The potential for recovery of herbaceous vegetation after release from a long history of sheep grazing in a species-rich woodland

Jodi N. Price, Nathan Wong and John W. Morgan
Department of Botany, La Trobe University, Bundoora, Victoria, 3086

Final report to the Australian Flora Foundation

May 2008

Summary

We examined the response of understorey plant communities to the removal of sheep grazing in an herb-rich *Eucalyptus camaldulensis* (Red Gum) woodland in western Victoria. Impacts of stock grazing on native grassy ecosystems in temperate southern Australia are well documented. However, less is known about the potential of ecosystems to recover after a long history of stock grazing and, in particular, whether the removal of stock will have positive, negative or neutral impacts on biodiversity. Using a space-for-time chronosequence, woodlands were stratified into groups based on their time-since-grazing removal; these were long-ungrazed (>20 years), intermediate-time since grazing (9-14 years), recently grazed (5 years) and continuously grazed. We found significantly higher species richness in long-ungrazed sites (>20 years) relative to sites with a more recent grazing history. No differences were found in species richness between continuously grazed sites and those grazed in the previous 14 years. Species composition differed with time-since-grazing removal and indicator species analysis detected several native species associated with long-ungrazed sites that were absent or in low abundance in the more recently grazed sites. Continuously grazed sites were significantly associated with several exotic species. Removal of sheep grazing in Red Gum woodlands can have positive benefits for understorey diversity but it is likely that recovery of key indicators such as native species will be slow.

Introduction

Stock grazing has been a major cause of degradation in a variety of ecosystems, causing reductions in vegetation cover and biodiversity, increased soil erosion and compaction, and major structural and compositional changes (Prober and Thiele 1995; Yates *et al.* 2000; Lunt *et al.* 2007a). In Australia, the removal of stock often follows reservation for conservation; however, little is known about the potential of ecosystems to recover after a long history of grazing. Indeed, the removal of stock can have positive, negative or neutral impacts on conservation values depending on a variety of factors, including productivity and site degradation (Lunt *et al.* 2007a; Lunt *et al.* 2007b).

Vegetation responses to the removal of grazing are largely driven by productivity. In areas of high resource availability, the removal of grazing (and other disturbances) often leads to increased biomass of dominant species which can reduce small-scale species richness due to competitive exclusion. Contrastingly, in areas with low resource availability, plant biomass may remain unchanged and species richness may increase with grazing removal (Lunt *et al.* 2007a). Lunt et al. (2007b) proposed a two-factor model to predict the impacts of grazing removal in temperate grassy ecosystems in Australia based on site productivity and initial site condition.

They predicted the removal of grazing to have positive outcomes in relatively intact sites of low productivity and to have negative or neutral outcomes in degraded, productive areas and found support for this in a degraded, low productivity riparian forest.

The aim of this study was to examine understorey responses to the long-term removal of stock grazing in herb-rich *Eucalyptus camaldulensis* (Red Gum) woodlands in the Woohlpooer State Forest (WSF), southern Australia. The staggered removal of sheep grazing over the last 24 years in the WSF provided an opportunity to examine recovery from grazing in these woodlands. Herb-rich Red Gum woodlands in this region are characterized by high small-scale species richness (Lunt 1990) owing ,in part, to low site productivity (Price and Morgan 2007). Reductions in small-scale species richness have been reported with fertilizer addition and subsequent increases in biomass (Price and Morgan 2007). The woodland site is not highly degraded, likely due to historically low stocking rates and lack of nutrient enrichment and hence, is dominated by native perennial species with a low cover and richness of exotic species. Based on the Lunt *et al*. (2007b) two-factor model, we predict that this little degraded, unproductive woodland may have a positive response to grazing removal with possible increases in small-scale species richness.

The Woohlpooer State Forest

The study was conducted in the Woohlpooer State Forest (WSF) (37^o 19'60" S, 142^o 9'0" E) in western Victoria, southern Australia. The WSF consists of an open *Eucalyptus camaldulensis* woodland above an herbaceous ground layer. Soils are duplex, consisting of a loamy sand, 0.5 m in depth, above a heavy mottled clay, and are usually waterlogged in winter and spring (Rayment and Higginson 1992). The climate is temperate with cool winters (mean minimum temperature of the coldest month (July) is 4 ^oC) and warm summers (mean maximum temperature of the warmest month (January/February) is 26.6 ^oC) (Bureau of Meteorology, Hamilton recording station, ca 35 km to the south of the study site). The average annual rainfall is 687 mm with a mean monthly maximum of 77 mm in August and minimum of 32 mm in February. Annual rainfall in the year of data collection was below the long-term average (annual rainfall 2005 = 427 mm).

