Fencing resulted in a range of responses which were highly variable between sites and vegetation types. In general, fenced sites had greater tree regeneration, cover of native perennial grasses, less cover of exotic annual grasses and weeds, and less soil compaction than unfenced sites. There was greater tree recruitment in remnants to the west of the study area, and tree recruitment was positively correlated with time since fenced. Within sites, tree recruitment tended to occur in more open are ...
Woodlands on farms in southern NSW: a longer-term assessment of vegetation changes after fencing

By Peter G. Spooner and Sue V. Briggs

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SUMMARY

Fencing incentive programs have been widely used throughout Australia to assist landholders to fence remnant woodland vegetation, to control grazing and improve native vegetation condition. This study investigated vegetation and soil condition in remnant woodlands fenced for 7-9 years in the Murray catchment area in southern NSW. Surveys were undertaken at 42 sites, where vegetation condition was assessed in paired fenced and unfenced sites. Semi-structured interviews were also conducted with landholders to gather management information. Woodlands surveyed were Yellow Box / Blakely’s Red Gum (*Eucalyptus melliodora* / *E. blakelyi*) (15 sites), Grey Box (*E. microcarpa*) (13 sites) and White Cypress Pine (*Callitris glaucophylla*) (14 sites).

Fencing resulted in a range of responses which were highly variable between sites and vegetation types. In general, fenced sites had greater tree regeneration, cover of native perennial grasses, less cover of exotic annual grasses and weeds, and less soil compaction than unfenced sites. There was greater tree recruitment in remnants to the west of the study area, and tree recruitment was positively correlated with time since fenced. Within sites, tree recruitment tended to occur in more open areas with a good cover of native perennial grasses, as compared to sites with a dense tree canopy, or dominated by exotic annuals grasses or weeds. However forty-eight per cent of fenced sites had no tree regeneration, and there was a significant decline in native perennial grasses, and increase of several unpalatable weeds in many fenced areas, suggesting certain ecological barriers may be preventing further recovery. However drought conditions and associated grazing are the most likely cause of this trend. A range of grazing strategies was implemented in fenced sites which require further research as a conservation management tool. Continued long-term monitoring is essential to detect key threats to endangered woodland remnants.

**Key Words:** grazing management, fencing, tree regeneration, vegetation condition, woodlands
Introduction

Since the late 1980s, Fencing Incentive Programs (FIP) have provided funds to landholders to fence remnant native vegetation to control stock grazing, and improve vegetation condition. Various local, state and federal government programs such as the *Natural Heritage Trust* (NHT) have directed millions of dollars towards fencing of remnant vegetation on private properties. In Phase 1 of the NHT program, 113 264 km of fences were constructed as part of 42 Bushcare and 6 Rivercare projects; mostly in Victoria (49% - 55 643 km) and NSW (25% - 28 331 km) (Hassall and Assoc. 2005). Although outputs such as kilometres of fencing and areas fenced appear to validate the success of such programs, the major goal of the NHT program ‘to reverse the decline in the quality and extent of native vegetation cover by 2001’ may not have been achieved (Reeves 1999). This is partly due to ‘an absence of reportable outcomes’ of restoration programs. Of equal concern, it has been reported that ‘landholders were unclear whether fencing will deliver environmental benefits’ (Hassall and Assoc. 2005, pp. 6, 96).

A better understanding of the ecological outcomes of management interventions, such as fencing to control stock grazing, is required to justify future expenditure on restoration of agricultural landscapes in Australia. This paper reports on one of the few ongoing ecological monitoring programs of a FIP funded by the NHT program. The Greening Australia and Murray Catchment Management Authority FIP began in 1996, and evolved from earlier programs based in the Riverina in the mid 1990s. Its aims were to provide assistance to landholders to manage remnant vegetation and to promote increased awareness and education of biodiversity conservation on private properties (for background, see Driver and Davidson 2002). In 2000, Greening Australia approached Charles Sturt University (CSU) to carry out ecological assessments of its FIP program. These assessments were undertaken in 2000 at 47 paired fenced and unfenced woodland sites in the Murray catchment (Spooner et al. 2002).

