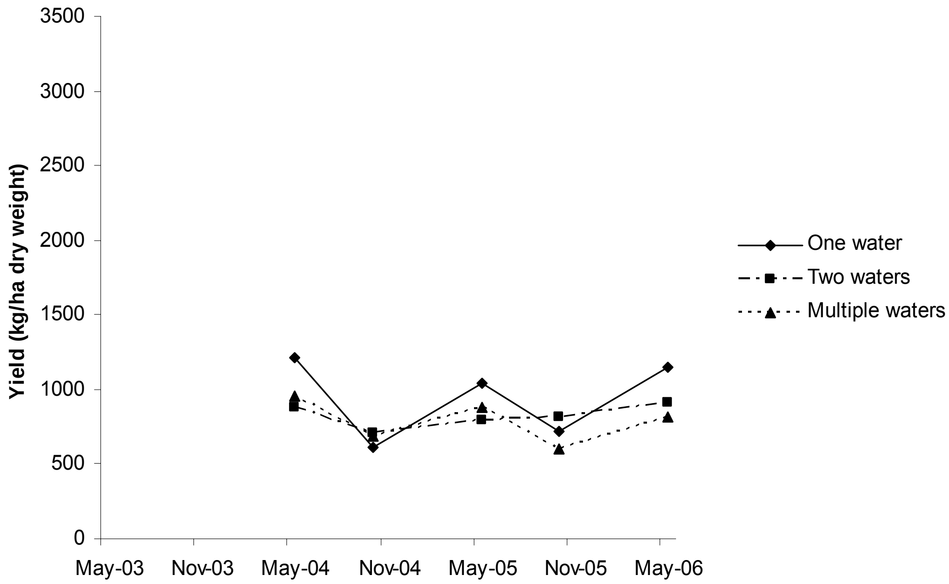


Figure 4.33. Yield of palatable forage for the three grazing distribution paddocks for the duration of the study.

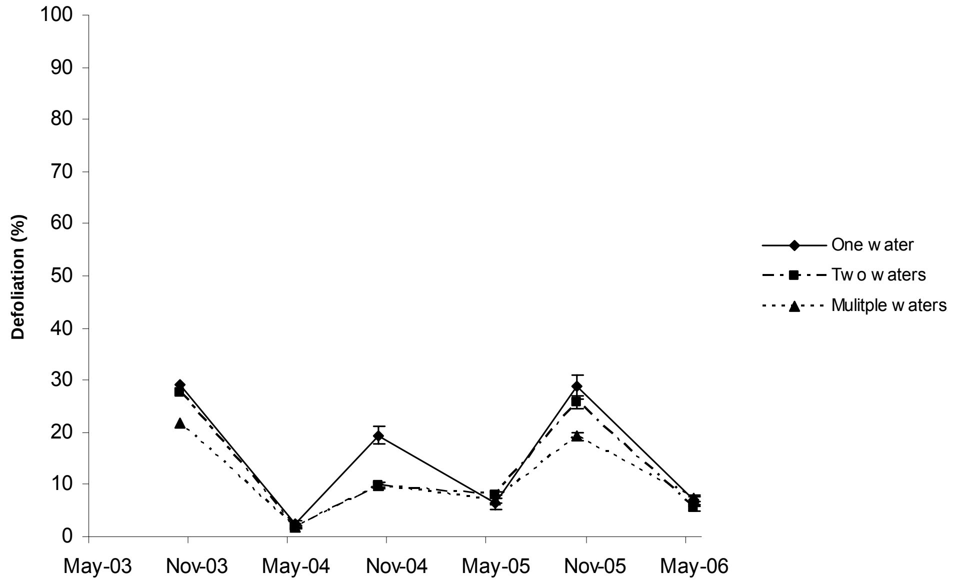


Figure 4.34. Percentage pasture defoliation (mean ± SE) for the three grazing distribution paddocks for the duration of the study.

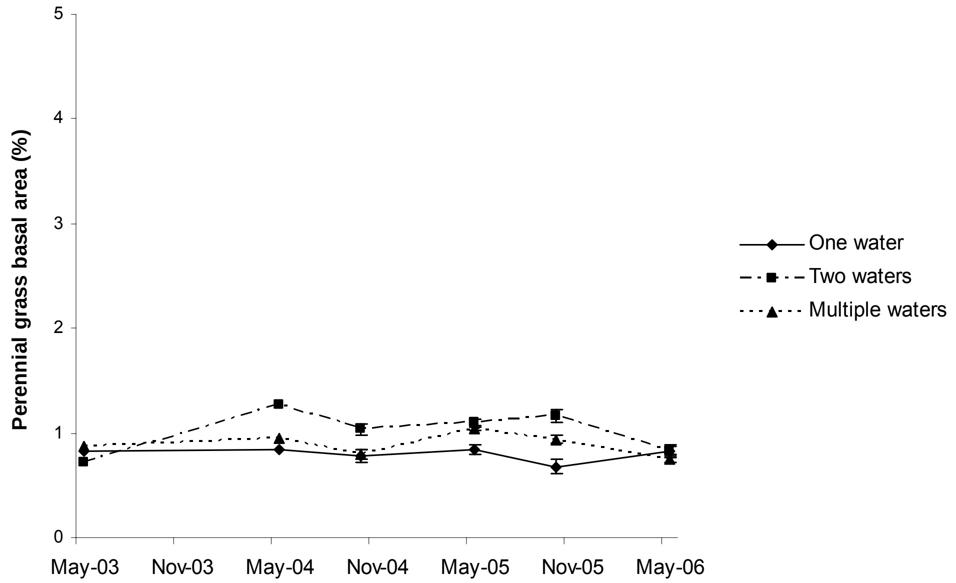


Figure 4.35. Perennial grass basal area (mean ± SE) for the three grazing distribution paddocks for the duration of the study.

Foliar cover (Fig. 4.36) shows a similar response to pasture yield in respect of the One Water treatment showing a general decline relative to the other treatments, although cover on the One Water treatment was marginally higher than the Multiple Water treatment in May 2006. Treatment, year and treatment*year were all highly significant in the overall analysis of cover (Table 4.10).

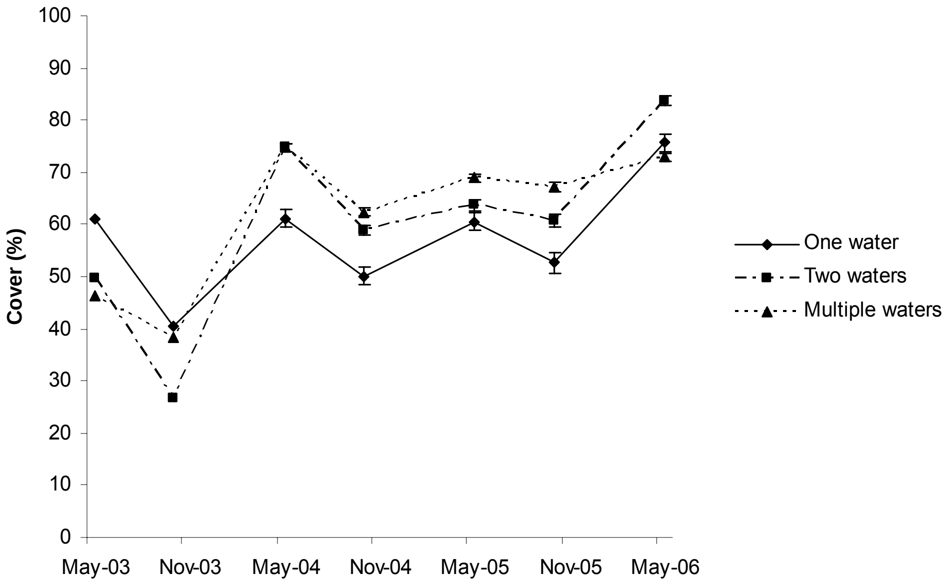


Figure 4.36. Total projected foliar cover (mean ± SE) for the three grazing distribution paddocks for the duration of the study.

Table 4.10. Results of the REML Generalised Linear Mixed Model analysis for the grazing distribution treatments for May pasture data from 2003-2005.

Effect	**Variables**			
	Yield	**Defoliation**	**Perennial Grass Basal Area**	**Cover**
Treatment	***	NS	NS	***
Year	***	***	NS	***
Treatment*Year	***	*	NS	***

*** = P<0.001, ** = P<0.01, * = P<0.05, NS = not sig.

While it could be argued that the apparent lack of treatment effect for some variables reflects the effectiveness of more even water distribution across each paddock in spreading out grazing impact, it is difficult to be confident drawing this conclusion at this relatively early stage of the study. In fact, given that differences appear to be emerging for some variables it is possible that overall grazing impacts differ between treatments because even grazing is not being achieved effectively in the larger paddocks by installing additional water points. Indeed, the cattle distribution data from the GPS collars presented later supports this conclusion.

4.2.2.2 Livestock performance and dietary quality

The branding percentage, live weight gain per animal and diet quality data are presented in Figs 4.37, 4.38 and 4.39, respectively. No clear trends are apparent in the data, although some differences between treatments are evident for the live weight gain data. As for the pasture data it remains too early to be able to draw any conclusions from the livestock performance data.

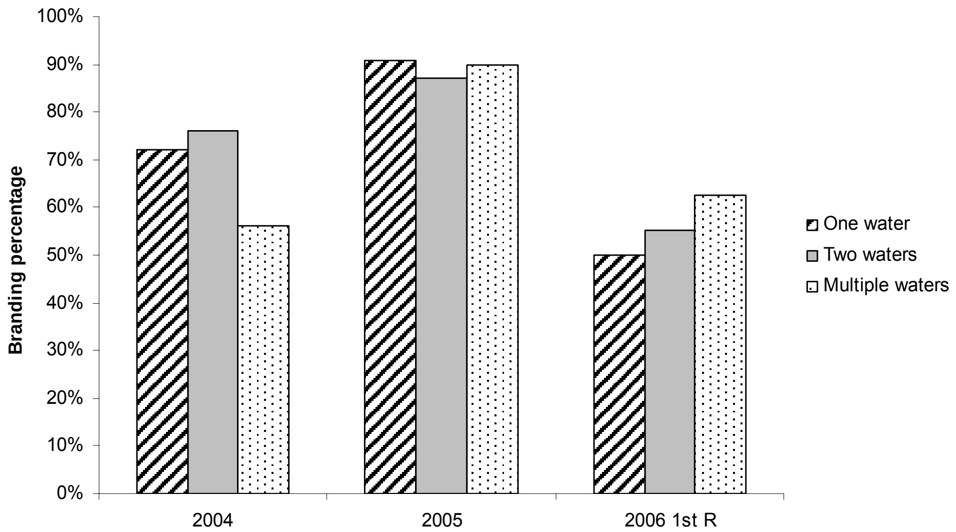


Figure 4.37. Branding percentage for the grazing distribution paddocks.

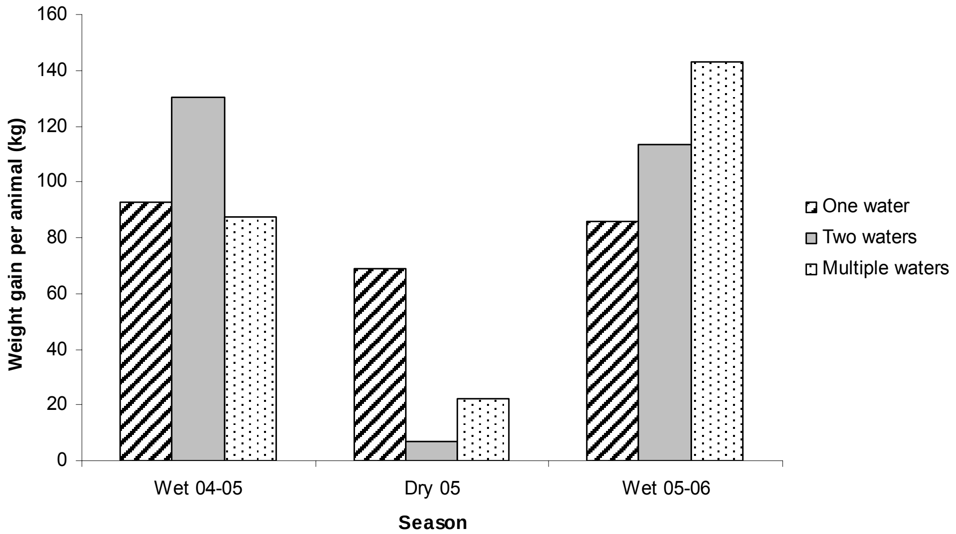


Figure 4.38. Live weight gain (kg/animal) for the grazing distribution paddocks.

