Restoration of eucalypt grassy woodland – effects of experimental interventions on ground layer vegetation

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The removal of livestock grazing can improve the condition of grassland vegetation by allowing native plant growth and plant litter to accumulate. Experiments over a four year period show that growing conditions can be additionally improved by reducing kangaroo densities and providing additional fallen timber. However in the short-term, favourable seasonal conditions can be the most important factor driving plant growth and increasing apparent plant diversity, particularly after a period of drought.

Running title: Restoration of woodland understory

Abstract

We report on the effects of broad-scale restoration treatments on the ground layer of eucalypt grassy woodland in south-eastern Australia. The experiment was conducted in two conservation reserves from which livestock grazing had previously been removed. Changes in biomass, species diversity, ground cover attributes and life-form were analysed over a four-year period in relation to experimental interventions: i) reduced kangaroo density, ii) addition of coarse woody debris, and iii) fire (a single burn). Reducing kangaroo density doubled total biomass in one reserve, but no effects on exotic biomass, species counts or ground cover attributes were observed. Coarse woody debris also promoted biomass, particularly exotic annual forbs, as well as plant diversity in one of the reserves. The single burn reduced biomass but changed little else. Overall, we found the main driver of change to be the favourable growth seasons which had followed a period of drought. This resulted in biomass increasing by 67%, (mostly due to the growth of perennial native grasses) while overall native species counts increased by 18%, and exotic species declined by 20% over the four year observation period. Strategic management of grazing pressure, use of fire where biomass has accumulated and placement of coarse woody debris in areas of persistent erosion will contribute to improvements in soil and vegetation condition, and gains in biodiversity, in the future.

Key words: Box-gum woodland; temperate grassland; coarse woody debris; kangaroo; grazing; grassland; Mulligans Flat Nature Reserve; Goorooyarroo Nature Reserve

Introduction

Removal of livestock has been considered a primary action in the restoration of post-production grassy woodlands being managed for biodiversity conservation (Spooner *et al.* 2002). For some organisms (e.g. beetles and small skinks), a reduction in grazing pressure has been associated with increases in abundance and species richness in three or fewer years (Barton *et al.* 2011; Manning 2013). Vegetation responses over similar time frames can include an increase in the abundance of grazing-sensitive grasses (McIvor *et al.* 2005) and regeneration of structural vegetation elements such as shrubs and trees (Spooner *et al.* 2002). However, the floristic composition of perennial grasslands may be quite inert to change after even five years (Milchunas and Lauenroth 1995) while landscape-scale changes may take decades (Geddes *et al.* 2011).

While the recovery of ecosystems from human impacts is generally considered to be a long-term proposition in low-productivity environments, there can be strong societal expectations of significant, and positive short-term change (Reeves 1999). The stakes are high in the case of eucalypt grassy woodlands, where depletion and modification of the ecosystem is great, and investment in their restoration has been a spending priority for governments (e.g. Prober *et al.* 2001). As many formal restoration activities have a funded and monitored time frame of less than five years (e.g. Spooner *et al.* 2002; Briggs *et al.* 2008), the question of what might realistically be observed in the vegetation over these short time frames is an important one.

Trajectories of native species recovery may be influenced by prior land use and the legacy effects of past disturbances (Lunt and Spooner 2005; Prober *et al.* 2013), nutrient enrichment (McIntyre 2008) and weed invasions (Spooner and Briggs 2008). At some sites, degradation may be effectively permanent, taking the form of degraded soil, persistent weeds and absent species (Prober *et al.* 2002; McIntyre 2011). Interventions aimed at initiating or speeding up recovery are an increasingly important part of conservation practice. Some are widely adopted (e.g. erosion control, control of exotic plants and animals), other are being explored e.g. the reintroduction of species and habitat elements to increase diversity and restore missing ecosystem functions (McIntyre 2011; Shorthouse *et al.* 2012). Broadly speaking, successful restoration of heavily grazed herbaceous understory would be expected to result in i) sustained or increased native species diversity; ii) increased dominance of native and reduced dominance of exotic species and iii) increased overall native biomass and reduced bare ground.

The importance of disturbances in the management of plant and animal diversity in grassy vegetation is an ongoing issue for conservation management. Livestock removal can moderate soil degradation and relieve pressure from grazing-sensitive species. However, grazing can promote high diversity (Trémont 1994), as the accumulation of perennial grass biomass in ungrazed swards has the potential to reduce diversity of inter-tussock forbs and grasses (Trémont and McIntyre 1994). Macropod populations may provide ongoing grazing pressure in the absence of livestock and fire can provide a non-selective mode of biomass reduction. Burning is not independent of herbivore activity as patchy fire can increase grazing pressure on recently burnt areas (Meers and Adams 2003). Small-scale soil disturbances provided by digging fauna are also a potential factor in the maintenance of plant diversity. The amount of bare ground at any point in time is the net result of total grazing, trampling, digging and burning, but should sufficiently low to promote rainfall infiltration and recycling of organic matter into the soil (McIntyre and Tongway 2005).

Here we report the four-year effects of two experimental interventions intended to accelerate ecosystem recovery in eucalypt grassy woodland: supplementation of coarse woody debris and reduction of total grazing pressure through management of kangaroo densities. We have applied these treatments experimentally in two conservation reserves in south-eastern Australia as part of the long-term 'Mulligans Flat – Goorooyarroo Woodland Experiment' (www.mfgowoodlandexperiment.org.au; Manning *et al.* 2011). To date, both treatments have produced increases in richness and abundance of beetles (Barton *et al.* 2011) and reptiles (Manning *et al.* 2013). As ground-dwelling fauna are highly responsive to the state of the herbaceous ground layer (McIntyre 2005; Dorrough *et al.* 2012) we predict that beetle and reptile effects reflect vegetation responses to these experimental treatments. In addition, localised increases in surface soil fertility have been reported next to logs in the coarse woody debris treatment after only two years (Goldin and Hutchinson 2013). Logs provide heterogeneity in growing conditions for ground layer vegetation with the potential to increase plant diversity but also the potential to favour exotic species through enhanced fertility (Dorrough *et al.* 2006).

The objective of this paper is to assess, over a four-year period, the effect of the following on ground layer vegetation (i.e. biomass, ground cover, life form, origin, perenniality, species counts) :

1) Seasonal climatic conditions.
2) A reduction in kangaroo density.
3) The addition of coarse woody debris (CWD) in the form of logs.
4) A single burning event five months prior to the commencement of sampling.
5) High and low tree and shrub densities.

Objectives 2-5 are addressed through the application of experimental treatments, with 2-4 representing experimental manipulations and 5 controlling for existing variation in density of trees and shrubs within the reserves . The rationale for the treatments is summarized in Table 1. Assessing the effects of seasonal climatic conditions (Objective 1) involves interpretation of the overarching drivers of change in biomass and composition. This influences the expression of the experimental treatments, as climatic variability is linked to population fluctuations and local extinction risks (Jongejans *et al.* 2010). Being uncontrolled, seasonal conditions are confounded by other management that are applied across the entire reserves (Table 1). Nonetheless, seasonal conditions are important for the overall interpretation of change and of the experimental results. We predict that the experimental manipulations (2-4) are likely to have only modest effects on the ground layer vegetation over the four-year observation period, but that stronger effects will emerge over the long-term.