In 2005, Greening Australia, the NSW Department of Environment and Conservation and CSIRO Sustainable Ecosystems approached CSU to re-survey the paired fenced and unfenced sites in the Murray catchment, as part of the NSW Environmental Trust project *Better Knowledge, Better Bush*. The aims of the survey were to (1) report on the condition of the vegetation in paired fenced and unfenced woodland remnants in the Murray catchment, and (2) investigate short-term or longer-term trends by comparing results from 2005 with those from the 2000 surveys.
Materials and Methods

The study was conducted in remnant woodlands in the southern Riverina and South Western Slopes, in the NSW Murray Catchment. Materials and methods follow Spooner et al. (2002), where study sites were previously selected from a database of over 366 sites fenced under the Greening Australia (NSW Riverina) Fencing Incentive Program. Sites were originally selected if the following conditions were met: (1) the entire remnant had not been fenced due to various management constraints, in order to use the unfenced area as a control; (2) the remnant was fenced for a minimum of 2 years; (3) vegetation in fenced areas was not disturbed since fencing, and was not regularly grazed by domestic stock; (4) unfenced areas had been maintained under the same grazing regime as when fencing was erected, and had not been mechanically disturbed or cropped; and (5) each pair of fenced and unfenced areas had similar vegetation characteristics, crown cover, size, slope and aspect.

Only 47 sites satisfied these criteria and were sampled in 2000 (Spooner et al. 2002). The selected sites were representative of remnants across the catchment, and varied in size, shape, and landscape position. A split-plot design was used to assess the effects of stock grazing practice, by comparing fenced and unfenced areas at each woodland remnant. The underlying assumption was that the fenced area was in a comparable condition and under the same management regime as the unfenced area when fences were erected. Fences excluded domestic stock, but not rabbits or native herbivores.

In August 2005, the owners of the 47 sites were re-contacted to participate in this survey. Difficulties in contacting the owners of a number of properties, some of which had changed owners in the last few years, resulted in a total of 42 paired fenced and unfenced sites for this survey (15 dominated by Yellow Box/ Blakely’s Red Gum – *Eucalyptus melliodora/ E. blakelyi* sites; 13 Grey Box – *E. microcarpa* sites; and 14 White Cypress Pine - *Callitris glaucophylla* sites). These vegetation types were the most commonly fenced under the Fencing Incentive Program (Driver et al. 2000). The locations of sites are shown in Figure 1.

Sampling

At each site, a 200m transect (or 100m in smaller remnants) was placed in the middle of the fenced and unfenced areas using GPS coordinates from 2000 surveys. Transects were
equidistant from remnant boundaries, and aligned parallel to the longer boundary. Where overstorey crown cover was spatially variable, transects were placed to cover the variation in crown cover as much as possible. A nested plot technique was used to measure tree, shrub and herb strata, as previously used by Spooner et al. (2002).

Ten 5 x 5 m quadrats were arranged at equal intervals along each transect. Within each of these quadrats, the percentage cover of trees and shrubs was visually estimated to the nearest 10 per cent, and the identity of all tree and shrub recruits recorded. To identify trees which recruited after fencing, only tree recruits (seedlings and resprouts from lignotuber) less than 3.8 m in height were measured, as these were estimated to have established post 1997 assuming mean growth rates of 48 cm yr\(^{-1}\) (Semple and Koen 2001).