The WSF has a long history of sheep grazing dating back to the earliest European occupation in 1880. Sheep were removed for ca. 30 years from 1890 to 1920 when selectors walked off the land due to hardship. Timber harvesting is currently the main land use in the WSF and has been since the early 1900's. To promote Red Gum regeneration, sheep grazing has been phased out of the woodland since 1981. The WSF is fenced into 'paddocks' differing in time-since-grazing removal with stock removed from three paddocks in 1981, from one paddock in 1991, 1994 and 1996, and from three in 2000. Grazing ceased in a final four paddocks in 2005. Stocking rates were relatively low and similar across all paddocks ranging from 0.3 – 0.7 DSE/ha. The WSF is also grazed by native macropods and it is believed kangaroos densities have increased there over the last 20-30 years (Department of Sustainability and Environment 2004).

Field methods

Using a space-for-time substitution, ‘paddocks’ were divided into four categories based on time-since-grazing (TSG) removal (Figure 1). These were: (1) long-ungrazed (24 years, 2 paddocks), (2) intermediate ungrazed (9-14 years, 3 paddocks), (3) recently grazed (5 years, 2 paddocks) and (4) continuously grazed at the time of data collection in 2005 (2 paddocks). A total of 36 quadrats (16 m^2) were sampled, with at least 8 quadrats per grazing category. Quadrats were selected to detect some of the within paddock variability. Floristic data was collected in October 2005 in peak floristic season when most species could be easily identified. In each quadrat, the presence of all vascular plant species was recorded and abundance assigned using Braun-Blanquet cover-abundance classes. Data were also collected on moss cover (%), litter cover (%), bare ground (%) and tree density/400 m^2. Above-ground biomass was collected (30 x 30 cm) in each quadrat, dried at 80 ^oC for 48 hr and weighed. Soils were analysed for phosphorus, potassium, sulphur, organic carbon, conductivity, pH and total nitrogen. Samples were collected by taking four random soil cores in each quadrat (20 x 100 mm) which were combined, air dried, sieved (2 mm sieve) and set to the CSBP Soil and Plant Laboratory for analysis.

