BIODIVERSITY RESEARCH GROUP

# Grazing and burning of the Wilderness Area in Guy Fawkes River National Park

## Impacts of past management and monitoring effects of management change.



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*Cover photos*: Fenced quadrat after the experimental burns, M. Henderson/NPWS (left); Experimental burns in progress near Bowen's Hut, M. Henderson/NPWS (middle); Round-leaved gum (*Eucalyptus brunnea*) and red gum (*E. amplifolia*) forest with herbaceous understorey, M. Henderson/NPWS (right).

## Contents

## Summary

1) Areas of warm temperate eucalypt forests of northern NSW escarpment, previously managed for timber and cattle production, were transferred into the NSW NPWS conservation reserve system in 1999. The forests were seasonally grazed by cattle and were burnt frequently to promote green pick for stock feed.

2) Conclusions:

   a) Historical grazing of domestic cattle and related burning practices has lead to a decline in species richness, plant density and a change in species composition.

   b) Simply removing the causes of this decline (ie reducing fire frequencies and removing stock) will not necessarily lead to a quick recovery of the understorey woody plants. There may be substantial time lags for the recovery of the understorey species relating to the persistence, dispersal and establishment of species at the disturbed sites.

3) Recommendations for future management of these areas are to:

   a) maintain a moratorium on stock grazing within the Wilderness Area, with resources being dedicated to the enforcement of stock removal and Wilderness Area entry gates being locked;

   b) to increase intervals between successive fires by minimising use of planned fires to those essential for the protection of assets and preventing unplanned fires from entering the Wilderness Area;

   c) To maintain the experiment and dedicate resources to continued annual monitoring for 10 years so that results contribute to State of the Parks and State of the Environment processes.

   d) NSW NPWS executive should endorse the recommendations.

   These recommendations may present some difficulty for the Area staff, as stray cattle and the presence of feral horses are controversial issues for the Guy Fawkes River NP and Guy Fawkes River Wilderness Area. In addition to the grazing issues, the occurrence of unplanned fires (ie arson and escaped fires from leasehold lands or private property) in the Park makes strategic fire planning a challenge. However, these difficulties must be overcome if the conservation values of the Wilderness Area and National Park are to be restored and maintained.

4) A complementary study into the germination and establishment of understorey shrub species may reveal some insights on how to perhaps augment some sites with some shrubby species and what conditions are favourable for the promotion of woody species germination.

## Context and background

The effects of multiple fires with short inter-fire intervals have not been studied in the forests of the north eastern tablelands. Anecdotal evidence from northern New South Wales suggests that there is a shift in the vegetation structure from complex to simple. Little detail exists on the types (ie, exactly which functional groups and what species) of plants that are affected by frequent disturbance. Often we see the imposition of fire (and other disturbance) regimes without a detailed understanding of the long-term effects of these regimes on vegetation. This report outlines a study that addressed these issues.

### Study Area

The study area is located on the eastern edge of the northern tablelands between Glen Innes (151°44′E, 29°44′S) and Grafton (152°56′E, 29°41′S) on two plateaux, Glen Nevis and London Bridge, in the Guy Fawkes River National Park (Fig. 1). The study area is dominated by late Carboniferous mudstones, and has an average annual rainfall between 950 mm and 1300 mm with a summer maximum. The vegetation of the plateaux is a mosaic of dry and semi mesic sclerophyll forest communities with an open grassy understorey, covering some 20–25% of the plateaux (Watson *et al.* 2000).