A 2 x 2 m quadrat was nested within each 5 x 5 m quadrat. Within each 2 x 2 m quadrat, the following vegetation condition attributes were measured: percent cover of native and exotic perennial grasses, exotic annual grasses, native and exotic herbs and forbs, and the three groundcover species with greatest cover (designated "common plants") were identified and visually estimated to the nearest 10 per cent, or to the nearest 1 percent where cover was less than 10 per cent. Tree and shrub cover were also re-measured in 2 x 2 m quadrats (following methods used in 5 x 5 m quadrats) to provide accurate data to correlate against groundcover characteristics. The percent cover of the following condition attributes was also assessed: logs (>10 cm diameter), branches (1-10 cm diameter), leaf litter (< 1 cm diameter), bare ground, exposed rock and undisturbed lichen crust. In addition, soil surface pH and moisture (1-8 ordinal scale) were recorded in each quadrat using a hand-held electronic pH-moisture meter. Soil penetration resistance (used to estimate soil compaction) was recorded by averaging readings taken from the four corners of each 2 x 2 m quadrant using a calibrated 0-500 kPA pocket penetrometer. Soil penetration resistance readings were taken in early spring in a short sampling period after heavy rains, to ensure consistent soil moisture readings (as verified with soil moisture meter).

**Site management**

Site management information was gathered from landholders using a brief phone questionnaire and semi-structured interviews conducted on-site; specifically stock grazing practices in fenced and unfenced areas. As it became apparent that grazing practices had changed at many sites due to past drought conditions, details of past grazing intensity were estimated and assigned to four grazing intensity categories (nil, light, moderate and heavy).
using landholder records, following methods similar to Durrough et al. (2004). Total exclusion (nil grazing) sites were those where livestock were excluded all year, except for occasional stock escapes when fences were down. In many cases, such sites were still grazed by native herbivores and rabbits. Lightly grazed sites were grazed for short duration, typically a short 3-week period every 2-3 years. Moderately grazed sites were those which were grazed annually for extended periods, or crash grazed 1-3 times per year. Sites which were heavily grazed due to drought, but not grazed prior to this, were assigned to this category. Heavily grazed sites were those where continuous heavy grazing was described, or as one farmer candidly put it - ‘flogged’.

**Data analysis**

For most analyses, data from all quadrats in each fenced and unfenced area were averaged, to obtain a pair of mean values for each variable at each site. These values were statistically compared between fenced and unfenced areas using pooled data from all three woodland vegetation types, and for each vegetation type separately. Individual non-parametric Wilcoxon and Kruskal-Wallis signed ranks tests were used to determine whether tree recruitment and ecosystem variables differed significantly between the three vegetation types, fenced and unfenced areas, and between 2000 and 2005 surveys. Comparisons between grazing categories within fenced and unfenced sites were also carried out. Correlations between site, tree recruitment and ecosystem attributes were explored using Spearman’s non-parametric rank-order correlation. Analyses were performed using SPSS v14.

As tree regeneration was a key outcome of the fencing program, general linear modelling was used (SPSS v.14) to perform analysis of covariance on mean site data, with tree regeneration as a dependent variable (log transformed), woodland type as a fixed factor, and the following site attributes as covariates; altitude, GPS location coordinates, grazing intensity and other management factors, and vegetation and condition and soil attributes. We retained only those variables that contributed to the largest significant change in deviance from the null model, where any falling below the criterion level of $F = 2.5$ was discarded. The final model was reached using observed power estimates, when the variables included had a significant effect at $P<0.05$ (McCullagh and Nelder 1989).
Results

Fence-line contrasts: tree regeneration

Tree recruitment was highly variable within and between sites. In fenced and unfenced site comparisons, significantly more eucalypt trees regenerated in fenced areas (mean = 193 +/- 40 recruits ha\(^{-1}\)) than in unfenced areas (17 +/- 4 recruits ha\(^{-1}\)) for all woodland vegetation types combined (\(Z = -4.105, P < 0.001\)), and in individual Yellow Box/ Blakely’s Red Gum (fenced = 256 +/- 88 ha\(^{-1}\); unfenced = 90 +/- 16 ha\(^{-1}\); \(Z = -2.675, P = 0.007\)) and Grey Box sites (fenced = 221 +/- 68 ha\(^{-1}\); unfenced = 8 +/- 7 ha\(^{-1}\); \(Z = -2.524, P = 0.012\)). Recruitment was also greater in fenced White Cypress Pine sites (fenced = 100 +/- 52 ha\(^{-1}\); unfenced = 12 +/- 8 ha\(^{-1}\)), however this difference was not statistically significant (\(Z = -1.866, P = 0.06\)).