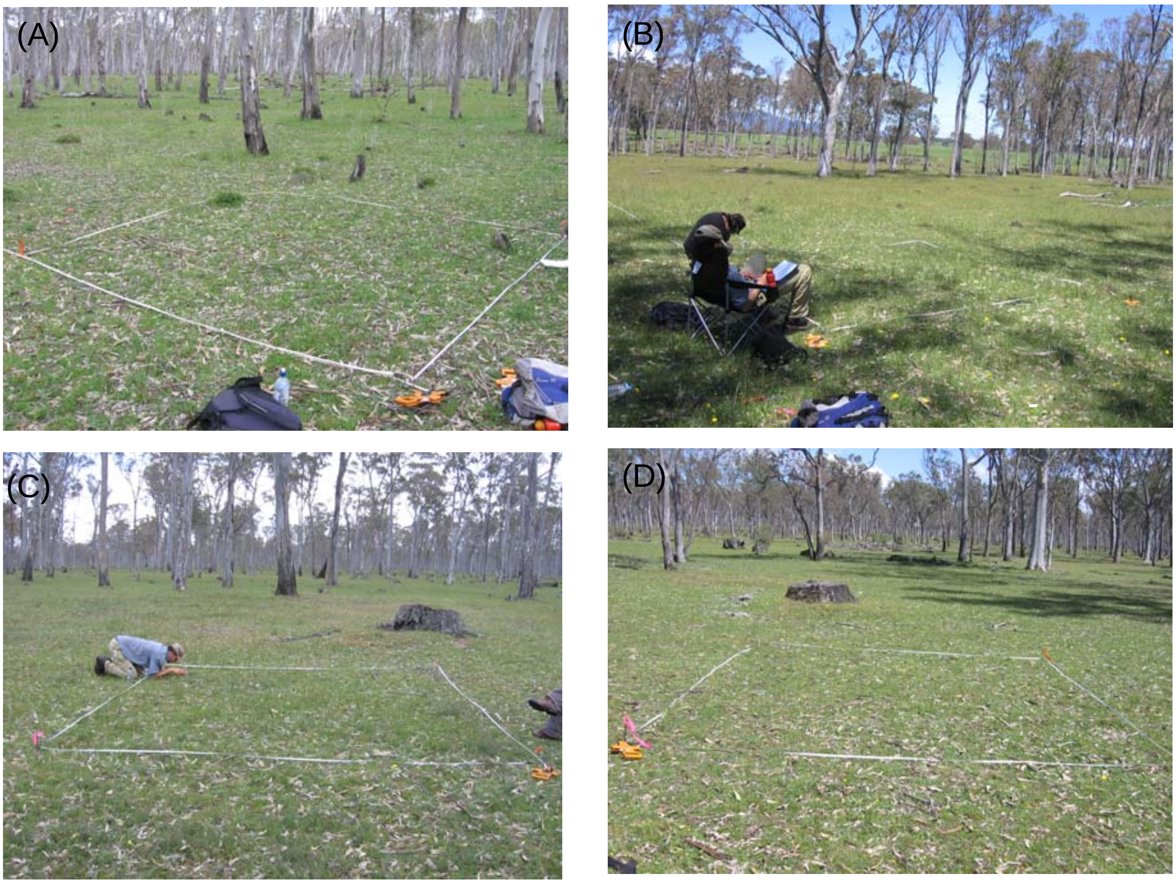

Figure 1. Quadrats in the four time-since-grazing categories, A = long-ungrazed (LU) 24 years since grazed, B = intermediate ungrazed (IU) 9-14 years since grazed, C = recently grazed (RG) 5 years since grazed, D = continuously grazed (CG).

Results and Discussion

We found a total of 152 mostly herbaceous, native (82%) and perennial (76%) species. Species richness was high in all sites with a mean of 52 species per 16 m^2**.** Average vegetation cover was 62% with no-one species dominating; rather, total cover comprised many species with low cover (<5%). Ground cover (% moss, litter and vegetation) did not differ significantly between any of the time-since-grazing categories (Table 1). Increased potassium was found in the more recently grazed sites compared to the long ungrazed (Table 1). Total N decreased with time-since-grazing removal (Table 1).

Table 1. Mean (±1 SE) soil properties and ground cover conditions in each of the time-since-grazing categories

	Time-since-grazing removal			
	Long	Intermediate	Recently	Continuously
Soil properties				
Phosphorus mg/kg	2.9 ± 0.3	4.6 ± 0.9	3 ± 0.4	3.4 ± 0.3
Potassium mg/kg*	117.2 ± 10.6[a]	125.6 ± 10.1[ab]	134.3 ± 13.7[ab]	177.1 ± 18.8[b]
Sulphur mg/kg	1.8 ± 0.2	2.8 ± 0.2	2.3 ± 0.4	2.8 ± 0.4
Organic carbon %*	2 ± 0.1[a]	2.9 ± 0.2[b]	2.6 ± 0.3[ab]	2.8 ± 0.1[ab]
Conductivity dS/m	0.04 ± 0.003	0.06 ± 0.003	0.05 ± 0.004	0.05 ± 0.004
pH	5.86 ± 0.06	5.78 ± 0.07	5.8 ± 0.08	6.0 ± 0.09
Total N %*	0.12 ± 0.005[a]	0.16 ± 0.009[b]	0.14 ± 0.02[c]	0.17 ± 0.01[d]
Ground cover				
Vegetation %	68.7 ± 2	69.8 ± 2	66.6 ±4	65.6 ± 5
Bare ground %	3.7	9.6 ± 2	8.4 ± 2	8.1 ± 3
Moss %	12.5 ± 1	11.2 ± 2	10.6 ± 1	12.5 ± 3
Litter %	15 ± 2	9.4 ± 1	14.3 ± 1	13.7 ± 3

As predicted by the model for this low productivity woodland, no significant increases in biomass were found with the removal of sheep grazing ($p = 0.085$). Biomass was relatively low in all quadrats (< 80 g/m^2) and may have been constrained by low resource levels. Rainfall was below average for this region for the previous twenty years; however, Price and Morgan (2007) found nutrients to be more important than water availability in influencing understorey productivity in these woodlands. Studies have also found that competition from trees in woodlands may reduce the productivity of understorey species (Scanlan and Burrows 1990; Prober *et al.* 2002; Scanlan 2002) and this has been hypothesized to limit recovery from grazing (Shultz 2007). Kangaroo exclosures (in the Grampians National Park, approx. 50 km from the study area) indicate biomass accumulation can be substantial in the absence of total grazing (authors, personal observation) and hence, the role of kangaroo grazing needs to be explored in these woodlands.