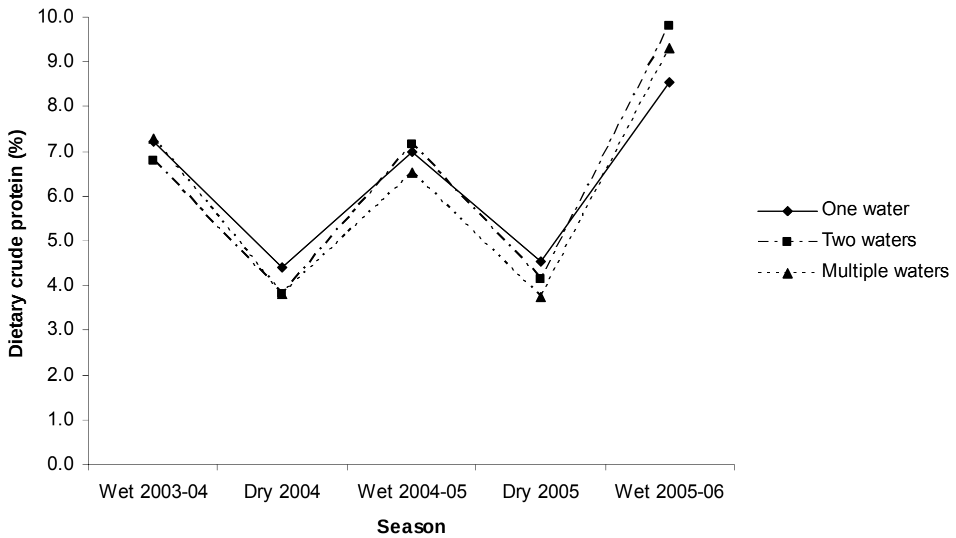


Figure 4.39. Dietary crude protein (%) in the diet for the grazing distribution paddocks.

4.2.2.3 Cattle distribution and grazing behaviour

Patterns of use

The cattle distribution data from the GPS collars in the three grazing distribution paddocks (i.e. paddock size and diversity treatments) show a very clear effect of paddock size on the effectiveness of use of the landscape. This is demonstrated in Fig. 4.40 which uses the home range of cattle as a proportion of the paddock in which they grazed as a measure of effective use of a paddock. In the smallest paddock (which had one water), the home range of most cows in both wet and dry seasons was very close to the size of the paddock. As paddock size increased, paddocks were used less effectively by cattle despite the larger paddocks having additional water points (and generally similar grazing radii).

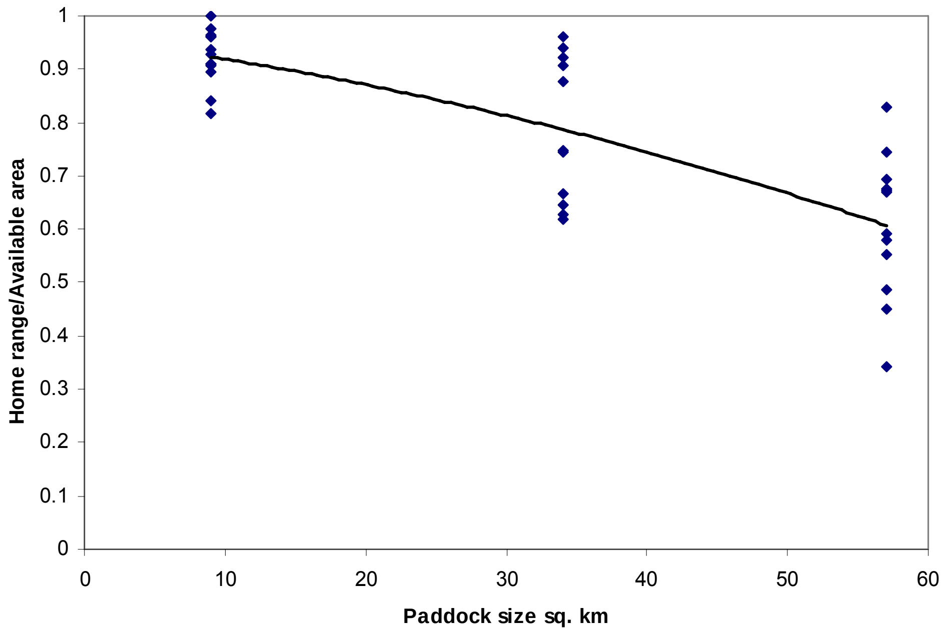


Figure 4.40. The effectiveness of paddock use as determined by the ratio of home range to paddock size for three paddocks. Data obtained in both wet and dry seasons. Each point represents a single cow over a six month period. The smallest paddock contained one water, the intermediate paddock two and the large paddock five water points.

These data suggest there is improved effectiveness of use of the landscape overall and more even use within paddocks when paddock size is reduced. When smaller paddocks are used it is readily apparent that more effective landscape use will result because cattle movements are more restricted and they are simply held on the land where they are placed. With more, smaller paddocks on a property greater use of the land is possible than with larger paddocks where cattle can exercise considerable choice of habitat. On the other hand, a close correlation between home range and paddock size in small paddocks while on the surface suggests more even use of a paddock, use within the paddock has remained uneven to some degree. Overall more of the paddock is used, but cattle continue to heavily use certain areas at particular times. In this study these areas were often riparian areas (despite the creeks usually being dry) and areas of red soil (depending on the season and seasonal conditions). However, other areas were also favoured and these appeared to be associated with past grazing use.

Differences between individual cattle in the areas they used most also resulted in more even use of the larger paddocks overall than is suggested by Fig. 4.40. It is often the case that particular water points and associated areas are favoured by some cattle but others prefer different waters and habitats so that their use is complementary.

As mentioned earlier, this evidence for more effective landscape use in smaller paddocks, and conversely less even use in larger paddocks despite the latter having additional waters, is consistent with the data that shows some pasture variables are responding differently between paddocks. If grazing use of all paddocks is relatively even then we should expect little difference in pasture variables between paddocks.

<u>Factors influencing patterns of use</u>

A number of pasture and landscape characteristics have been examined as being potentially important in determining how cattle use the land. Total forage available, palatable forage available and soil type were expected to be very influential factors. Preference indices for these factors for data collected over the 2005 dry season are presented here. Work is continuing on deriving this data for other seasons.

No strong preferences were shown for different soil types, and the results were not consistent between paddocks (Fig. 4.41). In the One Water paddock there was an apparent preference for intermediate soil, but this was not apparent in the other paddocks. A strong preference for riparian soils/ areas was evident in the Two Waters paddock. Given the ambiguous nature of these results it is reasonable to conclude that whether cattle were able to exhibit a preference depended on the location of different soil types in relation to the water points.

There were surprising trends in relation to the use of land with different total pasture availability. In all paddocks there was an apparent preference for areas with lower quantities of pasture (Fig. 4.42). Given that this analysis was based on the pasture available at the beginning of the sampling period the results do not necessarily reflect the recent impact of grazing on pasture biomass. Rather it suggests cattle are using areas that do have lower biomass levels possibly because these areas are within easy walking distance of water, or for other reasons. This situation may have arisen by coincidence depending on where the waters were placed, or a longer term preference for these areas that has resulted in grazing impacts that have reduced their productivity. The origin of this preference may have been a result of proximity to water, higher nutrient content in the soils and hence pasture, or preferred plant species. The effects of grazing in keeping the pasture short and stimulating nutritious regrowth may be perpetuating a preference for these areas despite lower forage availability. Similar preferences were evident for areas with lower palatable (rather than total) forage biomass (Fig. 4.43).

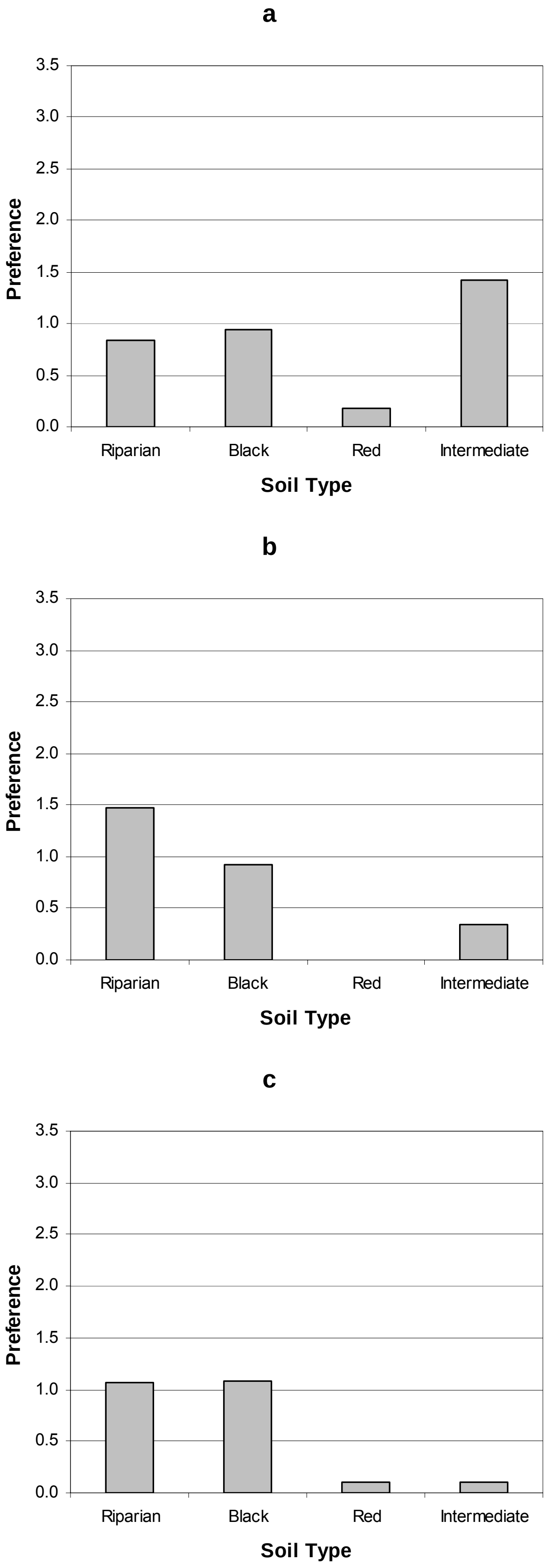


Figure 4.41. Use of different soil types by cows in a) One Water, b) Two Waters, c) Multiple Waters treatments (2005 dry season). A preference index > 1 indicates preferential use, <1 indicates avoidance. Preference indices derived from all GPS fixes (except those within 250 m of water points) from 2-4 cows.