Watson *et al.* (2000) mapped the vegetation of the flats as a dry open forest community of *Eucalyptus dorrigoensis, Eucalyptus dalrympleana, Eucalyptus saligna* and *Eucalyptus brunnea*, whereas State Forests mapping (Forestry Commission of New South Wales 1989), shows the flats as forest type 161a (gum dominated by *Eucalyptus brunnea*). The flats may also be dominated by *Eucalyptus amplifolia* ssp. *sessiliflora*, and minor species include *Eucalyptus campanulata, Eucalyptus cameronii, Eucalyptus nobilis* and *Eucalyptus radiata* ssp. *sejuncta*. Grass species available for cattle forage include *Poa sieberiana, Entolasia marginata, Microlaena stipoides, Cymbopogon refractus, Imperata cylindica* and *Themeda triandra*. The most common herbaceous and woody understorey species are *Acacia implexa, Acacia irrorata, Allocasuarina littoralis, Exocarpos strictus, Hibbertia scandens, Leptospermum polygalifolium* ssp. *montanum, Leucopogon lanceolatus* var. *lanceolatus, Lomandra longifolia, Polyscias sambucifolia, Persoonia oleoides, Ozothamnus diosmifolius, Dichondra repens, Glycine clandestina, Pratia purpurascens, Haloragis heterophylla, Hydocotyle peduncularis* and *Goodenia bellidifolia* ssp. *bellidifolia* (M. K. Henderson & D. A. Keith, unpubl. data, 1999). It is unknown which of these species the cattle use as forage or whether they are incidental browse.