Species richness was significantly higher in long-ungrazed plots in comparison to all the more recently grazed sites by approximately 10 species (Figure 2). A key finding in this study was the substantial time-lag before any responses were detected, with no differences in species richness between continuously grazed plots and those not grazed for 14 years. Many of these species are known to have small and transient seed banks (Lunt 1995; Morgan 1998) and recovery may have been constrained by propagule supply as species may need to re-disperse from surrounding vegetation. Reductions in species richness in more recently grazed sites were due to reductions in native species richness compared to the long ungrazed sites (Figure 2) and, in particular, due to reductions in richness of perennial forbs and geophytes. Significant increases in exotic species richness (particularly forbs species) were also found in continuously grazed sites relative to intermediate and recently grazed sites, although no significant difference was found with the long ungrazed sites (Figure 2).

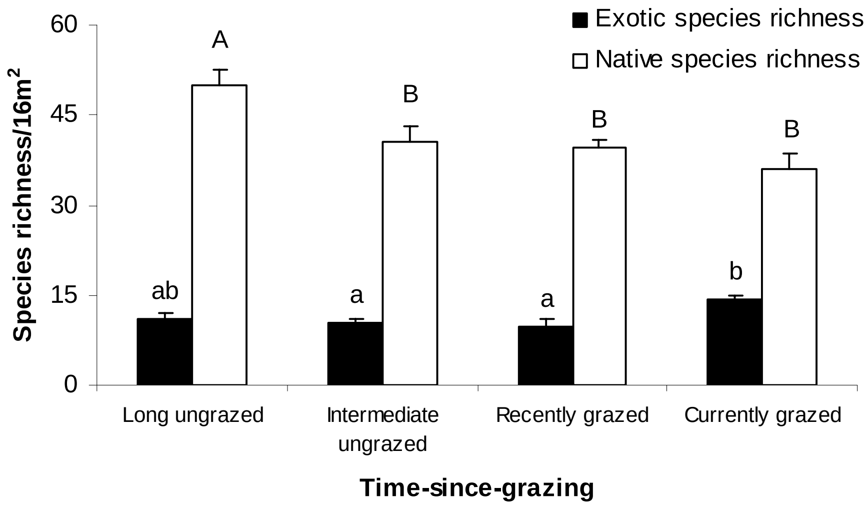

Figure 2. Mean (±1 SE) native and exotic species richness in each of the time-since-grazing categories. Grazing categories not significantly different have the same letter.