In the previous surveys in 2000, tree regeneration was recorded in 18 fenced sites (38%). In 2005, this number had increased to 22 fenced sites (52%), where there was a significant increase in tree regeneration for all vegetation types combined, and for individual Yellow Box/ Blakely’s Red Gum and Grey Box sites (Figure 2). In contrast, tree regeneration was recorded in only five (11%) unfenced sites in 2000, and this number slightly increased to seven unfenced sites (17%) in 2005. Using combined 2000 and 2005 data for fenced sites, there was a significant positive relationship (\(Rs = 0.339, P = 0.001\)) between the density of tree regeneration and time since fencing (Figure 3). Tree regeneration was also significantly negatively correlated (\(Rho = -0.397, P = 0.009\)) with overstorey tree cover, and significantly positively correlated (\(Rho = 0.331, P = 0.032\)) with the cover of native perennial grasses.

Understorey and groundcover attributes

Shrub cover was significantly greater in fenced than unfenced areas (\(Z = -2.533, P = 0.011\)) for all vegetation types combined, but these results were not significant for individual vegetation types (Table 1). Increased shrub cover in fenced sites was mainly attributed to recent revegetation activities. Percent covers of native perennial grasses, native forbs and lichen crust were significantly greater (all \(P < 0.01\)) in fenced than unfenced areas for all vegetation types combined, with variable results for individual vegetation types (Table 1). In contrast, there was a significant increase in the cover of exotic forbs (\(Z = -3.642, P < 0.01\)) and of exotic annual grasses (\(Z = -2.059, P < 0.05\)) in unfenced areas compared with fenced areas for all vegetation types combined, and for some individual vegetation types (Table 1).
Changes in selected groundcover attributes between 2000 and 2005 in fenced and unfenced areas are shown in Figure 4. There was a significant decline in the cover of perennial (native and exotic) grasses in fenced (-31.8%; $Z = -3.641$, $P < 0.001$) and in unfenced (-50.1%, $Z = -3.176$, $P = 0.001$) sites between 2000 and 2005 (Figure 4a). In contrast, there was a slight increase (+6.1%; $P > 0.05$) in the cover of exotic annual grasses in fenced areas in 2005 (Figure 4b). There was also a significant increase in the cover of (combined) native and exotic forbs in fenced (+21.1%; $Z = -2.547$, $P = 0.011$) and unfenced (+25.3%; $P > 0.05$) sites between 2000 and 2005 (Figure 4c). Note: the method of data collection in 2000 did not distinguish between native and exotic forbs, however most forbs recorded in 2000 were exotic species (see Common plants below).

Investigating groundcover relationships further, there was a significant negative correlation ($Rs = -0.473$, $P = 0.002$) between tree cover and cover of native perennial grasses (Figure 5a) across all fenced woodland sites. There was also a significant positive correlation ($Rs = 0.531$, $P < 0.001$) between cover of native perennial grasses and native forbs, and a significant negative correlation between native perennial grasses and exotic annual grasses ($Rs = -0.793$, $P < 0.001$) (Figure 5b).

**Common plants**

Overall, 26 native understorey plant species were recorded as "common plants" in fenced areas in 2000, and 37 species were recorded in 2005, which is an increase of over 30% for all fenced sites. This increase in common native species was partly attributed to different survey periods (September 2005, as compared to previous survey in July 2000). Thirty of the common plants recorded in fenced sites in 2000 were exotic species, and 31 exotic species were recorded in 2005. Fewer common native species were recorded in unfenced areas in 2000 (14) than in 2005 (16). As this is not a full species inventory, it is likely that more exotic and native plant species occur in fenced and unfenced woodlands in low abundance.