Methods

Study area

Ninety-six experimental sites were established in 2007 in two nature reserves located on the northern boundary of Canberra in the Australian Capital Territory, Australia. The reserves (Mulligans

Flat and Goorooyarroo) are within the coordinates 35^{o} 9-13' S; 149^{o} 9-12' E. They total 1,3623 ha and are joined along a boundary of 300-400 m. The experimental sites are in grassland, woodland and forest associated with *Eucalyptus blakelyi* , *Eucalyptus melliodora* and *Eucalyptus macrorhyncha*. A full description of the study site, plant survey methods and the ground layer vegetation is given in McIntyre *et al.* (2010). The experimental treatments and design are described in detail in Manning *et al.* (2011) and Shorthouse *et al.* (2012) and summarized below.

Experimental treatments

Each reserve has 48 experimental sites, 1 ha in size (200 x 50 metres). The two reserves were treated as separate experiments, with all the Mulligans Flat sites being within a fence designed for exotic predator exclusion for the future re-introduction of fauna. The treatments that had been in operation for the four years between vegetation sampling were:

1) Woody debris (fallen timber) augmentation (none; 20 tonnes.ha^{-1} (dispersed); 20 tonnes.ha^{-1} (clumped); 40 tonnes.ha^{-1} (both clumped and dispersed)). Logs were introduced to supplement the fallen timber that had been previously depleted by tree and firewood removal.

2) Reduction in kangaroo density, achieved through fencing and periodic herding out of animals that had breached the fenced exclusion areas. Fences were either wire netting stock fences with three additional wires to a height of 2.1 m or newly-constructed 1.8 m high predator-proof fencing.

3) Burning, which was applied to 24 sites in Goorooyaroo only. While a burning regime is planned, the first burn was in May 2011, five months before the second vegetation survey. Overall, fire intensity was low due to wet conditions. The intensity of the majority of plots was between 10 and 40 kW/m. Three of the woodland plots had very damp fuel which was too wet to burn. The highest intensity recorded was 89.5 kW/m. Vegetation was not burned beyond the 1ha experimental sites.

Experimental design

The key stratifying units of this experiment were 'polygons' which were homogenous areas of vegetation structure, that had been previously surveyed and mapped by ACT government staff for management purposes. From this survey, four of vegetation structures were identified as combinations of high and low tree (LT, HT) and shrub structure (LS, HS). Shrubs included some *Acacia* spp. that formed small trees. In each reserve 12 'polygons' were selected randomly from a larger set of candidates, with four 1 hectare 'sites' per polygon (2 reserves x 12 polygons x 4 sites = 96 sites). Fixed effects were factorial combinations of the treatments which occurred at either the polygon level or the site level, summarized in Table 2.

Plant survey

We surveyed the ground layer vegetation in both reserves using the same methods applied in 2007 (reported in McIntyre *et al.* 2010) and again in 2011. We included all herbaceous species and woody plants < 0.5 m high (regardless of potential height). Vegetation in both surveys was sampled in late spring (12th Oct – 27th Nov. in 2007; 17th Oct. - 22nd Nov. in 2011). Thirty quadrats (0.5 x 0.5 m) were located systematically across each of the 96 sites (200 x 50m). We used point–based estimates of ground cover, one point in each of the four corners of the quadrats, giving a total of 120 points per site. At each point, we recorded the ground cover as: litter, litter depth, cryptogams, bare ground, rock, fallen log (>10 cm diameter, > 0.5 m long) or live plant basal area.

We used the BOTANAL method for estimating species abundance (t' Mannetje and Haydock 1963, Tothill *et al.* 1992) which requires the total biomass to be estimated, and species to be ranked by the relative amount of their biomass. Three observers were trained using a process of photographing, cutting and weighing a range of samples, with the photographs forming an ongoing reference during the field season. Consistent bias by individual observers was addressed by using calibration regressions of estimates following the approach of Tothill *et al.* (1992) on 24 quadrats in the fifth week of sampling. Values of R^2 ranged from 0.7 to 0.9. Total biomass was estimated for each quadrat, resulting in 30 estimates per site, 2880 estimates over all 96 sites.

To calculate species composition from the estimate of total biomass and species rankings in each quadrat, the proportional contribution (PR) was calculated using the following geometric series:

$$PR = (1-k)*kR^{-1}$$

where R is the rank order, and k is a parameter. We used a k=0.3 (best match for empirical results, Scott 1986), which give % contributions of: Rank 1 = 70%, Rank 2 = 21%, Rank 3 = 6.3%, Rank 4 = 1.9%, Rank 5 = 0.6%, Rank 6 = 0.2%. Ties were used if two species had similar biomass, in which case, the next rank was not filled. For ties, the two or three relevant tied ranks were added together and divided evenly. In this way abundance could be reported for each species in $kg.ha^{-1}$. The top six species, ranked by biomass were recorded in each quadrat. This geometric series therefore indicates that species with <0.2% of the biomass in a quadrat were not recorded in the survey.

Species counts were the total number of species recorded at each 1 ha site i.e. those ranked 1-6 in all 30 quadrats. Note that species ranked seven or lower in a quadrat would not have been recorded as present in that quadrat, so the species counts are relative, not absolute. We acknowledge that this will exclude some rare species from the data set.

Estimated biomass was analysed grouping species into native and exotic components, and into seven life-forms (annual forb, annual graminoid, fern, perennial forb, geophyte, perennial graminoid, shrub), by adding the component species biomass values. Treatment effects were analysed only for the more abundant life-forms: exotic annual forbs and graminoids and native perennial forbs and graminoids. Nomenclature followed the Australian Plant Census (http://www.cpbr.gov.au/chah/apc/about-APC.html).

Statistical analyses

Our data had a multi-level structure involving variation between polygons, between sites within polygons, and between times within sites. As positive or negative change in response to the addition of CWD (and vegetation class) was of central interest in this study, we included analyses of change (from 2007 to 2011) in the response variables as well as treatment effects in 2011. We used cross-sectional linear mixed models, with random effects for polygon and site, to quantify and assess the effects of treatments, vegetation class and kangaroo grazing on the difference in species richness between 2007 and 2011; thus inferences pertain to a four year period, only (see Galway 2006). Fixed effects were estimated by least squares and random effects by restricted maximum likelihood. Statistical significance of fixed effects was assessed by Wald statistics with an appropriate adjustment for degrees of freedom (Kenward and Roger 1997). The data from Mulligans Flat and Goorooyarroo were analysed separately due to differences in management history, vegetation, timing of treatments and co-variate availability (Manning *et al.* 2007; McIntyre *et al.* 2010; Manning *et al.* 2011).