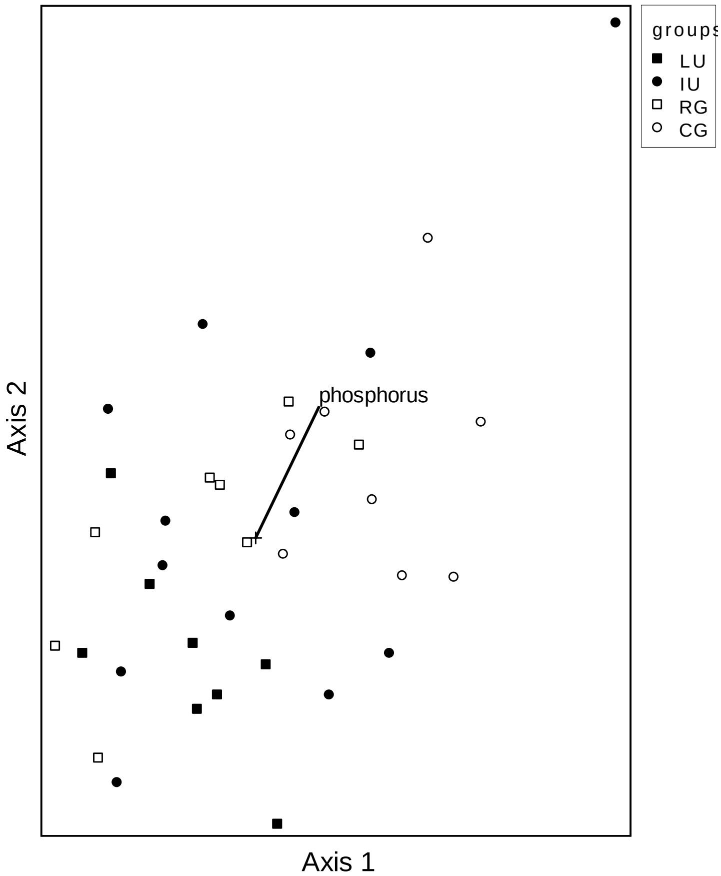

Figure 3. Non-metric multidimensional scaling ordination of all quadrats based on presence/absence data. Time-since-grazing removal categories are LU = Long ungrazed (24 years), IU = intermediate ungrazed (9-14 years), RG = recently grazed (5 years) and CG = continuously grazed. Significant vectors with an r^2 of > 3.5 are shown on the configuration. Minimum stress = 0.19.

Time-since-grazing removal was associated with a shift in community composition (Figure 3). Dissimilarity was particularly evident between the long-ungrazed quadrats and the continuously grazed quadrats. Community composition differed significantly between all time-since-grazing removal categories with the exception of intermediate ungrazed and recently grazed. Soil phosphorus was the only significant environmental variable associated with the vegetation patterns and was increased in more recently grazed sites, although the r-value was relatively low (r^2=3.5). We used indicator species analysis to identify species which are most characteristic of each time-since-grazing category. We found several mostly native species that were significantly associated with long ungrazed plots that were absent or with low indicator values in more recently grazed sites (Table 2). Intermediate and recently grazed plots had few significant indicator species (i.e. **Hypochoeris radicata*, *Isotoma fluviatilis* and *Ajuga australis*). Several mostly exotic species were significantly associated with continuously grazed sites (e.g. *Trifolium* spp., *Galium divaricatum* and *Vulpia* spp., Table 2). These were common in all time-since-grazing categories but found more frequent and abundant in more recently grazed sites.

There were no major structural changes associated with grazing removal in these woodlands. In particular, we found no response from the perennial grass component to the removal of stock, in contrast to other studies which have found increased cover of native perennial grass following stock removal (Pettit and Froend 2001; Spooner *et al.* 2002). In temperate grassy ecosystems in southern Australia, introduced stock grazing has converted systems dominated by tall perennial summer growing grasses to short, winter growing annuals (Lunt *et al.* 2007a) and hence, community recovery may be measured by a response of the perennial grasses. The neutral response of the perennial grass component to stock removal may be an irreversible change (at least without active management), as species most sensitive to grazing may have been depleted some time ago. However, grasses such as *Austrodanthonia* spp. and *Themeda triandra* were commonly found in the sampling plots, but were rarely dominant. This suggests that other factors may be limiting the growth of perennial grasses in these woodlands and this requires further exploration.

Conclusions

The exclusion of stock in herb-rich woodlands can have positive outcomes for conservation management, with increased species richness and shifts to a more native community found. Recovery, however, was slow (> 20 years). Findings were consistent with the Lunt et al. (2007b) two-factor model which predicted positive responses to the removal of stock in this little degraded, low productivity woodland. As predicted by the model, increases in small-scale species richness were found in long-ungrazed plots along with no change in biomass. A key finding in this study was the substantial time-lag before any responses were detected, with no differences in species richness between continuously grazed plots and those not grazed for 14 years. The scale of the response was also relatively minor, although large increases in species richness were found, there were no major structural changes associated with grazing removal. We found no negative responses to grazing removal. Stock grazing does not provide any benefits for conservation management of herb-rich woodlands and hence, there is no reason to retain stock in reserves managed primarily for conservation.

Table 2. Significant indicator species and indicator values for the discrimination of the time-since-grazing removal categories. Probability values refer to Monte Carlo tests while values associated with the time-since-grazing categories are indicator values.