Barley grasses (*Hordeum* spp.) was the most abundant genus in fenced and unfenced areas. However the mean cover of barley grasses in fenced areas declined by 24 % between 2000 and 2005. The cover of most exotic annual weeds increased between 2000 and 2005 e.g. Capeweed (*Arctotheca calendula*) and Paterson’s Curse (*Echium plantagineum*). The cover of some native forbs (e.g. Chocolate Lily, *Dichopogon strictus*) was also greater at some fenced sites; however this result may be a function of different sampling periods. In contrast, the
cover of most native perennial grasses decreased since 2000 in fenced areas e.g. spear grasses (\textit{Austrostipa} spp.: -13%), wallaby grasses (\textit{Austrodanthonia} spp.: -77%), and Kangaroo Grass (\textit{Themeda australis}: -47%).

**Soil attributes**

Soils in fenced areas were significantly ($Z = -4.893, P < 0.01$) less compacted than in unfenced areas for all vegetation types combined (Table 1). Soil compaction differed greatly between fenced and unfenced sites in 2005 due to a non-significant decrease (-11.1%) in compaction in fenced, and significant increase (+20.3%, $Z = -3.575, P < 0.001$) in unfenced woodland areas since 2000 (Figure 4d). In 2005, the percentage cover of soil lichen crust was also significantly higher ($Z = -3.022, P < 0.01$) in fenced areas than unfenced areas for all vegetation types combined.

**Effects of grazing in fenced woodlands**

A summary of grazing management in fenced and unfenced areas is shown in Table 2. As 62% of fenced areas were grazed (Table 2), further analyses were carried out to explore any relationships between vegetation condition attributes and grazing regimes in fenced woodlands. Due to lack of replication, no statistics could be performed on data for heavily grazed sites. Density of tree recruitment was greatest in moderately grazed sites (mean of 364 recruits/ha by 2005), compared with ungrazed, light or heavy grazed categories; but differences in the density of tree recruits between grazing categories were not statistically significant (Wilcoxon tests: $P > 0.05$) (Figure 6a). Increases in tree recruitment between 2000 and 2005 were similar in all grazing categories except those heavily grazed (Figure 6a).

The cover of perennial grasses (native and exotic) markedly decreased between 2000 and 2005 in all grazing categories, and this effect was significant in moderate grazed fenced areas ($Z = -2.578, P = 0.010$; Figure 6b). In contrast, the cover of exotic annual grass strongly increased between 2000 and 2005 in light (+17%), moderate (+58%) and heavily grazed (+185%) categories, and slightly decreased in sites excluded from grazing (Figure 6c); but these results were not significant (all $P > 0.05$). There was little difference in the cover of native and exotic forbs in all grazing categories except nil (exclosure), where there was a significant increase ($Z = -2.481, P = 0.013$; Figure 6d).
Predictors of tree regeneration in fenced areas

A general linear model were used to explore and compare the combined effects of management (e.g. grazing), and site attributes (e.g. tree cover, cover of perennial grasses) on tree regeneration. The final model significantly (Table 3; F = 4.888, P = 0.003) predicted tree regeneration, with woodland type and location (site easterly coordinate - negative relationship) significant variables (P < 0.05), and time since fenced a strong contributing variable in the final model (Table 3). Grazing intensity was not a significant variable in the model.

Summary of tree recruitment results: Fencing, and resultant changes in grazing management, led to increased tree regeneration in fenced areas. Tree recruitment varied between vegetation types, and was greater in remnant woodlands in the west of the study area, where grazing generally is not as extensive (mixed cropping zone), and those fenced for longer duration. Within woodland sites, tree recruitment was positively correlated with the cover of native perennial grasses, and negatively correlated with overstorey tree cover and the cover of exotic annual grasses and forbs.

Discussion

The result of this study have shown that incentives such as the Greening Australia Fencing Incentive Program (FIP) play an important role in improving the condition of native vegetation on farms in south-eastern Australia. Fencing of remnant woodlands can enhance tree regeneration, improve native groundcover and improve soil conditions. These are key indicators of healthy functioning ecosystems (e.g. Noss 1990; Gibbons and Freudenberger 2006).