Results

1) Seasonal conditions and overall changes between 2007 and 2011

Rainfall patterns around the time of sampling were similar in both sampling periods (Table 3) with an initial dry start in September-October and a wet November. The growing season was very dry in the spring-summer preceding the 2007 sampling and extremely wet in the spring-summer preceding the 2011 sampling. These differences are evident in the biomass averages (Table 4). Total biomass increased overall by 67% over the four years. This increase was primarily in perennial, native species. Exotics increased by 15%, but their representation declined from 12 to 8% of the total (Fig. 1). Annuals increased by 67% but represented a steady 7% of total biomass (Table 4). Like biomass, litter depth increased dramatically overall (from 12 to 19 mm depth where litter present). However, overall changes in litter % cover, basal area and bare ground were slight (Table 5).

The life-form profile differed between native and exotic biomass components (Table 6). In both cases, perennial graminoids dominated, followed by perennial forbs. However, there were no exotic ferns or geophytes, instead, forbs were strongly represented in the exotic biomass. Forbs formed a very small component of the native biomass, but shrubs were more abundant and perennial graminoids were extremely dominant. There was a more even biomass distribution across the exotic life-forms. Most species diversity is associated with the perennial life-forms in natives and annual life-forms in exotics.

The greatest biomass increases between the two surveys were of native perennial graminoids and forbs (increases of 277 and 54 $kg.ha^{-1}$ respectively) and native annual graminoids (41 $kg.ha^{-1}$). There were only two species of annual native graminoids recorded and these both increased in biomass: *Schoenus apogon* (from 0.1 to 41 $kg.ha^{-1}$) and *Lachnagrostis filiformis* (from 0 to 0.4 $kg.ha^{-1}$) both are species of wet areas and were responding to the higher rainfall conditions. Exotic increases were smaller, with the greatest contribution from perennial graminoids and forbs (both increased by 10 $kg.ha^{-1}$). The other three life-forms declined or stayed the same (Table 6). Details of species composition and biomass changes are given in Appendix 1.

Comparing the species lists for each of the 2007 and 2011 surveys, changes in composition was most apparent amongst exotic annuals (11species lost, 10 gained) no evidence of change in native perennial grasses (no species lost or gained), and most gain in other native perennial life-forms (3 lost, 14 gained).

2) Effects of reduced kangaroo densities

At Mulligans Flat the higher kangaroo densities more than halved the total biomass relative to the reduced grazing treatment after 4 years (1382 *cf*. 615 $kg.ha^{-1}$) ($p<0.01$). These effects were also evident in the native, but not in the exotic component. At Goorooyarroo the high kangaroo density treatment did not reduce total, perennial, annual or native biomass. It did result in a significant difference in annual biomass with lower annual biomass under low kangaroo densities (Table 7), but the change in exotic biomass between 2007 and 2011 was not significantly different between high and low density. There were no effects of kangaroo density on species counts, live plant basal area, litter depth or bare ground in either reserve.

3) The effects of the addition of coarse woody debris

The treatment with the highest amount of woody debris (40 tonnes.ha^{-1}, both clumped and dispersed) was associated with a total biomass of 1200 kg.ha^{-1}, significantly higher than the other log treatments ($p<0.05$) but only at Mulligans Flat. More specifically the presence of logs was associated with significant increases in biomass of exotic annual forbs ($p < 0.05$). In contrast, exotic annual graminoid biomass increased the most where kangaroo density was high and where there were no logs ($p<0.05$).

At Mulligans Flat, the overall decline of exotic species counts was 3 spp. (Table 8), but decline was significantly less at the highest log density (one species) ($p<0.05$) compared with the other three log treatments (none, dispersed, clumped). A significant response was also found for total species ($p<0.05$). While the overall average total species counts at Mulligans Flat barely changed between 2007 and 2011 (Table 8) in the highest log density, total species increased by 4.7 spp. These results suggest that at Mulligans Flat logs seemed to afford some protection to both native and exotic species, while the logs treatment effects were not significant for the Goorooyarroo species counts analyses.

There were no effects of logs at Mulligans Flat on live plant basal area, bare ground or litter. Nor were there any effects of logs at Goorooyarroo on any variables, apart from an interaction with fire discussed below.

4) The effects of burning

In Goorooyarroo, where the fire treatment was applied (5-6 months previously), the greatest effect was on biomass. Burning reduced total biomass by 55% compared with unburnt sites; exotic, native, annual and perennial components were similarly reduced (Table 7). Fire also reduced (725 *cf*. 291 kg.ha^{-1}) native perennial graminoids and exotic annual graminoids ($p<0.001$) relative to unburnt sites. At sites that had been burnt, litter cover and depth were reduced and bare ground % was higher (data not shown).

There was an interaction between fire and vegetation structure in relation to bare ground. In 2011, there was little difference between unburnt and burnt sites where trees and shrubs were high (14 *cf*. 16%). However the fire treatment (applied 5-6 months prior to sampling), significantly increased bare ground where trees were dense and shrubs were sparse (0 to 24%) and in open areas (8 to 32%) ($p<0.001$). These patterns were also evident in the changes in bare ground between 2007 and 2011. These effects may have been due to differences in litter type (grass *vs.* tree leaves) and flammability at the time of burning, and the rate of accumulation of litter after burning. Where shrubs were dense, bare ground was already highest (14%) and increased little (to 16%).

While an average of five native species were gained in Goorooyarroo between 2007 and 2011, there were no effects of fire on the changes in species counts. There was an interaction of fire with logs whereby some logs maintained species gains in the presence of fire, but reduced gains in the absence of fire, the net effect being that logs appeared to make no difference to diversity gains (Fig. 2).

The biomass responses to grazing and log addition that were observed at Mulligans Flat were not detected in the analysis of Goorooyarroo data. While it was possible that the similar responses to logs were obscured by the immediate and dramatic effects of fire on biomass, examination of the data suggested that, even in the absence of fire, there was little to indicate that low grazing, or the presence of logs promoted total biomass increases at Goorooyarroo (Table 9).

5) The effects of tree and shrub density

The presence of trees and shrubs did have some direct influence on the variables analysed. There was a greater increase in total species counts where tree (but not shrub) densities were high. This was observed in both Mulligans Flat ($p<0.05$) and Goorooyarroo ($p<0.05$). The results in relation to tree and shrub density need to be treated with caution, as there is evidence that vegetation structure is sometimes confounded with past land use and soil differences, which may be a more important influence than the presence of trees. For example, in Goorooyarroo the 'High tree, low shrub' (HTLS) sites were mostly *Phalaris*-dominated with elevated nutrient levels, which have more exotics than low fertility sites (see McIntyre *et al.* 2010). This interpretation is supported by the observation that exotic annual forbs persisted in significantly greater amounts at the Gorooyarroo the 'High tree, low shrub' sites, than at the other sites.

Discussion

Biomass accumulation and the effects of reduced kangaroo densities

The experimental observation period was characterized by three growing seasons with higher than average rainfall which resulted in a 67% overall increase in biomass between 2007 and 2011 (Tables 3 & 4). The growth response was primarily that of native perennial grasses, while litter depth also increased. Both these changes are associated with an increase in the supply of organic matter to soils, increased microbial activity (Northup *et al.* 1999), nutrient recycling (Lindsay & Cunningham 2009) and are indicative of a trajectory of improving soil condition (Northup *et al.* 2005) with potentially bottom-up cascading effects on other trophic levels (Mooney *et al.* 2010).