Indicator species	Probability	Time-since-grazing removal (species indicator values)			
		Long	Intermediate	Recently	Continuously
Long ungrazed					
Goodenia geniculata	0.002	71	1	1	0
Wahlenbergia gracilenta	<0.001	70	0	0	16
**Centaurium erythraea*	0.01	63	3	1	5
Senecio quadridentatus	<0.001	59	0	0	0
Centrolepis strigosa subsp. *strigosa*	0.001	54	5	20	3
Viola cleistogamoides	<0.001	54	12	0	1
Astroloma humifusum	0.001	52	8	4	0
Hypoxis vaginata var. *vaginata*	0.004	51	23	5	0
Phyllangium divergens	0.011	47	4	0	5
Austrodanthonia setacea	0.01	44	2	2	8
**Cicendia quadrangularis*	0.006	40	14	20	14
Arthropodium fibriatum	0.01	36	0	0	0
Centrolepis aristata	0.05	34	14	24	17
Hydrocotyle foveolata	0.04	32	23	11	26
Intermediate ungrazed					
**Hypochoeris radicata*	0.04	18	45	18	20
Isotoma fluviatilis subsp. *australis*	0.05	0	25	0	0
Recently grazed					
Ajuga australis	0.01	1	0	44	0
Continuously grazed					
**Galium divaricatum*	0.001	0	0	7	58
**Trifolium dubium*	0.007	4	1	13	53
**Trifolium campestre*	0.004	2	19	19	47
Triptilodiscus pgymaeous	0.01	0	1	3	42
**Vulpia* spp.	0.01	15	16	7	41
**Anagallis arvensis*	0.01	23	20	13	38
**Romulea rosea*	0.04	8	28	16	35
**Briza minor*	0.01	16	30	19	32

(The asterisk '*' denotes exotic species)

References

Department of Sustainability and Environment (2004) 'Workshop report: biodiversity in State Forests.' Victorian Government, Melbourne.

Lunt ID (1990) Species-area curves and growth-form spectra for some herb-rich woodlands in western Victoria, Australia. *Australian Journal of Ecology* **15**, 155-161.

Lunt ID (1995) Seed longevity of six native forbs in a closed *Themeda triandra* grassland. *Australian Journal of Botany* **43**, 439-449.

Lunt ID, Eldridge DJ, Morgan JW, Witt GB (2007a) TURNER REVIEW No. 13. A framework to predict the effects of livestock grazing and grazing exclusion on conservation values in natural ecosystems in Australia. *Australian Journal of Botany* **55**, 401-415.

Lunt ID, Jansen A, Binns DL, Kenny SA (2007b) Long-term effects of exclusion of grazing stock on degraded herbaceous plant communities in a riparian *Eucalyptus camaldulensis* forest in south-eastern Australia. *Austral Ecology* **32**, 937-949.

Morgan JW (1998) Composition and seasonal flux of the soil seed bank of species-rich *Themeda triandra* grasslands in relation to burning history. *Journal of Vegetation Science* **9**, 145-156.

Pettit NE, Froend RH (2001) Long-term changes in the vegetation after the cessation of livestock grazing in *Eucalyptus marginata* (jarrah) woodland remnants. *Austral Ecology* **26**.

Price J, Morgan J (2007) Vegetation dynamics following resource manipulations in herb-rich woodland. *Plant Ecology* **188**, 29-37.

Prober SM, Lunt ID, Theile KR (2002) Determining reference conditions for management and restoration of temperate grassy woodlands: relationships among trees, topsoils and understorey flora in little-grazed remnants. *Australian Journal of Botany* **50**, 687-697.

Prober SM, Thiele KR (1995) Conservation of the grassy White Box woodlands: relative contributions of size and disturbance to floristic composition and diversity of remnants. *Australian Journal of Botany* **43**, 349-399.

Rayment GE, Higginson FR (1992) 'Australian laboratory handbook of soil and water chemical methods.' (Inkata Press: Melbourne)

Scanlan JC (2002) Some aspects of tree-grass dynamics in Queensland's grazing lands. *Rangeland Journal* **24**, 56-82.

Scanlan JC, Burrows WH (1990) Woody overstorey impact on herbaceous understorey in *Eucalyptus* spp. communities in central Queensland. *Australian Journal of Ecology* **15**, 191-197.

Shultz N (2007) The effects of grazing on Victorian grassy ecosystems. Unpublished Honours Thesis, La Trobe University.

Spooner P, Lunt I, Robinson W (2002) Is fencing enough? The short-term effects of stock exclusion in remnant grassy woodlands in southern NSW. *Ecological Management & Restoration* **3**, 117-126.

Yates CJ, Norton DA, Hobbs RJ (2000) Grazing effects on plant cover, soil and microclimate in fragmented woodlands in south-western Australia: implications for restoration. *Austral Ecology* **25**, 36-47.