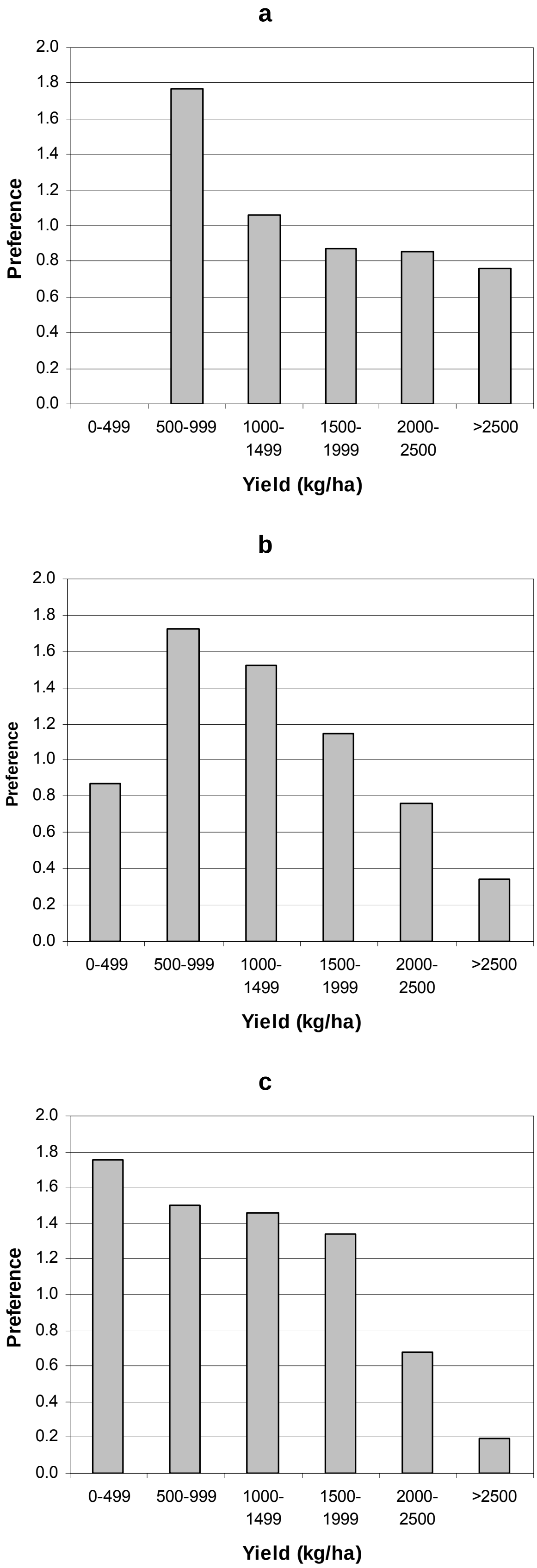


Figure 4.42. Use of areas supporting different total pasture biomasses by cows in a) One Water, b) Two Waters, c) Multiple Waters treatments (2005 dry season). Preference index as in Fig 4.41.

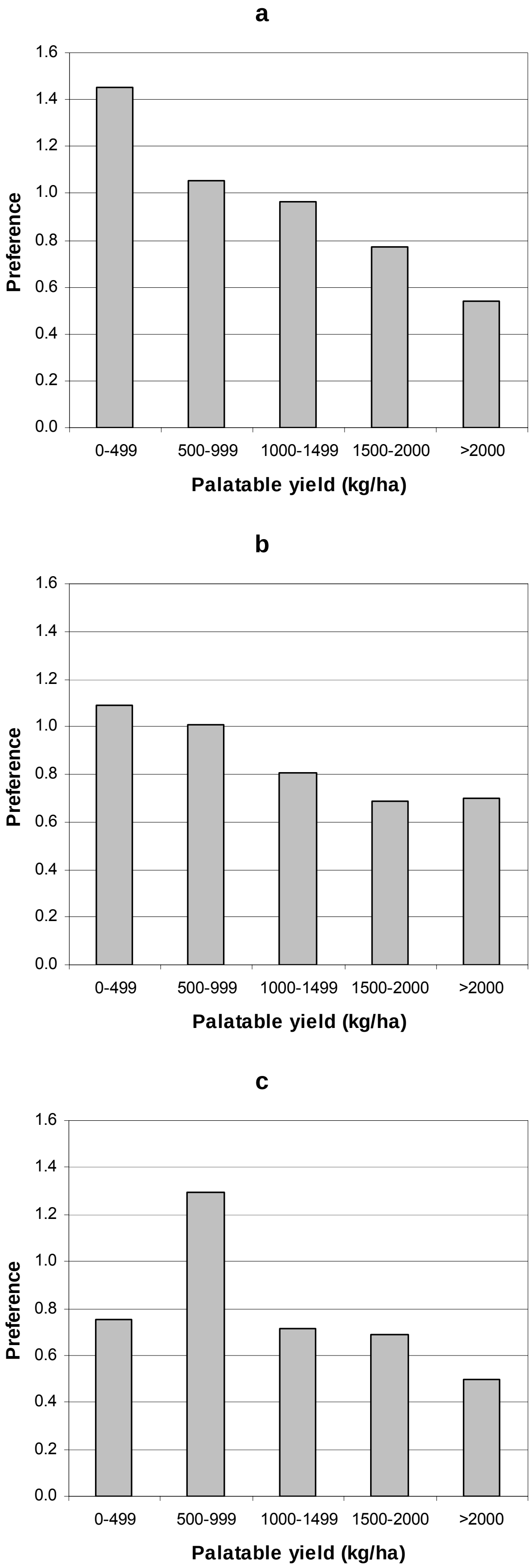


Figure 4.43. Use of areas supporting different palatable forage biomasses by cows in a) One Water, b) Two Waters, c) Multiple Waters treatments (2005 dry season). Preference index as in Fig 4.41.

The intention in associating grazing distribution with pasture and landscape variables was to identify those factors that are likely to be useful in models designed to explain and/or predict the use of the landscape by cattle. However, none of the above variables are likely to be useful for this purpose, at least in the way that was expected. Higher biomasses of palatable forage were expected to be positively related to preference but the reverse appears to be the case. Work is continuing to better define the characteristics of the areas that cattle appear to prefer in order to develop such predictive models. At this stage, proximity to water and the re-use of previously grazed areas appear to be strong determinants of grazing distribution.

4.3 Activity 3 - Implications of pastoral development options for biodiversity conservation

4.3.1 Description of biota

A total of 231 plant, 75 bird, 20 reptile, 4 small mammal and 63 ant species have been recorded from biodiversity sampling sites (some additional species have been recorded within the trial area, but not yet from our sites). Mean site richness across all sites is shown in Table 4.11. For all taxa there is substantial variation between sites in total richness; the highest richness values for plants and birds are associated with riparian sites. The vertebrate and ant fauna are relatively species-poor at site and study-area scale (in common with black-soil grasslands throughout northern Australia). There is a moderate local richness of plants, but relatively low species turnover between sites. For all taxa there is a substantial component of species restricted to, or with a strong preference for, black-soil grassland habitats. A number of rare or poorly recorded species of plants, ants and reptiles have been found.

4.3.2 Differences between years

There has been substantial inter-annual variation in both the vegetation and fauna, which cannot be attributed to grazing effects. While this presumably relates to seasonal conditions, particularly the amount and timing of rainfall and subsequent response of vegetation, patterns are not necessarily consistent between taxa. The total number of plant species recorded, and mean site richness of plants, was high in 2004 and markedly lower in 2005 and 2006 (Table 4.11). Interestingly, 16 plants species have been recorded only in 2004, while 6-7 were recorded only in each of the other years. By contrast, bird richness was markedly higher in 2005 than 2004 or 2006, while mammal and reptile site richness were slightly lower.

Table 4.11. Summary of the total number of species recorded, and mean site richness, for each major taxon in 2003-2005.

	2003	2004	2005	2006
Total species (within sites)				
Plants	171 [a]	197	178	180
Ants	54 [a]	-	63	-
Birds	62 [a]	63	71	65
Small mammals (pits)	3	3	2	2
Reptiles	19	17	18	18
Mean site richness: species per site (range)				
Plants	41.6 (21-74)	41.8 (19-85)	35.9 (17-69)	36.8 (18-63)
Ants	12.9 (5-21)	-	14.6 (6-26)	-
Birds	7.2 (1-18)	8.4 (2-18)	12.7 (2-24)	8.4 (1-25)
Birds (including adjacent spp)	11.4 (2-25)	10.4 (2-24)	14.4 (4-26)	10.0 (2-25)
Small mammals (pits)	0.6 (0-2)	0.6 (0-1)	0.3 (0-1)	0.6 (0-2)
Reptiles	2.4 (0-6)	2.4 (0-8)	2.2 (0-6)	2.7 (0-7)

[a] from 62 sites

Seasonal variation is also evident in mean values across all sites for various attributes of the understorey (Fig 4.44). There was a marked peak in total cover in 2004, which was reflected in a high cover of perennial grasses. However, perennial grass basal area has shown a downward trend during the study, while perennial grass frequency has been stable across years.

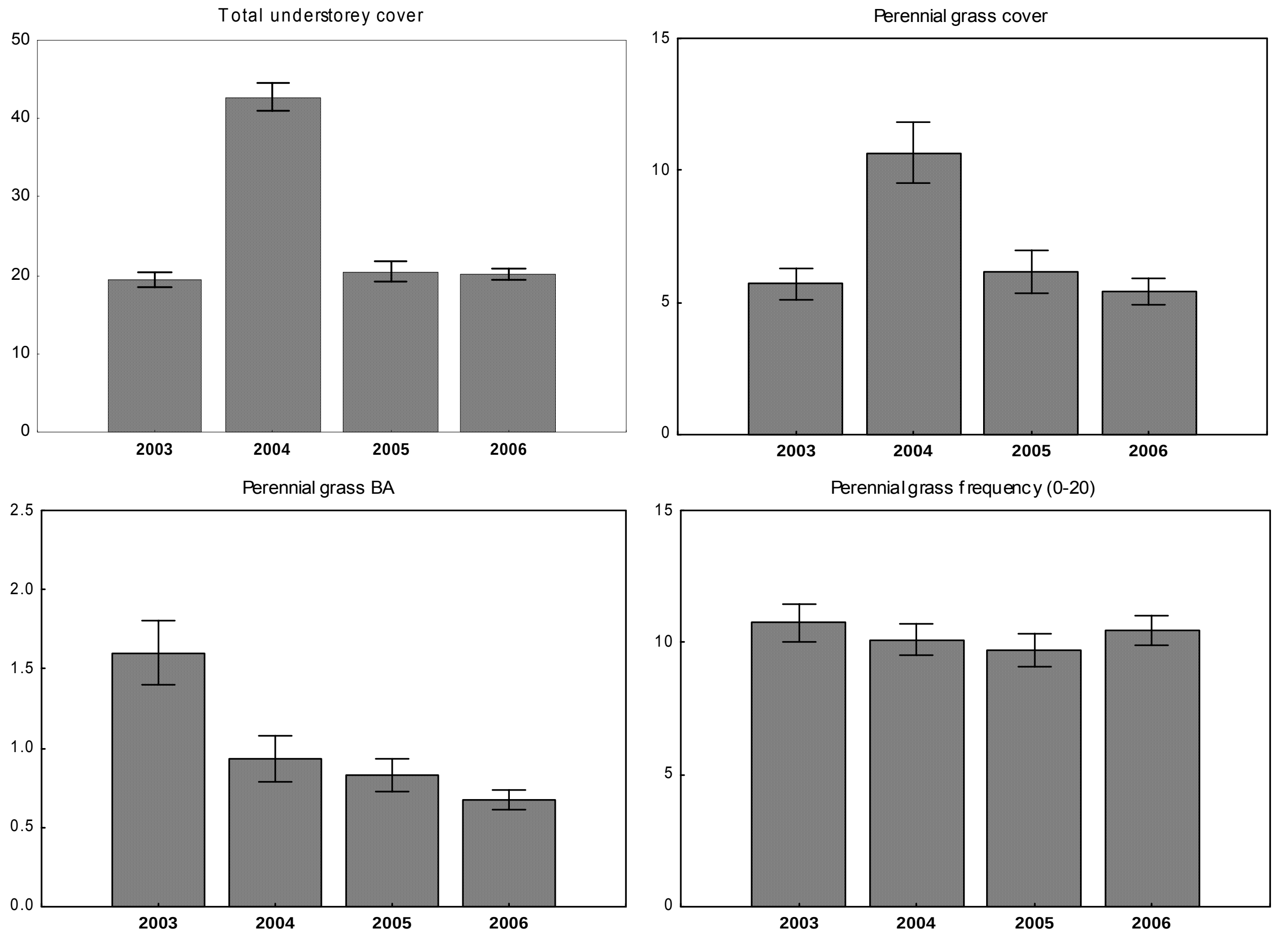


Figure 4.44. Comparisons between years (2003-2006) for total understorey cover, perennial grass cover, perennial grass basal area and perennial grass frequency. Mean value (with SE) is for all sites except riparian and exclosures.