The greatest accumulation of biomass was at Mulligans Flat, where experimentally reduced kangaroo densities enabled a total biomass increase of over 1300 $kg.ha^{-1}$, a doubling of the 2007 average in the reserve four years previously. Perennial native grasses accounted for most of the accumulated biomass (Table 4, Fig. 1, Appendix 1). The effects of reducing kangaroo densities were less evident in Goorooyarroo, where the only detected effect was to reduce biomass of annual plants (Table 7). Greater difficulties were encountered in reducing kangaroo densities in Goorooyarroo than Mulligans Flat, and we attribute the differences in results between the two reserves, to differences in the effectiveness of the treatments.

While the prevailing scientific view is that very high kangaroo grazing pressures can have adverse impacts on grassland condition (Neave and Tanton 1989; Cooper 2009; McIntyre *et al.* 2010), reducing kangaroo grazing pressure will prove difficult in these reserves, where natural predators are absent (Viggers and Hearn 2005). Nonetheless, we did observe an increase in the proportional representation of the functionally important large, grazing-sensitive tussock species (McIntyre and Lavorel 2001) with reduced grazing (*Themeda triandra*, *Aristida ramosa* and *Poa sieberiana*) suggesting improved grassland condition (Appendix 1). Given the low biomass starting point in 2007

(McIntyre *et al.* 2010), and the increases in abundance and richness of beetles (Barton *et al.* 2011) and reptiles (Manning *et al.* 2012) to reduced grazing, it is evident that a step improvement in ecosystem condition has occurred in the four-year period. This supports the hypothesis proposed by Manning *et al.* (2013), that experimental treatments can be used to positive ecosystem effect over relatively short time frames. While some ground-dwelling fauna are highly responsive to the state of the herbaceous ground layer (McIntyre 2005; Dorrough *et al.* 2012) it may take longer for responses to become evident among fauna that require compositional change, or particular changes to woody habitat structure.

Species changes and the role of coarse woody debris

Over the four years, there were small increases in counts of native species and small reductions in exotic species counts, suggesting improvement from a plant conservation perspective. This was not anticipated, in fact the productive seasonal conditions might have indicated the opposite result, owing to the more conservative growth strategies associated with native plants (Leishman *et al.* 2007). It is possible that continuing reductions of available phosphorus over the four years may have contributed to a decline in exotic species (McIntyre 2008). Of the new species that were recorded in 2011 most were exotic annuals and native perennial forbs and most of the 'lost' species were exotic annuals. While greater changes in annual species presence might be expected owing to their short life-span and dependence on seed banks, the high level of inertia in the dynamics of perennial native plants in consistent with observations elsewhere (Morgan 2001). The appearance, but not loss, of native forbs is likely to be mainly an increase in their apparency rather than recolonization. Most native perennial forbs are hemicryptophytes which retreat to buried perennial buds during unfavourable periods (McIntyre 1995; McIntyre *et al.* 1995).

The lowered kangaroo densities over four years at Mulligans Flat reduced grazing pressure, (as evidenced by biomass increase) but had no detectable effect on plant diversity, as reflected in the species counts. The long history of commercial livestock densities that preceded the experiment is likely to have selected for a plant community robust to grazing, and to have eliminated some grazing-sensitive species. A positive diversity response to reduced grazing would be less likely with the loss of these species.

The addition of significant amounts of timber could be expected to have a number of positive effects on vegetation amount and condition due to the provision of nutrients and organic material through 1) decomposition; 2) the interception of overland water flows leading to the accumulation of moisture, litter and seeds; and 3) the provision of fertile, protected microsites for plant growth (Tongway *et al.* 1989). Our analysis detected some vegetation differences associated with the presence of added timber, but only in Mulligans Flat, where there was a greater increase in the biomass of exotic annual forbs where woody debris was added, and where total biomass was greater at sites having the most timber (40 tonne.ha^{-1}).

These findings were consistent with those of Goldin and Hutchinson (2013) who documented higher levels of nutrients (including nitrates) and soil moisture levels adjacent to logs at Mulligans Flat. Significantly higher levels of total biomass and biomass of exotic forbs were also measured immediately adjacent to logs when compared to 0.8 m away (Goldin and Brookhouse 2014). Exotic forbs have been shown to be associated with increased soil nitrates in this vegetation (McIntyre *et* *al.* 2010). There was no evidence of coarse woody debris affording favourable microsites for native perennial plants in the Goldin and Brookhouse (2014) study. However, this could be expected given the observations were conducted in areas dominated by exotic species and grazing-tolerant native species. In settings where grazing-sensitive native species are present, the protective influence of logs could still potentially be detected.

The strategic placement of coarse woody debris in areas most affected by sheet erosion could serve to maximize future improvement of soil recovery and minimize advantages to exotic species over potential native colonizers. Assisted colonization of grazing-sensitive native species, by introducing seeds adjacent to logs, could also be considered as a means of overcoming local seed limitations and increasing diversity.

Effects of burning

While the more permanent effects of fire on vegetation are best assessed after a sustained regime of burning (McIvor *et al.* 2005), the dramatic effect of fire on biomass was evident five months after the first experimental burn. Burnt sites differed from heavily grazed treatments in that burning reduced litter cover and depth, but was similar in having no effects on species counts. Effects varied with tree and shrub densities which may have been due to differences in litter type (grass *vs* tree) and flammability at the time of burning. To some extent, fire and grazing are interchangeable disturbances; both are agents of biomass reduction. However, they differ in that fire is non-selective and will prevent unpalatable species dominating, and while fire can result in the short-term release of nutrients, frequent fire can lead to depletion of soil nutrients and carbon to the atmosphere and promote soil crusting (Knicker 2007) which may not be desirable for eroded areas that are already depleted of these elements. In contrast, grazing is more likely to result in organic matter incorporation into the soil. The effects of this disturbances on the balance of native and exotic species is a question of importance in plant conservation.

Managing disturbances in a spatially variable environment

In the future, the restoration management of the reserves must balance biomass accumulation with the promotion of species diversity. Higher levels of biomass contribute to soil health and provide habitat for fauna (McIntyre 2005; McIntyre and Tongway 2005) and prolonged accumulation of thick grass litter may be necessary to achieve more optimal soil health where soils have been damaged. However, the dominant native graminoids represented only 22% of the native plant taxa, while the native forbs, which comprised 52% of the total taxa recorded, may be adversely affected by thick litter accumulation in the longer term (Morgan 1998).