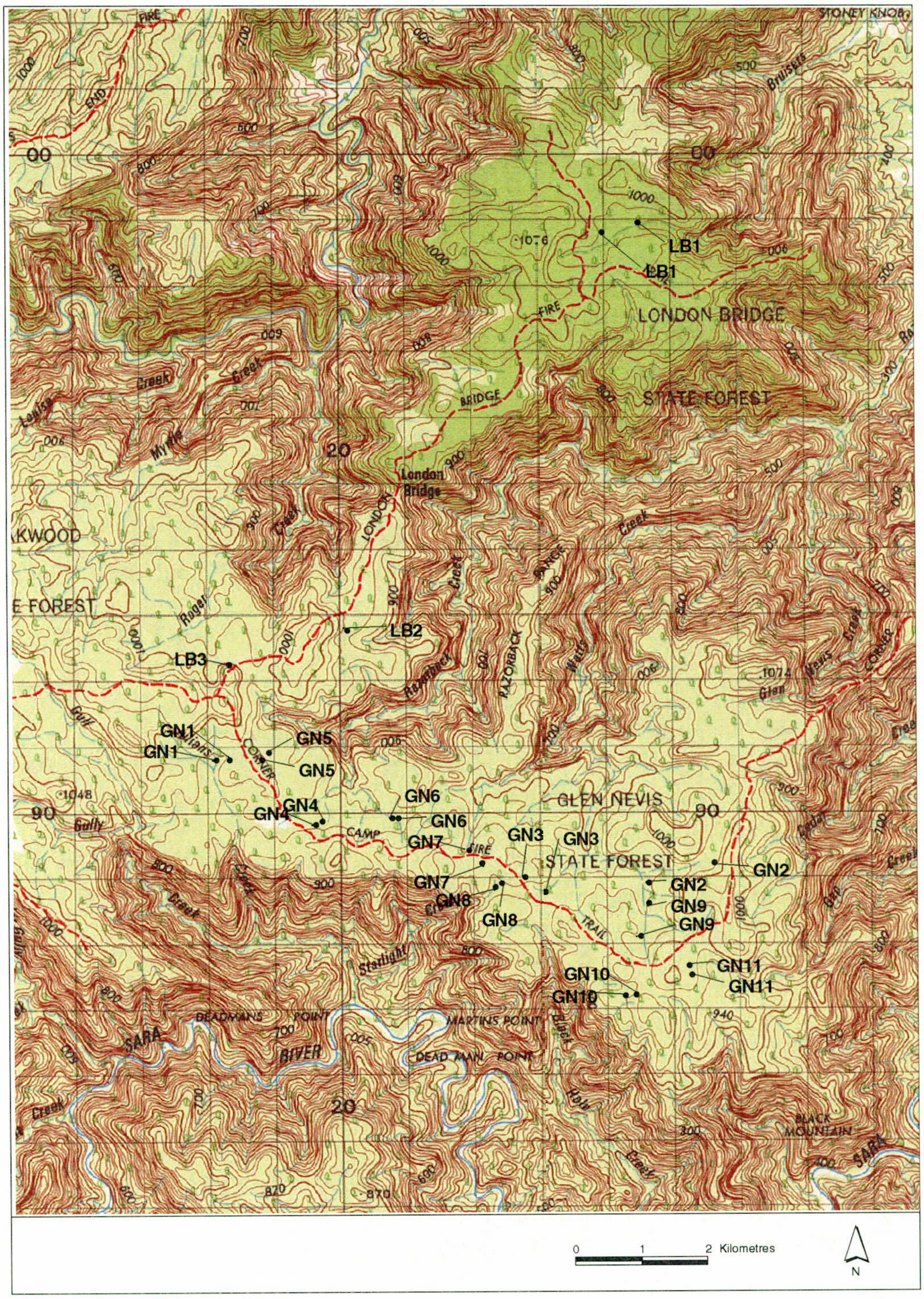


**Figure 1**: General locality map of the 14 study sites on the Glen Nevis and London Bridge plateaux in Guy Fawkes River National Park.

## Fire history

Most fire records of the northern escarpment forests (approximately from 1974 to the present) lack the accuracy and precision required for informed conservation management. There is often some difficulty in establishing which exact areas were burnt and when they were burnt. It is difficult to estimate the underlying variation in the standing vegetation caused by unknown fire regimes. Unrecorded and pre-1974 fires may account for most of the variation in vegetation that we see and not the more recent, recorded fires. This highlights the need to have accurate fire records with explanatory notes about the nature of the fire events, including estimated intensity and scorch patterns.

Many unpublished reports infer disturbance histories from the appearance of the vegetation, for example, forests with a grassy understorey have had frequent fires, and therefore the understorey is grassy. This is a largely uninformative process and must be replaced by well planned and well designed experiments.

In the Gibraltar Ranges / Washpool National Parks Management Plan (NPWS 1989), it is noted that fires frequently escape from surrounding leasehold land into the west of the Parks. These fires were presumed to have come from burns conducted by local graziers. Although an exact fire frequency was not stated, it was supposed that fire free intervals were not greater than 5 years.

In the Kempsey/Wauchope Management Area there were three zones of fire management conducted by State Forests NSW (Williams & Gill 1995). In the urban interface and plantation areas, the frequency of fire was 3-4 years; these areas were thought to be high fire hazard areas. In areas of low fire hazard, the frequency of hazard reduction burns was planned for every 10 years. It was suggested that about 70% of fires occurring in state forests in the Kempsey/Wauchope Management Area were caused by escapes from private property or leasehold land. The inference here is that areas leased by graziers have an exceptionally higher fire frequency than other areas of forest. Williams & Gill (1995) suggest that in NSW, regularly grazed forests are regularly burnt.

Low intensity fires regularly burned plateau forests in the Glen Innes Management Area, over a range of physical and geological attributes. Binns (1992) speculated that areas with a grassy understorey have had a less variable fire regime than either heathy areas or forests with sclerophyll shrub understorey; the implication is that a less variable fire regime results in a less variable understorey. These observations are yet to be tested by experimental studies in the region.

## Grazing history

Generally, most workers on the Northern Tablelands and surrounds have suggested a very close link between grazing and fire. Some workers (eg, Binns 1992) have found it very difficult to separate the effects of grazing from the effects of fire.

Grazing under various leases was encouraged in the Glen Innes Management Area and occurred in about 60 000 ha of open, regularly burnt Tableland Hardwood Forests

(Smith *et al.* 1992). There is a long history of pastoralism in this area and Smith *et al.* (1992) felt that pastoralism had greater effects on forest fauna than logging. It should be noted here that the effects of fire could not be separated statistically from grazing (Smith *et al.* 1992), therefore, since graziers are thought to have regularly burnt vegetation for fodder, the term pastoralism includes both grazing and fire. Smith *et al.* (1992) suggested that pastoralism was responsible for the biggest loss of forest fauna in the Glen Innes Management Area than any other land use practice, based on their regression analysis of site variables with bird species richness and abundance.

