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THE EFFECTS OF GRAZING MANAGEMENT AND FERTILIZATION ON GRASSLAND DIVERSITY AND PRODUCTIVITY.

W.McG. King[1] and D.R. Kemp[2]

Cooperative Research Centre for Weed Management Systems and Pasture Development Group

[1]New South Wales Agriculture, Orange Agricultural Institute, Forest Road, Orange, NSW 2800, Australia, warren.king@agric.nsw.gov.au

[2] University of Sydney, Leeds Parade, Orange, NSW 2800, Australia

Abstract

The effects of management practices on plant species diversity and productivity within a naturalised grassland was studied as part of a large-scale experiment designed to investigate issues of sustainability in temperate Australia. Fertiliser increased the production but reduced the diversity of the sward. The main decline was in exotic weed species. Strategic grazing resulted in a small increase in pasture diversity but a reduction in productivity. There was a consistent decline in diversity as productivity increased, across all treatments.

Keywords: Biodiversity, Sustainability, regional

Introduction

The perennial pasture zone (> 600 mm average annual rainfall, ~20m ha) of southeastern Australia accounts for over half of the total beef and sheep production of the country. The grasslands in this zone vary considerably in composition and diversity, from sown introduced species to swards wholly dominated by native perennial grasses. Knowledge is needed on what regulates the diversity of such important agro-ecosystems for a number of reasons:

- ecological theory predicts that the diversity of pasture systems will influence their productivity and stability (Waide *et al*., 1999),
- grazing practices are changing from continuous grazing to some form of rotational grazing as a result of research programs designed to enhance desirable species (Dowling *et al*., 1996) and,
- the community is concerned about losses in biodiversity.

This paper presents the preliminary results from a large grazing experiment of the impact of fertiliser and simple strategic grazing practices on the diversity and productivity of a complex naturalised grassland.

Material and Methods

The 60-hectare experimental site is at Carcoar, on the Central Tablelands of New South Wales (149° 10′ E 33° 35′ S; 800 mm rainfall, 800 m altitude) and forms part of the national Sustainable Grazing Systems program. More than one hundred plant species have been identified at the site. The most common were the C3 perennial grasses – mostly wallaby grasses (*Austrodanthonia* spp. especially *A. eriantha*) but also microlaena (*Microlaena stipoides*) and wheatgrass (*Elymus scaber*). There was substantial seasonal variation in species composition and C4 perennial grasses e.g. redgrass (*Bothriochloa macra*) and kangaroo grass (*Themeda australis*) were periodically abundant. Exotic volunteer species occurred at a high frequency, mostly as weeds (e.g. the dicots; Paterson's curse - *Echium plantagineum,* cat's ear - *Hypochaeris radicata* and sorrel - *Acetosella vulgaris* and monocots; vulpia - *Vulpia bromoides,* soft brome - *Bromus molliformis* and fog grass - *Holcus lanatus*) but also some useful forage species, e.g. ryegrass - *Lolium perenne*.

The soil is an infertile yellow podsol, derived from granite and heavily weathered. The $pH_{(CaCl_2)}$ of the top 10 cm varies between 3.9 and 6.0 (mean 4.5) while soil phosphorus levels range from 3 to 25 ppm (Bray No. 1: mean 6.1). Used for low-density cattle grazing, this site had never been ploughed and had not been fertilised within living memory.

Results are presented here for 4 treatments (3 replicates), which are a factorial combination of 2 grazing by 2 fertility treatments. The factors are:

- 'Continuously grazed' all year. The actual stocking rate was varied slowly through the year to maintain the herbage mass within low prescribed limits (yearly minimum of 0.5 t DM / ha) i.e. high utilisation, or
- 'Strategic grazing' where stocking rates were manipulated to achieve desirable impacts on pasture composition. Pastures were destocked over summer to allow the flowering, seed-set and recruitment of perennial grasses (Dowling *et al*., 1996). Overall stocking rates were also slightly lower than the continuously grazed treatment, to maintain higher average levels of herbage mass (yearly minimum 1 t DM / ha) and a lower level of utilisation,

by nil fertiliser or lime, or 250kg of single superphosphate and 2.5 tonnes of lime per ha, which aimed to increase soil phosphate by about 10 ppm and pH by about 1 unit.

In each plot (1.5 ha), fifty permanent sampling points ($0.1m^2$ quadrat), recorded the species present twice a year. Total annual herbage production was estimated with the use of 5 exclosure cages per plot that were sampled and moved at 6 weekly intervals.

The number of species present (species richness), three indices of species diversity (the Shannon-Weiner index, H′, the normalised Simpson's index, 1/D (Magurran, 1988) and Fisher's α (Rosenzweig, 1995) and one index of evenness (the Shannon-Weiner evenness index, E) were calculated.

Results

The results presented are from November 1999, approximately 18 months after the commencement of the treatments. Species diversity showed only a small, non-significant response to the grazing treatments (Table 1) but declined considerably in fertilised plots. This was largely a decline in many of the exotic volunteers and not in native species. Although there was a slight tendency towards a reduction in evenness with fertiliser application, there were no significant effects of the treatments on evenness either. There were no significant interactions. Error terms were large due to the considerable variability across the site.