However, other features of the ground layer (where unburnt) were little changed, regardless of grazing pressure e.g. proportion of bare ground, litter, cryptogams or plant basal area, suggesting that in some areas the accumulated biomass has yet to be incorporated into the soil layers and bare ground has yet to be replaced with litter cover or basal area. After four years, the effects of sheet erosion are still evident in parts of both reserves (e. g. see Fig. 3) and as are bare eroded areas between tussocks. The soils types occurring in the reserves (Burra, Campbell, Franklin and Williamsdale) generally have hardsetting subsoils that are compact when dry with poor water infiltration (Jenkins 2000). These eroded areas are not a favourable environment for seed germination and plant establishment. The slow recovery of scalded areas is evident from the proportion of quadrats with low biomass, which declined only slightly from 19% to 16% of quadrats between 2007 and 2011 (Fig. 3).

In managing grazing and fire in the reserves, it will be important to take this heterogeneity into account, and target biomass reduction to areas that are most productive and prone to dense litter accumulation. These areas tend to be avoided by herbivores (Tothill 1971) but can be burnt. Limited patch burning will present a potential interaction with grazing, as grazing pressure tends to be concentrated on small recently burnt areas (Meers and Adams 2003). Thus management of grazing pressure in conjunction with the use of fire at appropriately broad scales has the potential to enhance plant diversity in the reserves. As discussed above, a complementary strategy for accelerated restoration of eroded areas, is the placement of coarse woody debris on bare eroded areas, particularly on slopes where capture of water, organic matter and nutrients would be most beneficial.

Summary

We have shown that, over a period of four years, restoration treatments can initiate trajectories of improvement in terms of biomass response to reduced grazing and to the addition of coarse woody debris, thus setting the system for improvements in soil condition in areas affected by past overgrazing. Increases in native plant dominance and diversity can be seen to be mainly driven by the removal of livestock grazing and good growing conditions across both reserves, although there is some evidence of diversity increases in the presence of coarse woody debris. Overall the effects of a single burn were not considered to be of significance to plant diversity at this stage. Combining grazing pressure management and the use of fire, and taking into account variations in vegetation and soil condition will make future improvements in vegetation condition and diversity possible. Similarly, strategic placement of coarse woody debris in areas of persistent erosion is recommended.

Accessory publication

Appendix 1 is available as an accessory publications on the Journal's website.

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Table 1. **Restoration actions applied to two reserves (Mulligans Flat and Goorooyarroo) in south-eastern Australia and their anticipated effects on the ecosystems.**
a) actions applied as part of the experiment; and b) management applied across both reserves as part of established conservation practice.

a) Controlled experimental manipulations	**Rationale for implementation**
Kangaroo density maintained at a lower level than the wider landscape through semi-permeable exclosure.	To enable recovery from past livestock impacts. Increase in total biomass including grazing-sensitive species, improved soil condition, improved habitat quality for fauna.
Addition of coarse woody debris – eucalypt logs salvaged from urban areas, branches removed.	Past firewood removal had depleted this resource. Concentration of resources for plants and fauna through decomposition of wood, interception of water and nutrients. Provide sites protected from grazing and predators.
Controlled burning (one burn implemented 5 months prior to vegetation sampling)	To enhance plant diversity by reducing competitive effects of perennial grass.
b) Management actions applied to both reserves (no controls)	
Absence of livestock	Increase in total biomass including grazing-sensitive species, improved soil condition, improved habitat quality for fauna. Wild herbivores will still contribute to total grazing pressure.
Cessation of fertiliser applications	To reduce impacts of weeds and enable re-colonization of native plants.
Control of rabbits and hares (systematic) and kangaroos (episodic)	To reduce total grazing pressure.
Suppression of wildfire	To avoid complete burning of reserves and protect people and infrastructure.
Cessation of firewood removal	To restore nutrient recycling and other soil processes (see also 'addition of coarse woody debris').
Removal of proclaimed weeds (*Nasella tricotoma*, *Hypericum perforatum*, *Rosa rubiginosa*)	To avoid competition with native species. There is a legislative requirement to control certain species proclaimed noxious.

Table 2. Design of experiments in each of two nature reserves in the Australian Capital Territory summarizing experimental treatments associated with each. The 'vegetation structure' treatment was created through the identification of polygons of uniform structure in each reserve. The treatment levels represent the range of pre-existing structures in regard to tree (T) and shrub (S) density (H = high, L = low) combinations.

Experimental unit	Number of units	Treatment	No. of levels	Levels
Mulligans Flat Nature Reserve				
Polygon	12	Vegetation structure	4	HTHS, LTHS, LTLS, HTLS
		Macropod density	2	Uncontrolled, Reduced densities
Site	48 (4 per polygon)	Coarse woody debris	4	Dispersed, Clumped, Clumped + dispersed
Goorooyarroo Nature Reserve				
Polygon	12	Vegetation structure	3	HTHS, LTLS, HTLS
		Macropod density	2	Uncontrolled, Reduced densities
Site	48 (4 per polygon)	Coarse woody debris	4	Dispersed, Clumped, Clumped + dispersed
		Fire	2	Burnt, Unburnt

Table 3. **Monthly rainfall (in mm) totals for the survey years 2007 and 2011.** Sampling was conducted in October and November of each year (indicated in bold). Monthly totals exceeding the monthly average are underlined. Data from Bureau of Meterology (http://www.bom.gov.au/) 'Ainslie Tyson St' weather station no. 070000.

	2007	2011	Average
Jan	9	62	58
Feb	72	131	57
Mar	49	41	53
Apr	30	11	46
May	48	15	46
June	85	14	45
July	24	36	55
Aug	12	57	51
Sept	15	35	55
Oct	**25**	**26**	**65**
Nov	**111**	**121**	**66**
Dec	134	93	53
Total	613	643	643

Table 4. Biomass of annual and perennial ground layer vegetation components at Mulligans Flat (MF) and Goorooyarroo (GO) Nature Reserves.
Estimates are of above-ground biomass of all herbaceous species, and woody plants < 0.5 m high (regardless of potential height). Data are from a total of 96 x 1 ha sites with n = 48 for each reserve, assessed in 2007 and 2011. Annuals as a percentage of total biomass is given in brackets.

Biomass	MF	MF	GO	GO	All sites	All sites
(kg.ha^{-1})	2007	2011	2007	2011	2007	2011
Perennial	566	1020	482	747	524	884
Annual	21 (4%)	72 (7%)	60 (11%)	63 (8%)	41 (7%)	68 (7%)
Total	592	1095	546	811	569	953

Table 5. Percentages of different ground cover attributes at Mulligans Flat (MF) and Goorooyarroo (GO) Nature Reserves.

Data are from a total of 96 x 1 ha sites with n = 48 for each reserve. Note half the sites in Goorooyarroo were burnt 5-6 months prior to these measurements being taken, which influenced overall cover of bare ground and litter.

	MF	MF	GO	GO	All sites	All sites
% Cover	2007	2011	2007	2011	2007	2011
Litter	61.6	62.3	70.3	62.8	66.0	62.6
Bare ground	16.3	14.1	10.4	16.4	13.3	15.2
Plant basal area	12.7	12.5	12.2	14.0	12.5	13.3
Cryptogam	7.8	10.2	4.1	4.2	6.0	7.2
Fallen log	1.2	0.6	1.6	0.9	1.4	0.7
Rock	0.3	0.3	1.4	1.7	0.8	1.0
Total	100	100	100	100	100	100

Table 6. Representation of different life-forms in the ground layer vegetation in 2007 and 2011. Estimates are of above-ground biomass of all herbaceous species, and woody plants < 0.5 m high (regardless of potential height). Data are from a total of 96 x 1 ha sites averaged over both reserves.