4.3.3 Pre-treatment differences between paddocks

Comparison of the plant composition in sites from all sampled paddocks (Fig 4.45) shows that, although there is substantial overlap of paddocks in the ordination, overall within-paddock similarity is greater than between-paddock (ANOSIM R=0.21, p<0.001). A similar result (for a smaller number of sites and paddocks) was evident for plant data from 2003 (R=0.18, p<0.001), confirming that these are pre-experiment differences between the paddocks.

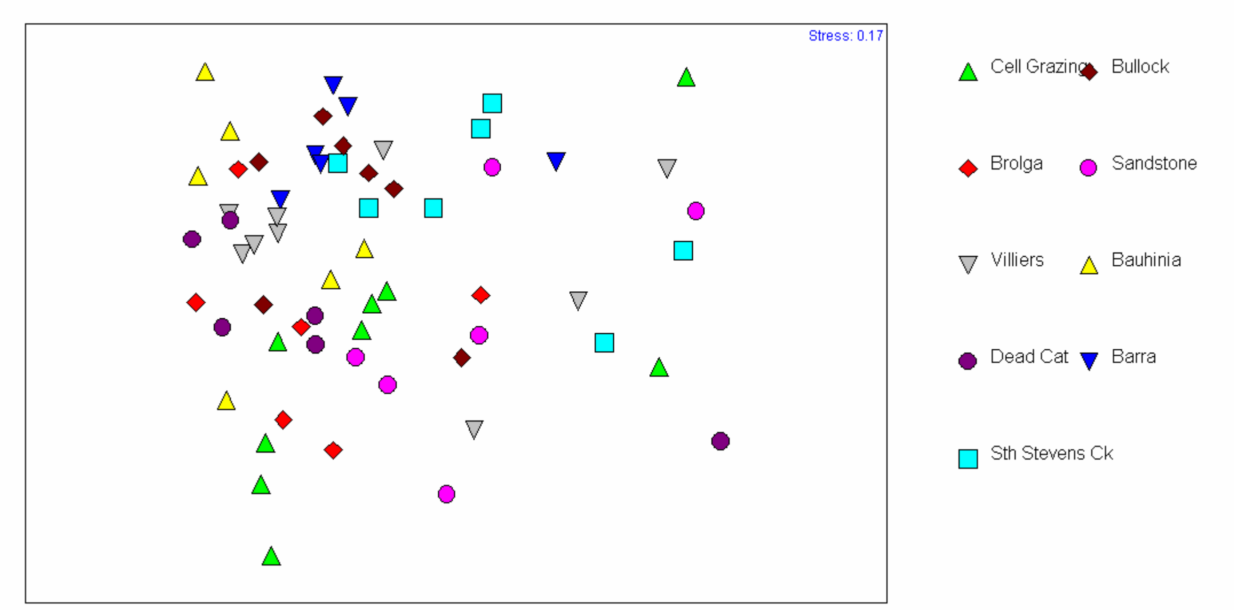


Figure 4.45. Ordination of sites by plant composition (square-root frequency) for 2004. Only 'normal' sites are included (i.e. riparian and exclosure sites excluded) and sites are labelled by paddock.

A similar analysis of plant, bird and ant data from 2003 (Table 4.12) shows that there were compositional differences between paddocks for each taxa, with these differences smallest for birds and highest for plants (which meshes with the expected relative levels of species turnover across geographic space).

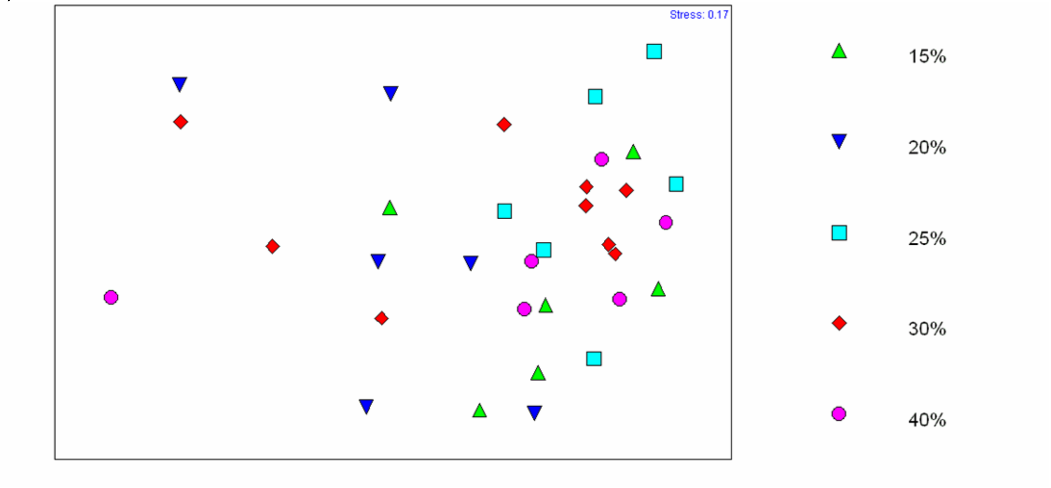
Table 4.12. ANOSIM tests for difference in comparison similarity between paddocks, using data from all sites sampled in 2003. The R value is for the global test for a "paddock" effect, but comparisons were also made between each pair of paddocks.

Taxon	ANOSIM	No. of pairwise comparisons between paddocks that were significant (total =28)
Birds	R=0.17, p<0.001	12
Plants	R=0.18, p<0.001	13
Ants	R=0.375, p<0.001	24

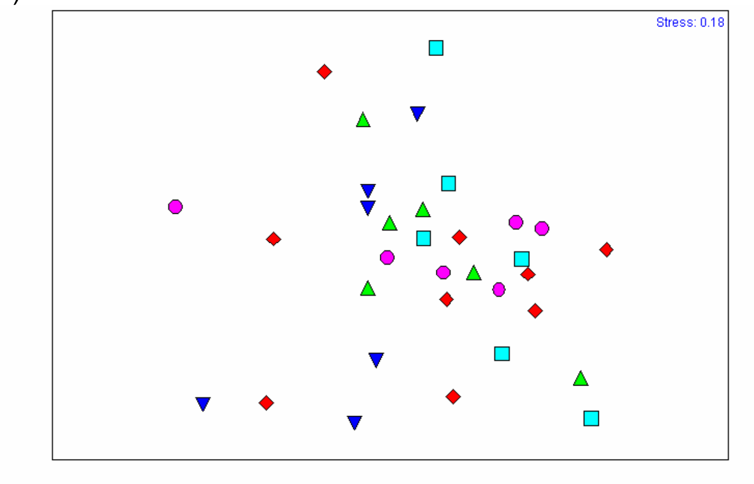
4.3.4 Utilisation treatment

The variation in plant composition between sites in the five utilisation paddocks was analysed in a similar way as described above. In early 2004 (which is before there would any expectation of significant treatment effects), there was general overlap of paddocks in the ordination diagram although differences between some paddocks were significant (Fig 4.46, Table 4.13). The compositional similarity between paddocks increased in 2005, and there was no significant global paddock effect in this year.

i) 2004



ii) 2005



iii) 2006

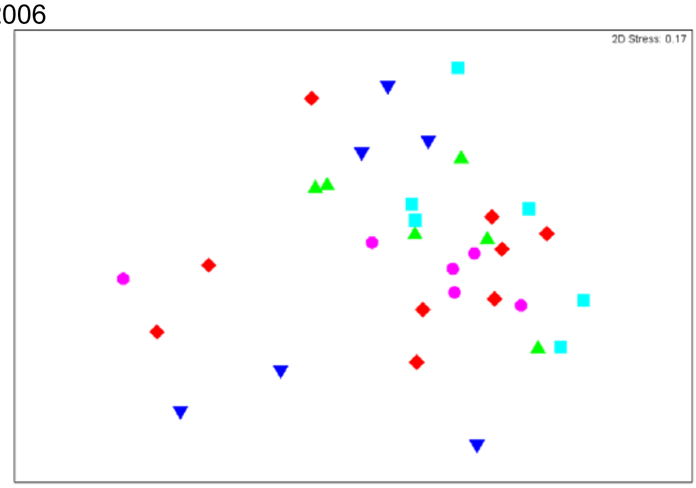


Figure 4.46. Ordination of grazed sites within the utilisation experiment by plant composition [sqrt(frequency)], labelled by treatment level. ANOSIM analyses are shown in Table 4.13.

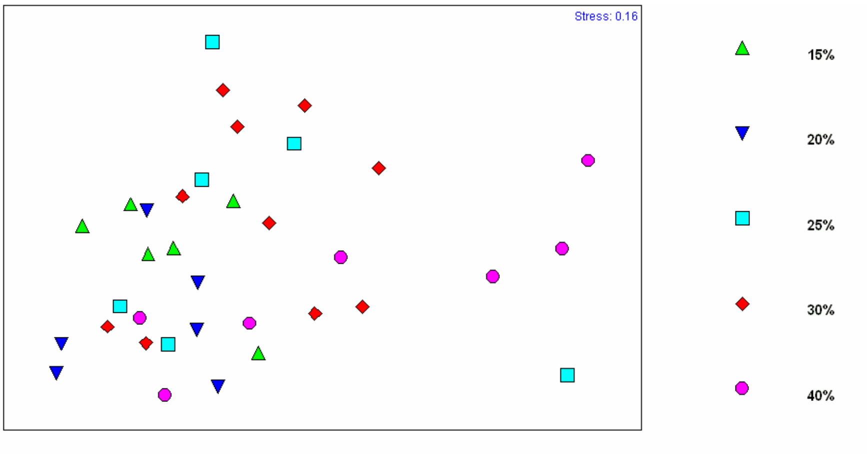
This analysis is reprised in Table 4.13, which includes 2003 data and pairwise comparison between individual paddocks. There is a clear trend of homogenisation of vegetation composition across the sites within the utilisation paddocks, so that there were no significant pairwise comparisons by 2006.

Table 4.13. ANOSIM analyses, comparing plant composition of sites in the five utilisation level paddocks, for 2003-2006. Global R and pairwise comparisons are reported; significant R values ($P<0.1$) are in bold. Riparian and exclosure (2004-06) sites are excluded.