In this study, each site had a paired ‘control’ grazed woodland. Grazing intensity in the ‘treatment’ fenced areas was highly variable, ranging from nil to various frequencies and intensities of stock grazing. Therefore this study provides a comparison between the effects of general pasture grazing management (status quo – grazing of unfenced woodlands) with a range of grazing regimes in the fenced areas (new grazing regimes - fenced area); it is not a simple grazing exclusion study. There was also inherent variability between sites due to prior grazing pressure, management inputs, land–use history and resultant site conditions (e.g. plant composition and structure) prior to fencing and consequent grazing management, and local
climate influences. Nevertheless, as site conditions were recorded in 2000, a number of conclusions regarding the ecological benefits of fencing incentive programs can be drawn:

**Vegetation condition**

Fencing and resultant grazing management which follows fencing (including stock exclusion) initiated a number of responses. Firstly, fencing and associated changes in management, can lead to increased cover of native perennial grasses, and decreased cover of exotic annual grasses and forbs, which conforms with other studies (e.g. Graetz and Tongway 1986; Scougall et al. 1993; Pettit et al. 1995). Variability in vegetation condition between sites in relation to fencing *per se* can be explained by differences in grazing histories (past and more recent), woodland vegetation type, and associated soil type and natural and induced fertility (e.g. Milchunas and Laurenroth 1993; Osem et al. 2004; Lunt et al. 2007). However the cover of many native groundcover species (e.g. wallaby grasses, spear grasses) in fenced areas significantly decreased between sampling periods, whereas the cover of several unpalatable exotic forbs (e.g. Capeweed, Paterson Curse, Horehound (*Marrubium vulgare*)) increased. This suggests that despite (positive) differences in vegetation attributes shown in fencing contrasts, further degradation may still be occurring in fenced woodland areas. Climatic influences (e.g. drought) and associated grazing by stock and native herbivores are the most likely explanation of this trend (Pettit and Froend 2001). The results highlight the importance of regular long-term monitoring to detect trends and potential threats to fenced remnant woodlands over time, and responses to management practices.

As (1) the number of fenced sites with tree regeneration increased, and (2) the mean number of tree recruits in fenced sites greatly increased between sampling periods (which included a severe drought year in 2002), and (3) few unfenced sites had tree regeneration, this study confirms results from the 2000 surveys that fencing remnant woodlands, and associated changes to management practice, promote tree regeneration – a key aim of this program. The significant positive relationship between density of tree recruits and time since fencing (and different regeneration rates in the vegetation types) highlights the importance of recovery time for long-grazed woodland vegetation (e.g. Wilson 1990; Lunt et al. 2007). Tree recruitment is often a long-term process, due to chance events such as seasonal rainfall, seed availability, and suitable conditions for germination (Curtis 1990; Cluff and Semple 1994; Vesk and Dorrough 2006). For example, recruitment of White Cypress Pine in most sites was negligible in 2000 but more extensive in 2005, which could be explained by drought in the
intervening period, associated increases in bare ground and subsequent destocking providing suitable conditions for species such as White Cypress Pine to regenerate (Lacey 1972).

Results from this study support results of other studies which have suggested that gaps between trees and perennial tussocks, which are free from competition by exotic annual grasses, provide suitable conditions for tree seedlings and other native species to regenerate (e.g. Lawrence et al. 1998; Yates et al. 2000). Greater tree regeneration may also be attributed to improved groundcover and soil conditions (Lawrence et al. 1998). Significant changes appear to be occurring at the soil surface as a result of fencing and consequent grazing management, which is consistent with other studies (e.g. Graetz and Tongway 1986; Eldridge et al. 2000). Differences in soil compaction between fenced and unfenced sites were more pronounced in 2005 than 2000 due to continued gradual recovery of soils in fenced areas, but also continued degradation of unfenced woodland areas.