Native biomass (kg.ha^{-1})	2007	2011	% of total in 2011
Annual forb	1.6	1.5	0.2%
Annual graminoid	0.1	42	5%
Fern	0.4	2.2	0.3%
Perennial forb	22	76	9%
Geophyte	3.1	1.9	0.2%
Perennial graminoid	446	723	83%
Shrub	23	29	3%
Total native	496	875	100%
Exotic biomass (kg.ha^{-1})	2007	2011	
Annual forb	23	11	15%
Annual graminoid	16	14	18%
Perennial forb	4.0	14	19%
Perennial graminoid	26	36	48%
Shrub	0.2	0.2	0.2%
Total exotic	69	75	100%

Table 7. Predicted means (adjusted for main effects) of average total, annual perennial and exotic biomass (kg.ha^{-1}) in Goorooyarroo under fire and kangaroo density treatments in 2011. Significance levels are for comparisons of pairs of means across high and low kangaroo density and burnt and unburnt treatments.

Kangaroo density	High	Low	Observed significance level
Total	690	608	n.s.
Perennial	621	566	n.s.
Annual	55	31	p<0.05
Native	576	547	n.s.
Exotic	28	22	n.s.
Fire May 2011	**Not burnt**	**Burnt**	**Observed significance level**
Total	966	435	p<0.01
Perennial	899	391	p<0.001
Annual	54	32	p<0.05
Native	856	368	p<0.001
Exotic	31	20	n.s.

Table 8. Average number of native and exotic species recorded at 1 ha sites in the two reserves in 2007 and 2011.

Species counts are pooled from 30 x 0.25m^2 quadrats in which the top six ranked species were recorded. Percentages refer to proportion of all species that are exotic.

	MF 2007	MF 2011	GO 2007	GO 2011	All sites 2007	All sites 2011
Native	25.3	28.7	22.9	28.1	24.1	28.4
Exotic	11.3 (30%)	8.2 (22%)	12.3 (35%)	10.8 (28%)	11.8 (33%)	9.5 (25%)
All species	36.6	36.9	35.2	38.9	35.9	37.9

Table 9. Average total biomass (kg.ha^{-1}) in 2011 at 48 sites at Goorooyarroo in of grazing, log and fire treatments.

Means are adjusted for main effects and one-way interactions. There were no significant differences between the means.

Fire	Kangaroo density	No logs	Dispersed	Clumped	Clumped and dispersed
Burnt	High	567	569	404	467
Burnt	Low	541	284	500	281
Unburnt	High	1125	897	898	1053
Unburnt	Low	1059	807	1282	820

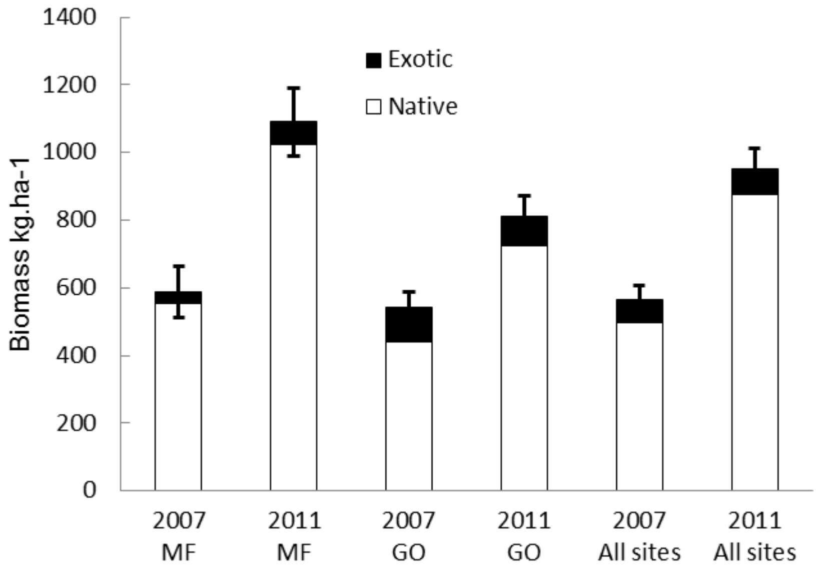

Fig. 1. Biomass of native and exotic ground layer vegetation components at Mulligans Flat (MF)(n= 48) and Goorooyarroo (GO) Nature Reserves. Estimates are of above-ground biomass of all herbaceous species, and woody plants < 0.5 m high (regardless of potential height). Data are from a total of 96 x 1 ha sites with n = 48 for each reserve, assessed in 2007 and 2011. Biomass was assessed from 30 x 0.25m^2 quadrats at each site. Bars are standard errors of total biomass.

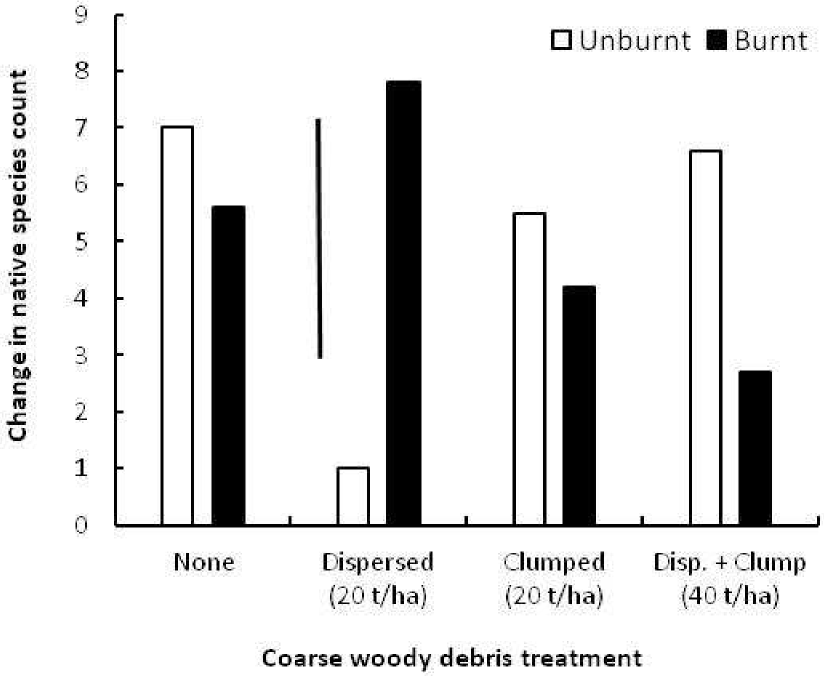

Fig. 2. Differences in native species count between 2007 and 2011 at Goorooyarroo, showing interaction between coarse woody debris treatments and fire. Bar represents LSD at ($p<0.05$).