There were large differences in annual herbage production for the twelve months up to November 1999 for both treatment factors. None of these differences was statistically significant, however (Grazing: Continuous = 7.9 t $ha^{-1}year^{-1}$, Strategic = 5.6 t $ha^{-1}year^{-1}$, $p = 0.09$; Fertiliser: Control = 5.8 t $ha^{-1}year^{-1}$, Fertilised = 7.7 t ha^{-1} $year^{-1}$, $p = 0.14$). This may partly reflect the low intensity of cages used.

The principal result was a consistent decline in diversity and evenness ($r = -0.45$ to -0.62) as productivity increased, no matter how diversity was estimated (Fig 1).

Discussion

Strategically grazed plots showed a slight increase in species diversity (as hypothesised), while the addition of fertiliser substantially reduced diversity. Whether these changes are biologically significant will depend as much on the actual identity of the species 'gained' or 'lost' from the pasture as on the magnitude of the changes. In the fertilised treatment, the species lost were all minor components of doubtful agronomic or conservation value – they were mostly exotic weeds. The native species persisted under each treatment suggesting that, as a group, they are adapted to this type of management, at least within the timeframe of this experiment

The ecological value of the minor species that declined is difficult to determine. One of the most keenly debated hypotheses in modern ecology has been the relationship between the diversity of an ecosystem and its productivity. A unimodal ('hump-backed') response curve has been postulated (Grime, 1973), although a recent review (Waide *et al*., 1999) found that the support for this is inconclusive. The negative relationship between productivity and diversity in this study (Fig 1) suggested that these pastures were beyond the peak of the 'hump' and that those species lost from the fertilised plots in this study were, in some way, functionally redundant. This does however, ignore the possibility that these species have a role to play in the stability of production (Naeem and Li, 1997) – an important consideration given the large variability of Australian weather patterns.

Any decline in evenness may suggest that the plant community is in some sense 'stressed' (Magurran, 1988). Despite a slight tendency towards a reduction in evenness in the fertilised plots no significant differences were observed.

The extent to which these results represent the initial responses of the sward to the application of the treatments remains to be seen. The long-term nature of this experiment will allow us to examine the broader issues of sustainability in future.

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Table 1 - Mean values for four indices of diversity and one of evenness for each of the fertiliser and grazing treatments. See text for definitions of treatment names. Analysis of variance significance levels - ns: p>0.1, +: 0.1>p>0.05, *: 0.05>p>0.01.

Index	Fertiliser Treatment			Grazing Treatment		
	Control	Fertilised	p=	Continuous	Strategic	p=
Species Richness	35.5	26.2	*	30.0	31.7	ns
Shannon-Weiner (H′)	2.91	2.58	+	2.71	2.77	ns
Simpson (1/D)	2.67	2.37	+	2.49	2.54	ns
Fisher (α)	0.99	0.58	+	0.70	0.87	ns
Evenness (E)	0.82	0.79	ns	0.80	0.81	ns

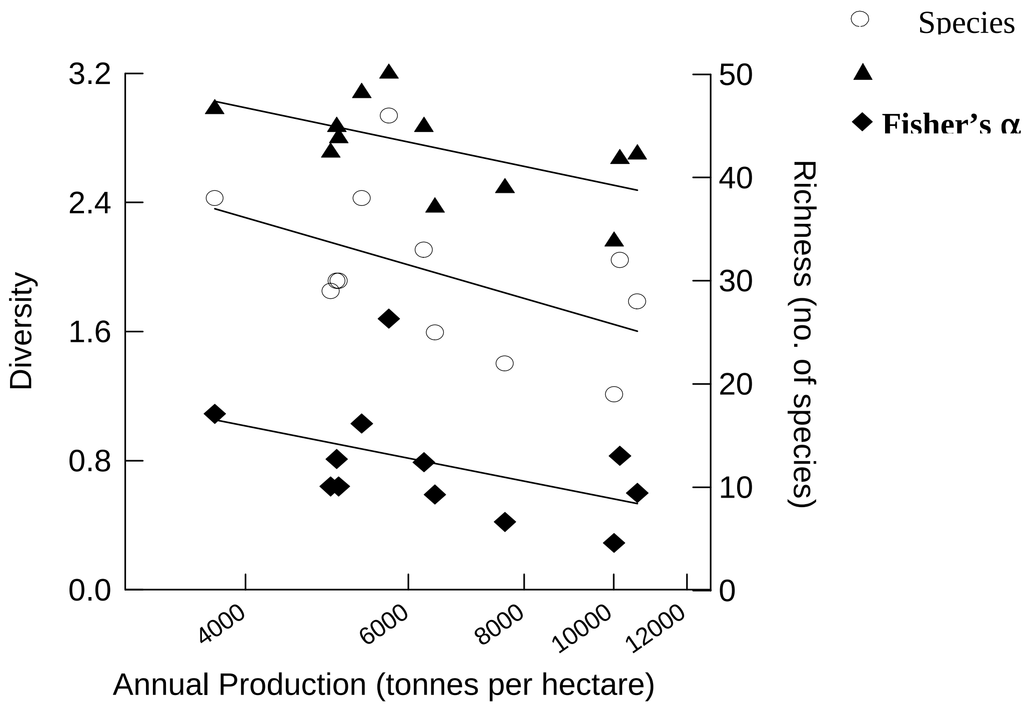

Figure 1. The relationship between pasture production and three measures of diversity: Species richness (○), Shannon-Weiner's H′ (▲) and Fisher's α (◆) - the Simpson's index and Shannon-Weiner Evenness index show a similar pattern but are not shown.