However as 45% of fenced sites had no tree regeneration, 7-9 years had elapsed since fences were erected, and a number of ‘normal’ rainfall years had occurred, certain ecological ‘barriers’ (Hobbs and Norton 1996; Yates & Hobbs 1997; Spooner and Alcock 2006) may be preventing tree regeneration. For example, the dominance of annual exotic species in many sites, particular those left ungrazed or heavily grazed, can prevent regeneration (Lawrence et al. 1998). Dense tree canopies, particularly in many White Cypress Pine remnants, may also prevent tree regeneration due to competition for light, moisture and space (Spooner et al. 2002; Thompson and Eldridge 2005).

**Grazing management of remnant woodlands**

The aim of providing fencing incentive funds is to assist land managers to better manage grazing within a remnant, not necessarily to create a grazing exclosure. Thirty eight percent of landholders in this study ‘locked up’ their remnants, with various results. Most of these landholders thought excluding stock was the only management action necessary; a result found elsewhere (e.g. Moore and Renton 2002; Trémont 2005). Such a (non)intervention approach is underpinned by the classical equilibrium paradigm, where reducing or removing stocking rates is thought to lead to recovery and greater stability of the ecosystem (Vetter 2005). Other studies have shown that removing stock grazing may not lead to reinstatement of native species, but instead promotes a species poor environment, dominated by exotic species (Trémont 1994; Lunt and Morgan 1999). As the case for this study; grazing exclosure led to
improvements (in terms of tree regeneration and maintenance of native groundcover species) in some sites, but in other sites, led to a significant increase in the cover of some exotic species e.g. Capeweed, Paterson’s Curse and Horehound.

A key aim of conservation grazing is to promote cover and diversity of native species over exotic species (e.g. Trémont 1994; Dorrough et al. 2004), whereas grazing for livestock production is about promoting high and consistent amounts of quality herbage for domestic stock (e.g. Lodge and Whalley 1989; Whalley 2005; Lunt et al. 2007). Sixty two percent of landholders grazed their fenced woodland sites to various extents, and the results suggest grazing is an important ecological management factor, in terms of tree regeneration and maintenance of groundcover conditions. The use of alternative grazing strategies (e.g. ‘spell’ ‘rest’ ‘crash’ or ‘strategic’ grazing) is underpinned by the non-equilibrium paradigm (e.g. Westoby et al. 1989; Olff et al. 1999) to better manage biomass levels within remnant woodlands. However analyses of grazing effects were mostly not significant, due in part to problems in quantifying grazing treatments, and compounding effects of drought and grazing by native herbivores. More targeted research is required to develop conservation grazing strategies of remnant woodlands to promote desired conditions.

The overall benefits of fencing incentive programs to maintain or improve vegetation conditions in woodland remnants are clear, but at a site scale, results are highly variable due to differences in vegetation type, locality, farm management and initial site conditions. Further management inputs may be required at many sites (e.g. revegetation, fire management, grazing management, weed control) to maintain present conditions or overcome ecological barriers preventing recovery to a desired ecosystem state. Climate change now adds a new dimension, stressing woodland sites that have been grazed by stock for many years. Support for conservation management of woodlands remnants on private properties needs to be continued to improve quality, extent and connectivity of woodland remnants, else we will witness the local and possibly wider extinction of many woodland species.

**Acknowledgements**

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program. We thank Ian Lunt and two anonymous reviewers whose comments greatly improved earlier drafts of this paper. The authors wish to thank the 42 landholders in the Murray catchment who generously made available their properties and time, and contributed their knowledge.

References


Table 1. Mean vegetation condition and soil attributes in 42 fenced and unfenced woodland sites in the Murray Catchment area in September 2005. Values are percent cover unless otherwise indicated.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>All vegetation types</th>
<th>Yellow Box/ Blakely’s Red Gum</th>
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<th>White Cypress Pine</th>
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<td>n=13</td>
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<td>Unfenced</td>
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</table>
Table 2. Stock grazing intensity categories and stock type in fenced woodland areas since 2000.