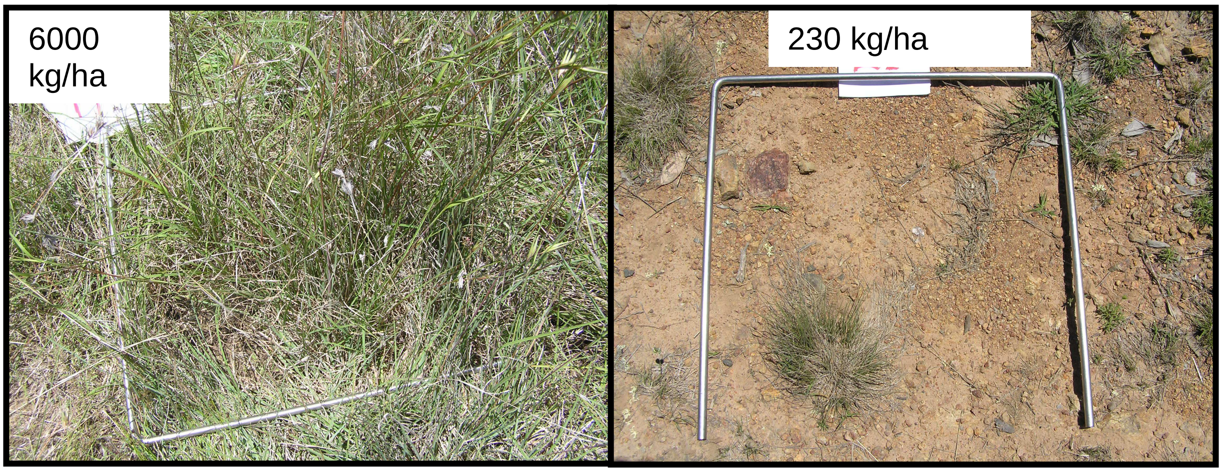

Fig. 3. Management of biomass in the reserves will be necessary to maintain diversity of herbaceous plants and improve soil function. Biomass control would be desirable for some of the areas of highest productivity (left) while eroded areas (right) indicate a need for biomass accumulation. In the 2007 survey 19% of quadrats were estimated to have ≤230 $kgha^{-1}$ biomass while in 2011 the proportion was 16% of (estimates from unburnt sites only, n = 2250 quadrats).

Accessory Publication

Appendix 1. Average biomass (kg.ha^{-1}) of species within different life forms from Mulligans Flat (MF) and Goorooyarroo Nature Reserves (GO) in 2007 and 2011.

Species are listed in order of descending total biomass within their groups. Names follow the Australian Plant Census (http://www.cpbr.gov.au/chah/apc/about-APC.html).

	2007 MF	2011 MF	2007 GO	2011 GO	2007 All sites	2011 All sites	All sites both dates
Native annual forbs (all species)							
Triptilodiscus pygmaeus	1.7	0.3	0.2	04	1.0	0.2	0.6
Isoetopsis graminifolia	00	1.5	0	0	000	0.8	0.4
Crassula sieberiana	03	0.1	0.4	0.1	0.2	0.1	0.2
Daucus glochidiatus	0.2	003	0.2	0.1	0.2	0	0.1
Erodium crinitum	00	00	03	0.3	01	0.2	0.1
Euchiton sphaericus	01	04	01	0.2	01	0.1	0.1
Ranunculus sessiliflorus	0.3	00	00	0	0.1	0	0.1
Centipeda sp.	0	01	00	0.1	00	0.1	03
Lythrum hyssopifolia	03	00	01	05	02	02	02
Cotula australis	00	01	02	00	01	01	01
Stuartina muelleri	00	00	01	02	01	01	01
Poranthera microphylla	00	02	00	01	00	01	01
Sebaea ovata	0	0	0	001	0	001	0
Native annual graminoid (all species)							
Schoenus apogon	0.1	50.3	0.2	32.2	0.1	41.2	20.7
Lachnagrostis filiformis	0	0	0	0.7	0	0.4	0.2
Native fern (all species)							
Cheilanthes spp.	0.2	1.1	0	3.2	0.1	2.2	1.1
Cheilanthes austrotenuifolia	0.1	0	0.5	0	0.3	0	0.1
Ophioglossum lusitanicum	0	0.1	0	0	0	0.1	0
Native perennial forb (species with overall biomass >0.3 kg.ha^{-1})							
Haloragis heterophylla	1.2	19.7	0.2	15.2	0.7	17.5	9.1
Gonocarpus tetragynus	3.6	19.4	1.1	9.8	2.4	14.6	8.5
Vittadinia muelleri	3.3	14.4	1.0	4.1	2.1	9.2	5.7
Hydrocotyle laxiflora	2.9	4.4	0.9	2.4	1.9	3.4	2.7
Acaena ovina	2.4	1.2	1.9	4.7	2.1	2.9	2.5
Leptorhynchos squamatus	1.7	1.7	2.5	3.4	2.1	2.6	2.3
Hypericum gramineum	1.0	6.7	0.1	1.2	0.6	4.0	2.3
Einadia nutans	0.8	0.7	2.2	4.3	1.5	2.5	2.0
Euchiton japonicus	0	6.7	0	1.1	0	3.9	2.0
Solenogyne dominii	2.6	1.8	1.0	0.3	1.8	1.0	1.4
Wahlenbergia sp.	0.4	1.3	0.6	2.2	0.5	1.7	1.1
Goodenia hederacea	1.5	1.5	0.2	0.6	0.9	1.0	1.0
Oxalis perennans	0.4	0.3	0.5	2.0	0.4	1.1	0.8
Desmodium varians	0.2	0.1	0.8	1.9	0.5	1.0	0.7
Vittadinia gracilis	0.1	2.2	0	0.3	0	1.3	0.6
Asperula conferta	0.7	0.8	0.1	0.9	0.4	0.9	0.6
Glycine tabacina	0.1	0.1	0.2	2.0	0.2	1.0	0.6