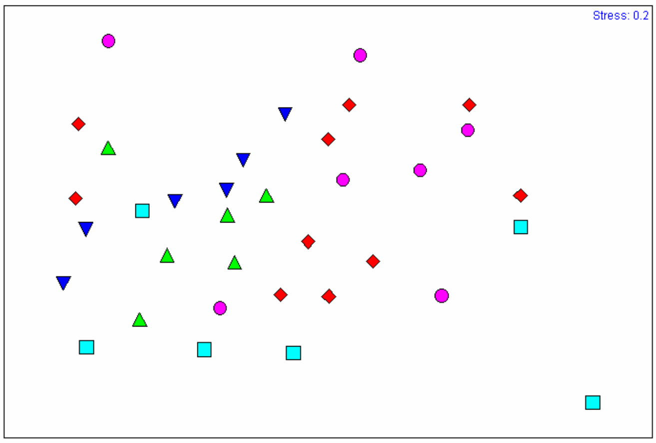
	2003		2004		2005		2006	
Overall R	**0.194**		**0.144**		0.063		0.035	
Overall P	0.003		0.014		0.126		0.248	
Groups	***R***	***P***	***R***	***P***	***R***	***P***	***R***	***P***
15%, 20%	**0.33**	0.008	**0.21**	0.045	0.05	0.255	0.06	0.264
15%, 25%	-0.04	0.545	**0.19**	0.069	0.03	0.314	0.04	0.327
15%, 30%	0.11	0.135	0.11	0.146	-0.04	0.625	0.01	0.391
15%, 40%	**0.15**	0.097	**0.15**	0.065	**0.2**	0.032	0.05	0.275
20%, 25%	**0.41**	0.004	**0.39**	0.002	**0.18**	0.065	0.12	0.141
20%, 30%	**0.37**	0.027	0.10	0.157	0.03	0.356	0.09	0.190
20%, 40%	**0.38**	0.015	**0.31**	0.019	**0.18**	0.054	0.10	0.197
25%, 30%	0.09	0.182	0.03	0.298	-0.03	0.541	-0.04	0.604
25%, 40%	**0.26**	0.017	**0.14**	0.089	**0.23**	0.017	0.07	0.203
30%, 40%	0.07	0.138	0.07	0.166	0.04	0.285	-0.08	0.820

A similar comparison was made between utilisation paddocks for bird data from 2004 and 2005 (Fig 4.47, Table 4.14). Again, there was a significant global paddock effect in 2004 and the majority of pairwise comparisons were significant, whereas bird composition was more similar between paddocks in 2005, and there was no significant difference between any treatments in 2006.

i) 2004



ii) 2005



iii) 2006

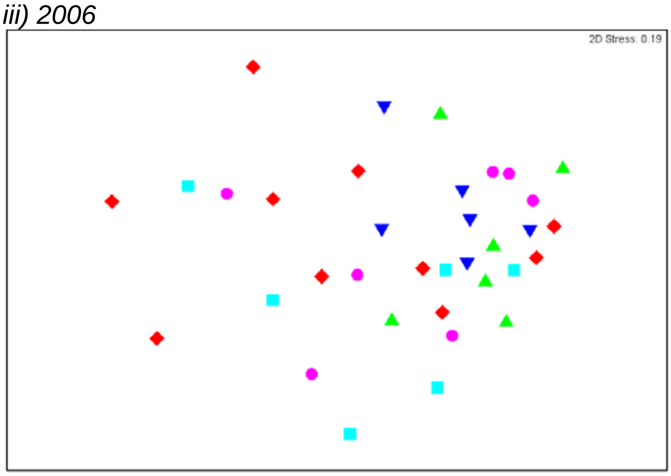


Figure 4.47. Ordination of grazed sites within the utilisation experiment by bird composition (late dry season; sqrt(frequency)), labelled by treatment level. ANOSIM analyses are shown in Table 4.14.

Table 4.14. ANOSIM analyses, comparing bird composition (late dry season) of sites in the five utilisation level paddocks, for 2004-06. Global R and pairwise comparisons are reported; significant R values (P<0.1) are in bold. Riparian and exclosure sites are excluded.

	2004		**2005**		**2006**	
Overall R	**0.138**		0.070		-0.03	
Overall P	0.016		0.115		0.690	
Groups	***R***	***P***	***R***	***P***	***R***	***P***
15%, 20%	0.08	0.238	-0.09	0.690	-0.06	0.699
15%, 25%	**0.17**	0.043	**0.18**	0.041	0.03	0.351
15%, 30%	0.07	0.232	0.09	0.186	0.06	0.246
15%, 40%	**0.31**	0.022	**0.22**	0.045	0.02	0.353
20%, 25%	**0.14**	0.093	0.10	0.121	0.11	0.136
20%, 30%	**0.21**	0.046	0.00	0.427	-0.02	0.530
20%, 40%	**0.20**	0.066	0.12	0.135	-0.14	0.942
25%, 30%	0.07	0.241	0.14	0.104	-0.03	0.570
25%, 40%	0.08	0.186	0.16	0.105	-0.09	0.768
30%, 40%	**0.17**	0.053	-0.09	0.850	-0.09	0.842

At this stage, only initial univariate analyses have been carried out using summary plant richness and cover variables. For these analyses, a simplified approach has been taken to the repeated measures issue: for each variable, the difference between successive years is calculated for each site, and then these difference variables are subject to standard comparison tests.

There is no significant difference between utilisation paddocks for any of the vegetation variables, either for changes between 2004 and 2005, or 2005 and 2006 (Fig 4.48). One issue illustrated by this analysis is the generally high variation in annual change for sites within each paddock, which reduces the power of these tests to detect between-paddock differences. Some of the relatively large changes in the 40% utilisation paddock can be attributed to the effects of an extensive fire in the 2004/05 wet season, which burnt half of the sites in that paddock. Most variables show a trend for a decline from 2004 to 2005, and then a recovery from 2005 to 2006.

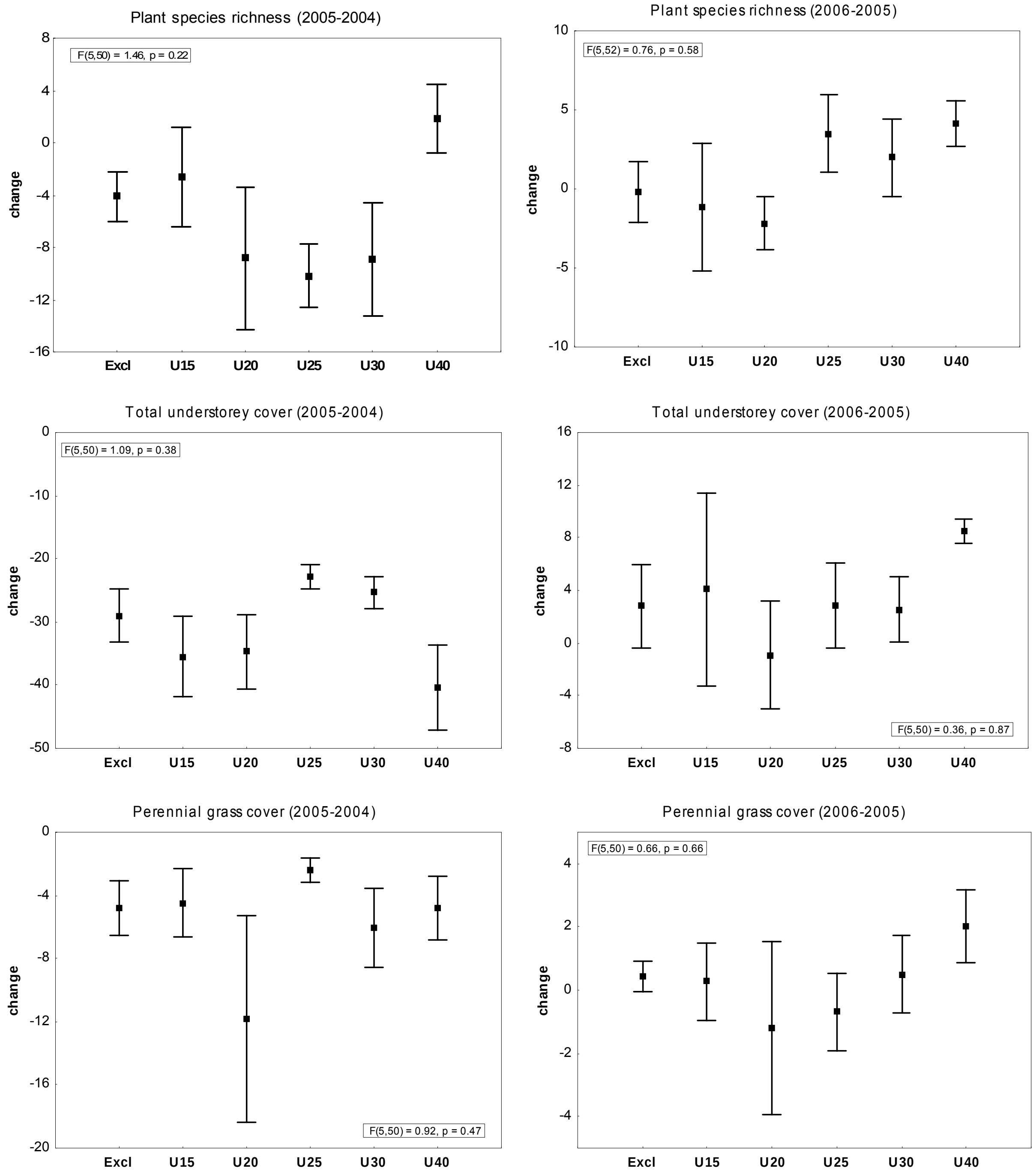
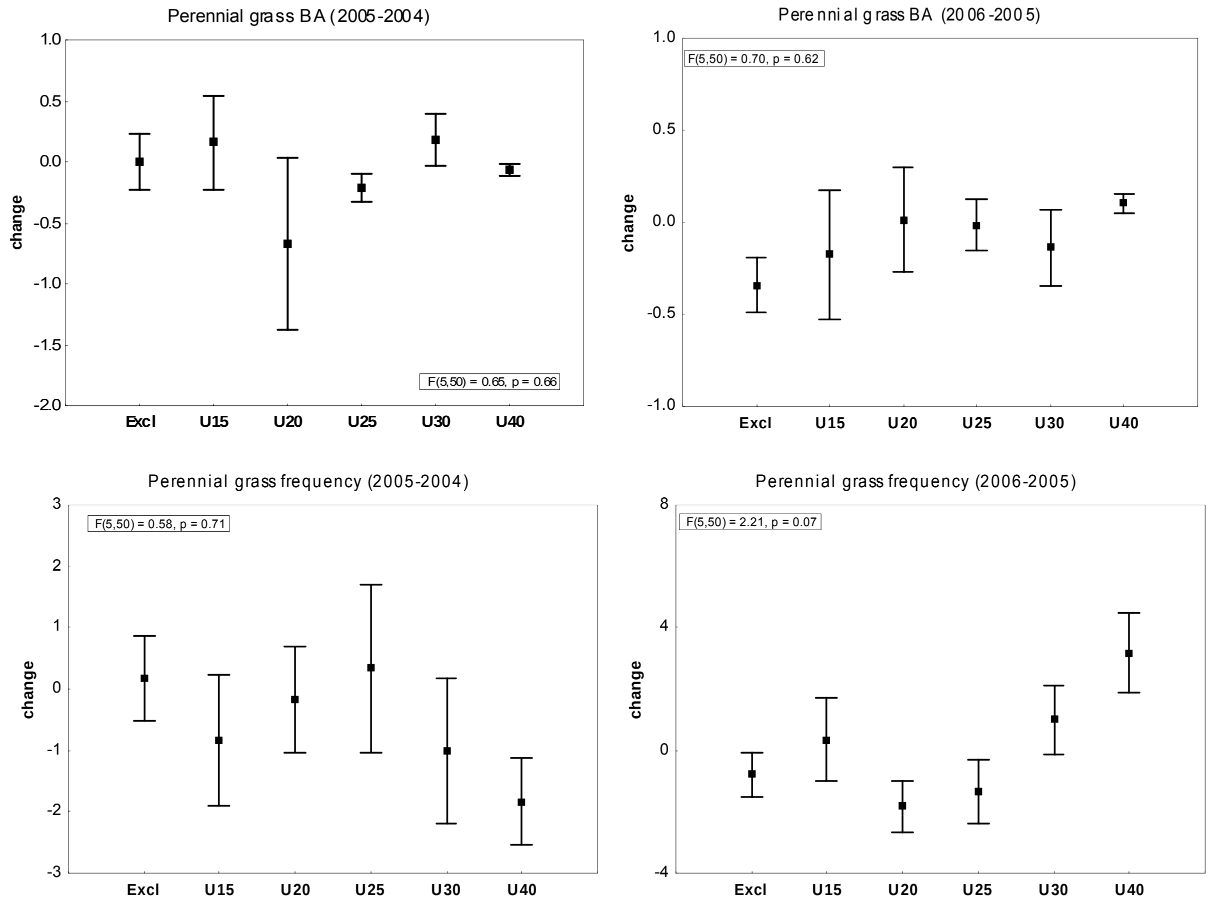


Figure 4.48. Comparison between utilisation levels and exclosures of change across years for plant species richness, total understorey cover, perennial grass cover, perennial grass basal area and perennial grass frequency. Change between consecutive years was calculated for each site, and the average change (with SE) is shown for each level. All exclosure sites were combined; riparian sites and those in Gregory NP were excluded. A simple one-way ANOVA was used to test differences between levels. Figure continued on following page.