<table>
<thead>
<tr>
<th>Grazing level</th>
<th>Description/ comments</th>
<th>Fenced</th>
<th></th>
<th></th>
<th>Unfenced</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>n</td>
<td>Frequency</td>
<td>n</td>
<td>Frequency</td>
</tr>
<tr>
<td>1</td>
<td>Exclusion</td>
<td>16</td>
<td>38.1%</td>
<td>3</td>
<td>7.1%</td>
</tr>
<tr>
<td>2</td>
<td>Light</td>
<td>12</td>
<td>28.6%</td>
<td>2</td>
<td>4.7%</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>11</td>
<td>26.2%</td>
<td>7</td>
<td>16.7%</td>
</tr>
<tr>
<td>4</td>
<td>Heavy</td>
<td>3</td>
<td>7.1%</td>
<td>30</td>
<td>71.4%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stock type</th>
<th>Fenced/ Unfenced</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Sheep</td>
<td>13 50.0%</td>
</tr>
<tr>
<td>2 Cattle</td>
<td>5 19.2%</td>
</tr>
<tr>
<td>3 Horses</td>
<td>1 3.8%</td>
</tr>
<tr>
<td>4 Mixed stock grazing (e.g. sheep and horses)</td>
<td>7 26.9%</td>
</tr>
</tbody>
</table>

Table 3. Final general linear model for tree regeneration in fenced woodland areas (n = 42), using mean site vegetation and management attributes.

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Observed Power(a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>6.575(b)</td>
<td>4</td>
<td>1.644</td>
<td>4.888</td>
<td>.003</td>
<td>.932</td>
</tr>
<tr>
<td>Intercept</td>
<td>4.157</td>
<td>1</td>
<td>4.157</td>
<td>12.361</td>
<td>.001</td>
<td>.928</td>
</tr>
<tr>
<td>E</td>
<td>4.189</td>
<td>1</td>
<td>4.189</td>
<td>12.457</td>
<td>.001</td>
<td>.930</td>
</tr>
<tr>
<td>time</td>
<td>.843</td>
<td>1</td>
<td>.843</td>
<td>2.506</td>
<td>.122</td>
<td>.338</td>
</tr>
<tr>
<td>woodland</td>
<td>2.329</td>
<td>2</td>
<td>1.165</td>
<td>3.463</td>
<td>.042</td>
<td>.613</td>
</tr>
<tr>
<td>Error</td>
<td>12.443</td>
<td>37</td>
<td>.336</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>28.830</td>
<td>42</td>
<td>.336</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>19.018</td>
<td>41</td>
<td>.336</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a  Computed using alpha = .05
b  R Squared = .346 (Adjusted R Squared = .275)
Figure 1. Locations of paired fenced and unfenced woodland study sites in the Murray Catchment area in southern NSW.
Figure 2. Mean density (+SE) of regenerating tree stems in fenced woodland areas in 2000 and 2005.

Figure 3. The relationship between time since fenced and density of regenerating tree stems in fenced woodland areas.
Figure 4. Mean percent cover (+ SE) of (a) native and exotic perennial grasses, (b) exotic annual grasses, (c) native and exotic forbs, and (d) mean soil penetration resistance (measure of compaction), in 2000 and 2005 in fenced and unfenced woodland areas.
Figure 5. Relationships between (a) tree cover and cover of native perennial grasses, and (b) cover of native perennial grasses and (i) native forbs, and (ii) cover of exotic annual grasses; in fenced woodland areas in 2005.
Figure 6. Mean percent cover (+ SE) of (a) tree recruits, (b) native and exotic perennial grasses, (c) exotic annual grasses, (d) native and exotic forbs, according to grazing intensity categories (Nil, Light, Moderate, Heavy) in fenced woodland areas in 2000 and 2005. * Denotes significant at P < 0.05 (Wilcoxon signed rank tests)