Plantago varia	0	0	1.2	1.1	0.6	0.6	0.6
Myriophyllum sp.	0	1.9	0	0	0	0.9	0.5
Chrysocephalum apiculatum	0.6	0.2	0.6	0.3	0.6	0.2	0.4
Geranium solanderi	0.5	0.8	0.1	0	0.3	0.4	0.4
Hydrocotyle peduncularis	0	1.3	0	0	0	0.7	0.3
Convolvulus erubescens	0	0	0.6	0.6	0.3	0.3	0.3
Native geophyte (all species)							
Tricoryne elatior	2.3	0.2	2.5	2.1	2.4	1.2	1.8
Dichopogon fimbriatus	0.1	0	0.2	0.3	0.1	0.2	0.2
Arthropodium spp.	0	0.5	0.1	0	0	0.2	0.1
Arthropodium minus	0.2	0.3	0	0	0.1	0.2	0.1
Bulbine bulbosa	0.3	0.1	0	0	0.2	0	0.1
Wurmbea dioica	0.2	0	0.1	0	0.2	0	0.1
Diuris sulphurea	0.2	0	0	0	0.1	0	0.1
Drosera peltata	0	0.2	0	0	0	0.1	0.1
Thysanotus patersonii	0	0.1	0	0	0	0	0
Orchidaceae	0	0	0	0	0	0	0
Thelymitra spp.	0	0	0	0	0	0	0
Native perennial graminoid (all species)							
Rytidosperma spp.	97.3	213.1	124.8	180.7	111.1	196.9	154.0
Joycea pallida	240.5	182.6	45.3	19.2	142.9	100.9	121.9
Themeda triandra	62.6	251.3	38.5	87.4	50.6	169.4	110
Aristida ramosa	28.5	58.0	41.7	28.7	35.1	43.3	39.2
Bothriochloa macra	7.1	35.5	27.7	76.1	17.4	55.8	36.6
Austrostipa densiflora	0.2	2.6	34.1	56.5	17.2	29.5	23.4
Lomandra filiformis	18.1	19.4	21.7	20.5	19.9	20	19.9
Austrostipa scabra	5.1	12.9	23.8	35.6	14.4	24.2	19.3
Microlaena stipoides	6.5	21.9	7.5	13.3	7.0	17.6	12.3
Poa sieberiana	4.7	11.2	4.2	23.4	4.4	17.3	10.9
Austrostipa bigeniculata	0.1	0.3	13.4	29.2	6.7	14.8	10.8
Elymus scaber	4.9	2.8	15.7	5.7	10.3	4.2	7.3
Panicum effusum	2.4	10	2.7	13.7	2.5	11.8	7.2
Eragrostis brownii	0.1	5.4	0	6.7	0.1	6.1	3.1
Juncus subgenus *Genuini*	4.0	3.1	1.9	3.2	2.9	3.1	3.0
Chloris truncata	1.2	2.9	1.2	1.2	1.2	2.1	1.6
Lomandra multiflora	1.3	3.8	0	1.4	0.6	2.6	1.6
Carex inversa	0	2.2	0.5	0.7	0.2	1.4	0.8
Enneapogon nigricans	1.8	0	0.4	0.2	1.1	0.1	0.6
Eleocharis acuta	0	0.4	0.1	1.8	0	1.1	0.6
Dichelachne spp.	0	1.6	0	0.1	0	0.9	0.4
Carex spp.	0.3	0.1	0.3	0	0.3	0.1	0.2
Luzula spp.	0	0.3	0.1	0.1	0.1	0.2	0.1
Carex breviculmis	0	0	0	0.2	0	0.1	0.1
Dichelachne rara	0	0	0	0.1	0	0	0
Cynodon dactylon	0	0	0	0	0	0	0
Native shrub (all species)							
Melichrus urceolatus	13.7	16.0	4.7	5.6	9.2	10.8	10
Lissanthe strigosa	10.1	6.6	3.7	4.3	6.9	5.5	6.2
Dillwynia sericea	1.0	5.4	1.0	5.6	1.0	5.5	3.3
Daviesia genistifolia	6.3	1.5	0	0.2	3.1	0.8	2.0
Acacia dealbata	0.3	2.6	0	0	0.1	1.3	0.7
Pultenaea procumbens	0.1	2.1	0	0	0.1	1.1	0.6
Acacia parramattensis	0	1.2	0.1	0.7	0.1	1.0	0.5
Brachyloma daphnoides	1.8	0.1	0	0	0.9	0	0.5

Hibbertia obtusifolia	0.1	0.6	0.8	0.3	0.4	0.5	0.5
Bossiaea buxifolia	0.3	0.6	0.2	0.4	0.2	0.5	0.4
Bossiaea prostrata	0.3	0.1	0	0.9	0.2	0.5	0.3
Hibbertia sp.	0	0	0	1.1	0	0.6	0.3
Daviesia leptophylla	0	0.8	0	0	0	0.4	0.2
Astroloma humifusum	0.1	0.3	0.3	0	0.2	0.2	0.2
Indigofera australis	0	0.5	0	0	0	0.2	0.1
Acacia gunni	0	0.2	0	0	0	0.1	0.1
Clematis microphylla	0	0.2	0	0	0	0.1	0
Hovea heterophylla	0.1	0	0	0	0.1	0	0
Pimelea linifolia	0	0	0	0	0	0	0
Exotic annual forb (species with overall biomass >0.3 kg.ha-1)							
Trifolium subterraneum	4.3	2.9	16.6	3.8	**10.5**	**3.3**	6.9
Hypochaeris glabra	2.2	0.5	2.0	3.2	2.1	1.8	2.0
Arctotheca calendula	0.6	0	6.3	0.4	3.5	0.2	1.8
Centaurium erythraea	0	5.1	0	0.5	0	2.8	1.4
Trifolium striatum	1.4	0	1.6	0.1	1.5	0.1	0.8
Trifolium glomeratum	1.0	0.1	1.6	0.1	1.3	0.1	0.7
Trifolium arvense	0.4	0.3	0.7	0.2	0.5	0.2	0.4
Conyza sp.	0	0.2	0	1.2	0	0.7	0.4
Tolpis barbata	0.7	0.3	0.1	0.2	0.4	0.3	0.3
Cirsium vulgare	0	1.0	0	0.1	0	0.5	0.3
Exotic annual graminoid (species with overall biomass >0.3 kg.ha-1)							
Lolium spp.	2.1	1.5	18.2	4.6	10.2	3.1	6.6
Bromus hordeaceus/molliformis	0.3	4.1	3.4	5.6	1.9	4.9	3.4
Vulpia spp.	1.1	1.1	1.0	4.2	1.1	2.6	1.8
Bromus diandrus	0.3	0.7	2.1	1.9	1.2	1.3	1.2
Aira spp.	0.9	0.2	0.6	0	0.8	0.1	0.5
Hordeum sp.	0	0	1.2	0.3	0.6	0.2	0.4
Briza maxima	0.3	0.9	0.1	0	0.2	0.5	0.3
Exotic perennial forb (species with overall biomass >0.3 kg.ha-1							
Hypochaeris radicata	2.3	4.1	2.5	9.3	2.4	6.7	4.6
Acetosella vulgaris	1.1	1.2	0.6	7.0	0.8	4.1	2.5
Plantago lanceolata	0	1.8	0	2.5	0	2.2	1.1
Chondrilla juncea	0	0	0.8	0.3	0.4	0.1	0.3
Exotic geophyte (all species)							
Romulea rosea	0	0	0	0	0	0	0
Exotic perennial graminoid (all species)							
Phalaris aquatica	11.2	35.2	36.5	28.8	23.8	32.0	27.9
Holcus lanatus	0	3.0	0	4.5	0	3.8	1.9
Poa bulbosa	0.7	0.1	2.8	0.3	1.8	0.2	1.0
Nassella trichotoma	0.2	0.1	0.2	0.6	0.2	0.4	0.3
Paspalum dilatatum	0	0	0	0.1	0	0	0
Exotic shrub (all species)							
Rosa rubiginosa	0.2	0.3	0.1	0	0.1	0.2	0.2
Hypericum perforatum	0	0	0.1	0	0	0	0