4.3.5 Conservation areas

Comparison of the plant species composition of sites in the exclosures and in the utilisation paddocks (Table 4.15, Fig 4.49) shows no significant difference between these treatments in 2004, and compositional similarity was actually higher in 2005 and 2006. There were some differences in composition between sites in Gregory National Park and those in the utilisation paddocks in 2004, and between sites in Gregory National Park and exclosure sites in 2006.

Table 4.15. ANOSIM analyses, comparing plant composition of grazed sites in the utilisation paddocks (Util) with ungrazed sites in exclosures (Excl) and Gregory National Park (GNP) for 2004-06. Global R and pairwise comparisons are reported; significant R values (P<0.1) are in bold. Riparian sites are excluded.

	2004		**2005**		**2006**	
Overall R	**0.084**		0.014		0.056	
Overall P	0.066		0.349		0.104	
Groups	***R***	***P***	***R***	***P***	***R***	***P***
Excl, GNP	0.136	0.139	0.058	0.299	**0.238**	0.045
Excl, Util	0.038	0.187	-0.009	0.543	0.007	0.361
Util, GNP	**0.212**	0.069	-0.086	0.261	0.176	0.104

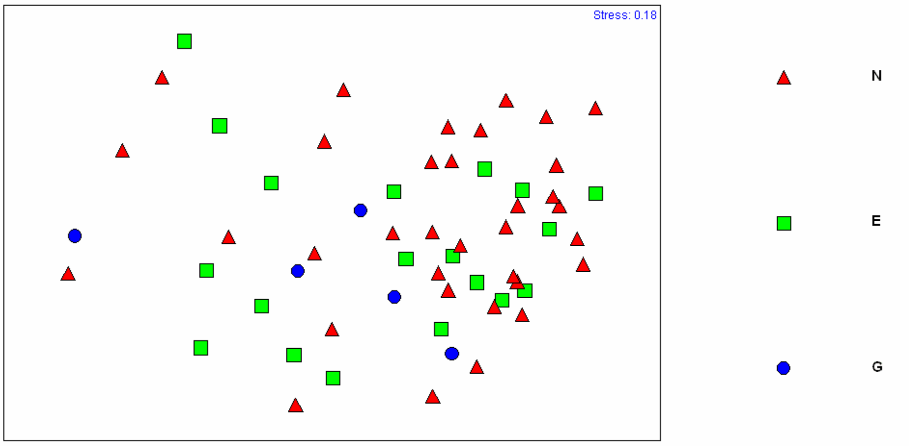
Similarly, for the vegetation summary variables there was no evidence that change over time was significantly different for exclosure sites compared to grazed sites, for either the 2004/05 or 2005/06 comparisons (Fig 4.48).

There was no difference in bird species composition between sites in exclosures and in the utilisation paddocks for late dry season samples in either 2004 or 2005, although there was a significant difference in 2006 (Table 4.16, Fig 4.50). This divergence in composition is visually evident in the ordination, although there is still considerable overlap between exclosure and grazed sites.

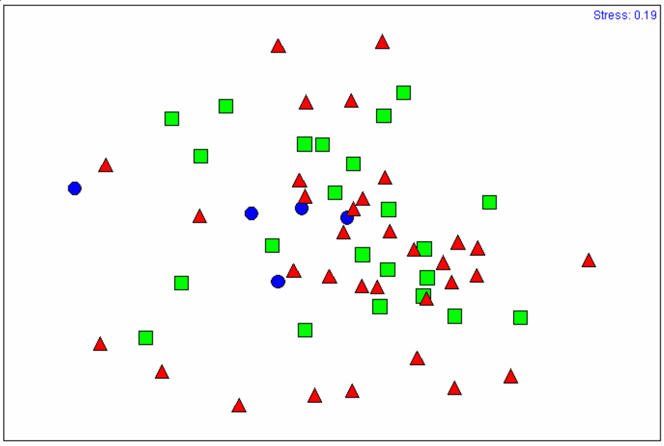
Table 4.16. ANOSIM analyses, comparing bird composition (late dry season only) of grazed sites in the utilisation paddocks (Util) with ungrazed sites in exclosures (Excl) and Gregory National Park (GNP) for 2004-06. Global R and pairwise comparisons are reported; significant R values (P<0.1) are in bold. Riparian sites are excluded.

	2004		**2005**		**2006**	
Overall R	-0.102		-0.011		0.045	
Overall P	0.973		0.546		0.168	
Groups	***R***	***P***	***R***	***P***	***R***	***P***
Excl, GNP	-0.044	0.596	0.069	0.300	-0.114	0.750
Excl, Util	-0.092	0.974	-0.023	0.656	**0.088**	0.030
Util, GNP	-0.130	0.827	0.037	0.342	-0.044	0.594

i) 2004



ii) 2005



iii) 2006

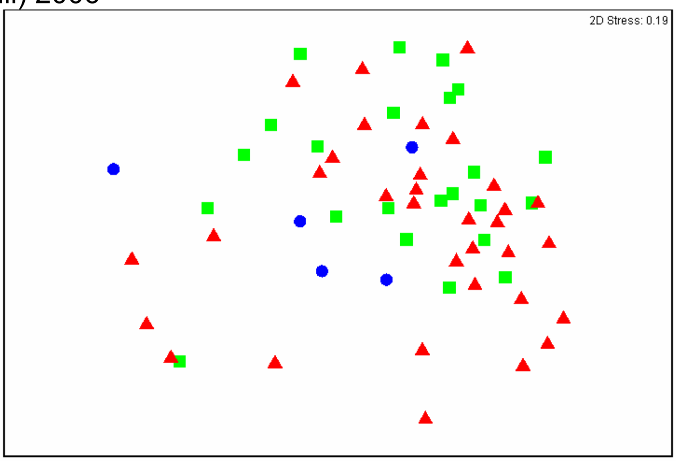
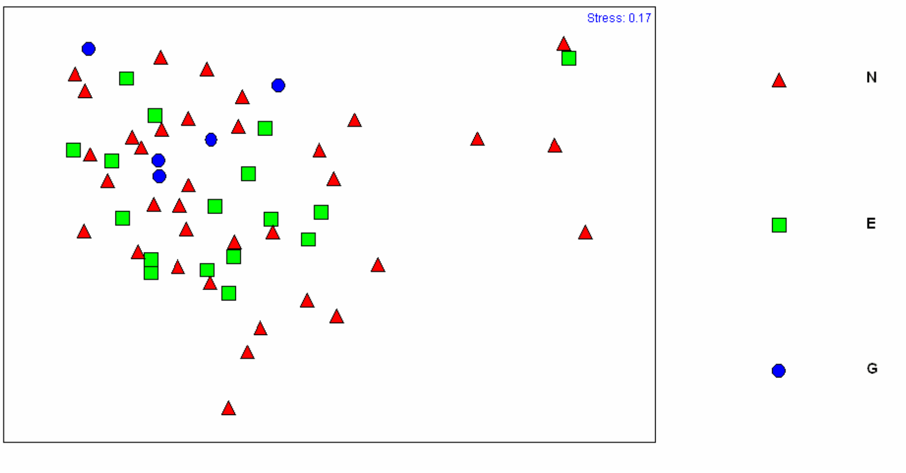
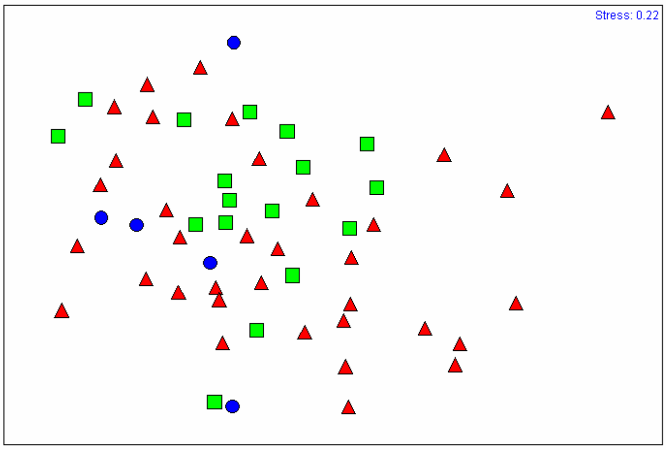


Figure 4.49. Ordination of sites by plant species composition for grazed sites in the utilisation paddocks (N), sites in exclosures (E) and in Gregory National Park (G). ANOSIM analysis shown in Table 4.15. Riparian sites are not included.

i) 2004



ii) 2005



iii) 2006

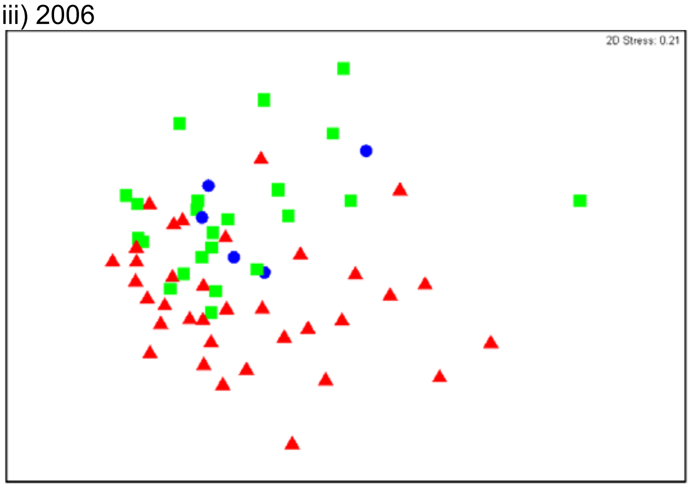


Figure 4.50. Ordination of sites by bird species composition for grazed sites in the utilisation paddocks (N), sites in exclosures (E) and in Gregory National Park (G). ANOSIM analysis shown in Table 4.16. Riparian sites are not included.

4.4 Economic and environmental analysis

4.4.1 Environmental assessments

The environmental assessment of the current management (Scenario 1) is shown in Table 4.17, the environmental changes with the other five scenarios are discussed below, and summaries of the environmental scores of each scenario are given in Table 4.18.

Table 4.17. Environmental assessment of portion of Pigeon Hole under current management (Scenario 1).

Attribute	Comments	Score
A1 Soils and hydrology	There is no evidence of major soil problems but there have been some small changes after more than a century of pastoral use.	+1
A2 Pastures	The Mitchell grass content of the pastures has declined and *Chrysopogon fallax* is now the major perennial grass. Some areas are dominated by annual sorghum. Ground cover levels are high.	0
A3 Weeds	There is some invasion/regrowth of native woody plants and small amounts of herbaceous weeds.	+2
A4 Feral animals	There are no feral animal problems.	+3
A5 Riparian areas	The only riparian area on this portion of Pigeon Hole is the Victoria River running through the south-east corner. This area has suffered from past grazing with some sediment in the water, bank erosion and loss of the herbaceous layer. There are drainage lines across the area but none of these could be considered to be riparian areas.	-1
A6 Atmosphere	There is little regrowth, animals are grazed at low stocking rates with low levels of pasture utilisation but there are some emissions, and fires are relatively infrequent.	+2
A7 Fire regime	There is little burning of this area although some accidental fires occur.	+3
B1 Native vegetation communities	There has been no clearing; the Wave Hill land system is widespread but there is little of it in reserves; some loss of important grass species (Mitchell grass) and increase in annual sorghum; no significant restricted native vegetation communities.	+1.3
B2 Native plant and animal species	There are no threatened, endemic or culturally significant species. Among the grasses there has been a shift in the decreaser/increaser balance towards the increasers.	+0.3
B3 Significant sites and habitats	There are no Ramsar sites, no wetlands on this part of Pigeon Hole, no threatened communities, no other special sites; and Pigeon Hole is not in one of the 15 national biodiversity hotspots.	0

For Scenario 2 (additional water points), there was no change in grazing pressure but with the more uniform distribution of grazing there was some improvement in the pastures and the decreaser/increaser balance. There was some increase in weeds in the sacrifice areas around the new water points. It is possible there could be some loss of grazing sensitive species in areas that were previously distant from water points but this has not been considered. The increase in cattle numbers results in an increase in greenhouse gas emissions.

For Scenario 3 (more paddocks), the increase in cattle numbers results in an increase in greenhouse gas emissions but otherwise there were no changes.

For Scenario 4 (wet season spelling), the pastures improve and are healthier but the increase in cattle numbers results in an increase in greenhouse gas emissions.

For Scenario 5 (cell grazing), the responses are similar to Scenario 4 but with a greater increase in cattle numbers.

For Scenario 6 (increased utilisation), there is a decline in pastures, vegetation condition and soils, increases in weeds and greenhouse gas emissions, and some deleterious impacts in the riparian zone from the large increase in cattle numbers.

Table 4.18. Summary of initial environmental conditions (Scenario 1) and environmental conditions with five management scenarios.

Attribute	**Scenario**					
	1	**2**	**3**	**4**	**5**	**6**
A1. Soils	+1	+1	+1	+2	+2	0
A2. Pastures	0	+1	0	+2	+2	-1
A3. Weeds	+2	+1	+2	+3	+3	+1
A4. Feral animals	+3	+3	+3	+3	+3	+3
A5. Riparian areas	-1	-1	-1	-1	-1	-2
A6. Atmosphere	+2	+1.2	+1.6	+1.7	0	+0.8
A7. Fire regime	+3	+3	+3	+3	+3	+3
Total Component A	+10	+9.2	+9.6	+13.7	+12	+4.8
B1. Communities	+1.3	+1.3	+1.3	+1.5	+1.5	+1.2
B2. Species	+0.3	+0.5	+0.3	+0.8	+0.8	-0.3
B3. Sites	0	0	0	0	0	0
Total Component B	+1.6	+1.8	+1.6	+2.3	+2.3	+1.1
Ratings						
Component A	48	44	46	65	57	23
Component B	18	20	18	26	26	12
Overall	**33**	**32**	**32**	**46**	**42**	**18**

4.4.2 Economic assessment

The baseline productivity (measured in total stock numbers as AE) of the enterprise is presented in Table 4.19, along with the changes to stock numbers carried and the financial impact associated with the implementation of the management changes underpinning the other five scenarios. The financial information is presented in the form of index numbers, which capture the relative change in the magnitude of the different stock and financial metrics for each scenario from that of the baseline case (Scenario 1 = 100). The use of indices was justified on the basis of making the relative differences between the various scenarios more readily apparent, and also to give consistency with the use of indices and scores in the ecological assessment.

Table 4.19. Summary of initial economic assessment (Scenario 1) and economic values for five management scenarios presented as indices (Scenario 1 = 100).

Attribute	**Scenario**					
	1	**2**	**3**	**4**	**5**	**6**
Stock numbers (AE)	4,680	6,240	5,400	5,190	8,530	7,000
Stock numbers	100	133	115	110	182	150
Total revenue	100	134	115	111	187	138
Total variable costs	100	133	116	131	198	149
Total gross margin	100	134	116	106	184	136
Overhead costs	100	143	126	111	344	150
Net profit	100	130	110	106	170	130
Return to capital	100	121	107	100	100	114
Capital value	100	117	109	105	172	123

The baseline case runs 4,680 AE. Each of the management scenarios involves an increase in the total number of stock carried, ranging between 10% for the wet season spelling Scenario 4 (due to the better carrying capacity of the spelled pasture) and 82% for the cell grazing Scenario 5 (due to the combination of the expanded area reached for grazing and higher stocking rates applied when the cells are grazed).

The total revenue, total gross margin, and net profit estimates for each of the Scenarios 2 to 6 also exceed the baseline case. There is a gain in net profit for each of the options (Scenarios 2 to 6), ranging from 6% to 70%. The gain for the wet season spelling option (Scenario 4) is fairly modest (6%). The last result stems from a significant increase in variable costs (31%) attributed generally to the need for an additional muster, as well as husbandry and marketing costs associated with running the additional stock.

The largest gain in projected profitability (70%) comes from the cell grazing option (Scenario 5) which stems from the much increased number of stock carried (82%) with commensurate increases in total revenue and total gross margin. The high labour and capital costs associated with the cell grazing option are reflected in the substantially increased levels of variable (98%) and overhead costs (344%). Nevertheless, net profit is increased by 70% relative to the baseline case (Scenario 1). However, the rate of return on total capital investment is essentially the same as that of the baseline case (~14%) because the total investment (including livestock capital and new infrastructure) involved with Scenario 5 has increased by 72%.

The highest gain in capital efficiency (21%) is for the Scenario 2 option of increasing access to grazing through the provision of additional watering points. While this option increased stock numbers carried and net profit by approximately 30% relative to the baseline case (Scenario 1), the gain was reaped with only a 17% increase in the level of total capital investment, most of which is the additional livestock.

For the more exploitative option that involved increasing pasture utilisation by 50% through raising stocking rates (Scenario 6), the projected gain in net profit is 30% above the baseline case (Scenario 1), despite the assumed deterioration in per animal productivity and herd reproductive performance.

4.4.3 Environmental-economic trade-offs

The tradeoffs associated with the various management options are summarised as follows:

Scenario 1 (baseline) - the baseline assessment for the enterprise reflects reasonable environmental conditions for the property; but there are some deleterious effects projected from a previous history of land use. This is reflected in the negative rating for the riparian areas and low scores for the pastures and soils. However, it is quite a profitable operation with reasonable returns to capital investment.

Scenario 2 (more watering points) - the number of livestock carried has increased by 33% with a commensurate increase in net profit. However, there is a projected small environmental decline (overall score falling from 33 to 32), suggesting that the trade-off for this scenario is only a relatively modest one.

Scenario 3 (more paddocks) - the increase in number of livestock carried is relatively modest (15%), as is the projected increase in net profit (10%). The projected ecological impact is also relatively small (overall score falling from 33 to 32).

Scenario 4 (wet season spelling) - the 10% increase in livestock numbers carried has given a small increase in net profit (6%). However, the projected environmental impact is quite significant (overall score rising from 33 to 46), largely due to improvements in the pasture and associated changes in soil condition.

Scenario 5 - there is a substantial increase in livestock numbers carried (82%), and a significant increase in net profit (70%). Nevertheless, the scenario also carried a large increase in overhead costs (244%) and a substantial increase in capital required to effect the change (72%). There is an improvement in ecological condition (overall score increase from 33 to 42), largely due to improvements in pastures and soils. However, this was partially offset by increased greenhouse gas emissions associated with the large increase in livestock numbers.

Scenario 6 (increased utilisation) - the doubling of livestock numbers carried has increased net profit by 30%. However, there are substantial environmental costs (overall score declines from 33 to 18), due to deleterious impacts projected on the pastures, soils and the riparian areas, as well as increased greenhouse gas emissions.

5 Success in Achieving Objectives

5.1 Achievements

The project is making excellent progress towards meeting its objectives, although at this stage it remains too early to draw defensible conclusions for some key elements of the project. This is because of the relatively short period that grazing treatments have been in place. Nevertheless, we can report some success in efforts to meet a number of the projects objectives.

Optimum levels of utilisation have been determined as part of the Mt Sanford study. Results from Mt Sanford suggest that utilisation levels above 25% are not sustainable, in terms of impact on both biodiversity and land condition. Animal production also appears to be more variable through time at utilisation rates above 25%. At the commercial scale at Pigeon Hole, in paddocks of 20 sq. km, land condition and animal production still appear to be independent of utilisation rate. This is in contrast to results at Mt Sanford and it is unclear if this is due to a shorter experimental timeframe at Pigeon Hole for treatments to have had an effect, or due to other differences between the studies (for example, greater spatial buffering in the larger paddocks at Pigeon Hole). As a consequence, we are unable to make recommendations based on results from the Pigeon Hole study at this time. In addition, since the whole-property economic analysis is yet to be completed we are not able to provide robust management guidelines for achieving sustainable and profitable pastoral development.

There has been considerable publicity about the results from the Mt Sanford utilisation study including at field days at Mt Sanford and Pigeon Hole in 2003 and 2005, in a Landline television feature, on the ABC Radio NT Country Hour, and in the Katherine Times newspaper and the Rural Review newsletter. These all reported the optimal utilisation rate of 25% for land condition and animal production at Mt Sanford. We are confident therefore that many producers are aware of the broad results relating to rates of pasture utilisation and pasture condition trends and sustainability. Results have also been incorporated into training material for the Grazing Land Management and Rangeland Management courses. However, we believe that an industry-targeted publication that includes economic analyses and is provided to all producers is needed to properly achieve this objective. This is planned for the Pigeon Hole Field Day in 2007.

Considerable progress has been made towards meeting the general objectives of assessing the effectiveness of reducing paddock size and installing additional waters in achieving more even grazing of the landscape, and developing an enhanced understanding of grazing distribution at paddock scales and how paddock and water-point configuration affects patterns of use. Additional work remains to be done towards fully meeting these objectives, as will be discussed below.

We have been less successful in meeting the specific objective of having 15% of beef producers in northern Australia having redesigned their large landscape paddocks. At this stage we are unable to provide robust recommendations on options for paddock design and water point configuration and the likely implications for livestock production and land condition, as clear trends are yet to emerge from the data.

Communication of project activities (as described above) as the project progressed would have been effective in achieving the objective of 25% of beef producers in northern Australia having a key understanding of the relationship between grazing behaviour, land condition and animal production, to the extent that project findings allowed.

An intensive biodiversity monitoring program has been implemented within most of the treatments at the Pigeon Hole study site and a comprehensive set of baseline biodiversity data has been collected during the early part of the project. Initial analyses of data collected during three years of experimental grazing regimes do not indicate pronounced impacts on biodiversity of any of the treatment levels. Rather, the new grazing regimes have tended to homogenise species composition amongst biodiversity sampling sites, reducing pre-existing differences between treatment paddocks. There is, however, some indication from 2006 data that bird composition within exclosures is diverging from that of sites in adjacent grazed paddocks; further sampling in 2007 is essential to confirm this divergence.

At this stage of the project, it is not possible to determine whether the lack of evidence of significant impacts on biodiversity of any treatment level results from the resilience of the landscape and extant biota to grazing pressure, or insufficient time for impacts to become discernable. Biodiversity data collected over four years demonstrates substantial inter-year variation in the abundance of many species, which will obscure management-related changes in biota over relatively short time periods.

As with the other components of the project, there has been substantial communication activity during the lifetime of the project, which has certainly lead to an increased awareness amongst producers and management agencies of issues related to biodiversity conservation on pastoral lands, although this has not yet extended to specific management recommendations.

5.2 What remains to be done

Additional work remains in several areas to fully meet the projects objectives. As mentioned above, the project is not able to meet a number of its objectives at this time because the grazing treatments imposed are yet to produce any clear and consistent effects on pasture and land condition, animal production and biodiversity. We are unable to say whether this is due to the resilience of the ecological system or because the treatments have not been in place a sufficient time for consistent and measurable effects emerge, although the latter is the most likely. This conclusion is supported to some extent by the time required for the effects of the higher utilisation treatments at Mt Sandford to become apparent.

Essential to satisfying the objectives, therefore, is the need to obtain data on the implications of the grazing treatments for pasture and livestock production over the longer term. Similarly, the impacts of the grazing treatments on biodiversity can only be adequately elucidated by continued sampling over a longer time period. It is possible that treatment effects will emerge only after a longer time once hysteresis in the ecological system is overcome, or when particular seasonal conditions (e.g. a sequence of poor seasons) occur that, in combination with certain grazing treatments, are potentially instrumental in pushing the system to a new ecological state (in terms of range condition). Under these circumstances clear effects on livestock production and biodiversity could emerge. Continued sampling for several more years will increase the range of seasonal conditions experienced and/or allow more time for the ecological system to respond.

More comprehensive analysis of much of the data is also required. For the utilisation work this analysis needs to include an assessment of the spatial impacts of grazing at the different utilisation rates and a whole-property economic analysis of the costs and benefits of intensified pasture use.

For the grazing distribution work, an economic analysis of options for paddock design and water point configuration is required to permit the development of a comprehensive package of recommendations that is likely to lead to beef producers redesigning their paddocks. There also remains the need to complete a more thorough analysis of aspects of the pasture data and the GPS collar data. This particularly relates to the analysis of spatial patterns in the pasture data, the development of explanatory models of the factors influencing use of the landscape by cattle. Work is continuing on these requirements.

There are significant analytical challenges presented by the biodiversity data related to pre-trial variation between paddocks, substantial natural within-treatment and between-year variation in biodiversity attributes and the repeated-measures nature of sampling. More sophisticated analyses than those described here may disentangle some of these sources of variation, and future analyses will also consider species-level responses to grazing treatments.

6 Impact on Meat and Livestock Industry – now & in five years time

It is anticipated that this project will have a substantial impact on the development of the meat and livestock industry in northern Australia over the next five years. Given the current interest at the national level for the development of agricultural industries in the region this project is very timely. The project will highlight the opportunities for, and ecological and economic limitations to, the expansion of the northern beef industry before intensive development occurs. This should help in avoiding the ‘over-development’ that has historically been a feature of pastoral industry development elsewhere in Australia’s rangelands. Having available comprehensive knowledge of the factors impinging on the intensification of pastoral use and the consequences should also provide potential investors, administrators and the wider community with confidence in decisions relating to intensification of the beef industry.

Based on the results of the Mt Sanford study that suggest utilisation rates of up to 25% are sustainable, and assuming average utilisation rates on properties are currently in the order of 10%, it is reasonable to conclude that there is potential for a substantial expansion of the beef industry in northern Australia by developing properties and increasing stocking rates. The magnitude of the expansion is difficult to quantify at this stage, given that not all producers will necessarily choose to develop their properties or have the capital resources to do so. Also, any expansion of the industry will need to incorporate the management recommendations for maintaining land condition and biodiversity values that are identified in this project, and as yet the impact of higher utilisation rates at commercial scales is unknown. The impact of greater beef production on beef markets, and thus on the economic circumstances of the northern beef industry, are also unknown.

In the shorter term, even without substantial intensification having occurred, this project is providing a better understanding of the impact of cattle grazing on pasture and biodiversity resources, how cattle use the landscape, and the levels of animal production that can be expected. This greater knowledge base should facilitate improved land management and enhanced cattle production at current levels of property development.

7 Conclusions and Recommendations

Tentative conclusions and recommendations can be made in relation to safe utilisation rates and paddock configuration and water placement options, but little can be concluded from the biodiversity studies at this stage.

Utilisation rates of up to 25% were sustainable in the small paddocks used in the Mt Sanford experiment. This utilisation rate was achieved with an average stocking rate of 20 AE/sq. km, approximately double the average stocking rate of 10-11 AE/sq. km recorded in recent years in the VRD (Dyer *et al.* 2001, Oxley 2004). However the reported stocking rates were averaged across all land types, and do not necessarily compare well with this study which was on the most fertile land type (basalt-derived black soils) in the Northern Territory. It may be that current utilisation of black soil areas is already at this level.

Factors that may determine the sustainability of this level of utilisation in other areas include the type of grazing system and land type. This study used a flexible stocking strategy, adjusting animal numbers to meet forage availability. Set stocking may present greater risk in dry years, if animal numbers are set to utilise 25% of average available forage, but are not adjusted during or following poor seasons. Poorer soils than those in this study may not be able to sustain the same level of pasture off-take. Where paddocks contain a number of different land types, animal preference may impede the ability to utilise land types according to their potential or resilience.

Recommendations on the optimum utilisation rate at the commercial scale (as derived from the Pigeon Hole study) cannot be made at this time. There is currently no clear relationship between utilisation rate and animal production or land condition, and the continuation of the grazing treatments and data collection are warranted. The feasibility of applying and achieving a certain target utilisation rate at commercial scales is likely to depend on the ability to achieve relatively even grazing across a paddock, and this will be determined to some extent by paddock size and water point configuration (i.e. number of waters and distance apart).

At this point in the study it seems reasonable to draw the following conclusions in relation to paddock size and water point configuration. Creating smaller paddocks results in greater use of the landscape as a whole, and is more effective in achieving even use than simply adding additional water points to large paddocks (using a grazing radius of 2.5 km). Smaller paddocks therefore appear to be the most effective way to increase the use of pasture resources across the landscape. However, it is not yet clear what paddock size is optimum. The question of optimum paddock size will also be a function of any benefits in livestock production and the trade-off with the cost of the infrastructure needed to create smaller paddocks, and the likely impact on pasture resources. Of course subdivision is a more expensive option than only adding new waters. In many cases it is expected pastoralists will choose the option of installing more waters in large paddocks.

The benefits to livestock production of achieving more even use of the landscape are not yet apparent in this study. More even use of the landscape is expected to increase the quantity of forage available to cattle as well as reduce the incidence of heavily grazing on preferred areas. Theoretically, if more of the landscape is subdivided overall stock numbers should be able to be increased compared to current commercial practice. We are yet to see improvements in cattle production in larger paddocks from the addition of more waters (on a per animal basis) although total production could increase if installing additional waters allows an increase in stock numbers overall. We have also seen no evidence that large paddocks with potentially greater landscape diversity will benefit production during the dry season because of the expected increased opportunity for cattle to select a diet of higher quality.

Achieving more even use of the landscape is expected to maintain better land condition by reducing the degree to which some areas are heavily grazed. While the GPS collar data shows that smaller paddocks result in more even use of the landscape as a whole they do not necessarily result in more even use within paddocks. Cattle still have considerable freedom to be selective in which habitats they use. However, at this stage we are unable to draw any conclusions from the pasture data about any impacts of paddock configuration on spatial patterns of grazing impacts. The choice of pastoral development options should also consider the potential effects on biodiversity values since more uniform use of the landscape may have adverse impacts on biodiversity values by reducing the areas that are remote from water, which are often important refugia for grazing-sensitive native fauna and flora. Appropriate strategies will be required as a part of property development to protect biodiversity values.

It is not possible to draw robust conclusions from this study on the implications for biodiversity of the various pastoral development options at this stage. Previous experience suggested that black-soil grassland systems were relatively resilient to grazing impacts and this study has confirmed that there are not significant short-term impacts on biota from relatively high levels of utilisation. In order to develop defensible management recommendations it will be necessary to continue monitoring the treatments into the medium-term.

An economic and environmental analysis of six scenarios involving differing property development and intensification options suggests that installing more water points is likely to generate the greatest gains in return on capital with the smallest environmental trade-off. The analysis suggests introducing wet season spelling has no effect on return on capital compared with current management but a substantial environmental benefit through improvements in pasture and soil condition. Cell grazing, on the other hand, produces the greatest increase in profit but the increased capital investment and overhead costs involved mean that return on capital is similar to that under current levels of development.

The complexities involved in conducting large landscape scale studies such as this one inevitably mean that unequivocal results are not guaranteed. Nevertheless, such studies merit the collection of data over periods that are of sufficient duration to be likely to generate useful results. In this case, there are good prospects for this as some weak trends appear to emerging in some aspects of the study. Ideally the treatments should continue to be monitored to confirm that emerging trends truly reflect the effect of the treatments, as they will have important implications for management and production in the northern Australian beef industry.

8 Bibliography

ABARE (2005). Australian Beef 05.1. Commonwealth of Australia.

Andrew, M.H. (1986). Use of fire for spelling monsoon tallgrass pasture grazed by cattle. *Tropical Grasslands* **20**:69-78.

Ash, A.J., Gross, J.E. and Stafford Smith, D.M. (2004). Scale, heterogeneity and secondary production in tropical grasslands. *African Journal of Range and Forage Science* **21**: 137-145.

Clarke, K.R. and Gorley, R.N. (2001). *PRIMER v5: User Manual.* Primer-E, Plymouth.

Coates, D.B. (1999) Faecal spectroscopy (NIRS) for nutritional profiling of grazing cattle. In: *People and rangelands, building the future. Proceedings of the VIth International Rangeland Congress, 19–23 July 1999, Townsville, Qld. Vol. 1 (Eds D. Eldridge and D. Freudenberger) 466-7.* VIth International Rangeland Congress Inc. Aitkenvale, Qld.

Dyer, R.M., Cafe, L.M., Cobiac, M. and Cowley, R.A. (2003) Developing sustainable grazing management systems for the semi-arid tropics of the Northern Territory. Final Project Report NAP3.211. Meat and Livestock Australia, Sydney NSW.

Fisher, A. (2001). Biogeography and conservation of Mitchell grasslands in northern Australia. PhD thesis, Charles Darwin University, Darwin.

Friedel M.H., Laycock W.A. and Bastin G.N. 2000. Assessing rangeland condition and trend. *In*: Mannetje L 't and Jones R.M. (eds), Field and Laboratory Methods for Grassland and Animal Production Research. CAB International Publishing, New York, pp. 227–262.

Jones, R.J. and Sandland, R.L. (1974) The relation between animal gain and stocking rate: Derivation of the relation from the results of grazing trials. *Journal of Agricultural Science, Cambridge* **83**, 335-342.

Kantvilas, G. and Minchin, P.R. (1989). An analysis of epiphytic lichen communities in Tasmanian cool temperate rainforest. *Vegetatio* **84**:99-112.

Lange, R.T., Nicolson, A.D. and Nicolson, D.A. (1984). Vegetation management of chenopod rangelands in South Australia. *Australian Rangeland Journal* **6**:46-54.

MacLeod, N.D. and McIvor, J.G. (2006). Reconciling economic and ecological conflicts for sustained management of grazing lands. *Ecological Economics* **56**:386-401.

McGuffog, T., Dyer, R. and Williams, B. (2001) Burning operations. In *Savanna Burning: understanding and using fire in northern Australia*. Tropical Savannas CRC, Darwin.

McIvor, J.G. and MacLeod, N.D. (2004) Environmental and financial implications of changing land management in Australian rangelands. Report to the Department of Environment and Heritage.

McIvor, J.G., Williams, J., and Gardener, C.J. (1995) Pasture management influences run-off and soil movement in the semi-arid tropics. *Australian Journal of Experimental Agriculture* **35:** 55-65.

Oxley, T.J. (2006) Pastoral Industry Survey 2004: Katherine. Northern Territory Department of Primary Industry, Fisheries and Mines.

Rogers, A.R. and Carr, A.P. (1998). HRE: The Home Range Extension for ArcView. Ontario Ministry of Natural Resources.

Scanlan, J.C., Pressland, A.J. and Myles, D.J. (1996) Run-off and soil movement on midslopes in north-east Queensland grazed woodlands. *Rangeland Journal* **18:** 33-46.

Scoones, I. (1995). Exploiting heterogeneity: habitat use by cattle in dryland Zimbabwe. *Journal of Arid Environments* **29**: 221-237.

Stokes, C.J., McAllister, R.R.J. and Ash, A.J. (2006). Fragmentation of Australian rangelands: processes, benefits and risks of changing patterns of land use. *The Rangeland Journal* **28**: 83-96.

Tothill,J.C., Hargreaves, J.N.G., Jones, R.M. and McDonald, C.K. (1992). BOTANAL – a comprehensive sampling and computing procedure for estimating pasture yield and composition. 1. Field sampling. CSIRO Division of Tropical Crops and Pastures. Tropical Agronomy Technical Memorandum No. 78, Brisbane.

Woinarski, J.C.Z. and Fisher, A. (2003). Conservation and the maintenance of biodiversity in the rangelands. *The Rangeland Journal* 25: 157-171.