In the temperate grassy vegetation of the New England Tablelands, several studies have been conducted on the responses of the vegetation to disturbance regimes including grazing (eg, McIntyre & Lavorel 1994; McIntyre *et al.* 1995; see also review by Trémont & McIntyre 1994). In sites that had sustained severe grazing, the richness of native species was lower than sites experiencing lower grazing intensities (McIntyre & Lavorel 1994). The occurrence of exotics was greatest at sites of higher grazing intensity. In terms of life-history attributes, moderate grazing supported the greatest diversity and, under the highest grazing intensity, the number of species without means of vegetative reproduction declined (McIntyre *et al.* 1995). Several life-history attribute groups were found to be disadvantaged by severe grazing and overall, in terms of evenness of life-history, reproductive strategy and seed dispersal mechanism. Clearly grazing intensity does have an effect on vegetation structure and changes observed in the floristics corresponded with patterns in the life-history attributes (McIntyre *et al.* 1995). A similar response was found for grassy ecosystems in Kosciuszko, where taller forbs replaced smaller forbs when grazing was removed (Wimbush & Costin 1979a, 1979b, 1979c). The studies on the northern tablelands set up a scale of grazing intensity that was related only to recent grazing ('natural experiment' set up and not manipulated) and they did not attempt to quantify responses to historical grazing histories.

## Management history of Guy Fawkes plateau forests

The general pattern of management by graziers involved movement of stock into the forests in autumn, allowing pastures on the adjacent tableland to be spelled. Stock over-wintered in the forests until spring, when they were withdrawn to graze on new growth in the pastures over summer. The prevailing practice was to burn the forest understorey in spring after stock withdrawal, allowing green pick to develop during the wet summer before reintroduction of cattle into the forest in the following autumn (Lennon 1999). Use of the forests for grazing was associated with the development of infrastructure including vehicular tracks, fences, dams and yards. These structures were usually associated with topographic flats in the headwaters of streams. Some areas of the escarpment forests also functioned as stock routes along which cattle were moved at regular intervals from the tablelands down to the coast (Lennon 1999). Sections of the stock routes were undoubtedly burnt on a regular basis. Some tens or hundreds of thousands of hectares of privately owned and leasehold forest were apparently managed in this fashion.

Graziers first moved onto the New England tableland in the 1830s and began to use the escarpment forests in the middle of the nineteenth century. In 1916 and 1918, State forests were declared over the London Bridge and Glen Nevis plateaux, respectively. Grazing leases were taken up in 1928 in Glen Nevis State Forest and in 1956 in London Bridge State Forest. However, sheep and cattle grazing have occurred on the plateaux since the 1850s. Only small amounts of timber were cut from the forests selectively until several coupes were harvested on London Bridge plateau in the late 1980s and early 1990s. The area was declared as National Park in 1997 (*Forestry Revocation and National Parks Reservation Act* 1996 (No. 131)) and was declared a Wilderness Area in 1999. Cattle grazing has been phased out since then, although stray stock still maintain a sporadic presence in the Reserve as of 2001.

Very few written records exist regarding the grazing leases in these two former state forests. The most complete set of written records found consisted of annual rental receipts for grazing permits. These dated back to 1928 for leases in Glen Nevis and from 1956/1957 for leases in London Bridge. No detail was given as to who held the leases or which particular areas were under lease or the stocking rates permitted. The notional stocking rate was one head of cattle per 20 ha for the Glen Innes Management Area (Forestry Commission 1986).

On the tablelands proper, there has been little research into the effects of fire on vegetation. Instead the main focus in these grassy ecosystems has been on the effects of grazing, soil disturbance and water enrichment (Trémont 1994; McIntyre & Lavorel 1994; McIntyre *et al.* 1995). One of the reasons for this is that there are difficulties in bringing together the fire and grazing histories in this area (P. Clarke pers. comm. 1999).

## Objectives of this study

It is postulated that seasonal grazing and regular burning led to a simplified forest structure brought about by the decline of woody understorey plants and the proliferation of certain herbaceous ground cover species (Binns 1992; Smith *et al.* 1992). Although there is some evidence to support the proposition that historical burning and grazing has led to loss of floristic diversity in dry coastal forests (Birk & Bridges 1989; Binns & Chapman 1992; Williams & Gill 1995; York 2000), the forests of the escarpment have received less research attention. Furthermore, the northern escarpment forests differ floristically, structurally and functionally from other Australian vegetation types, in which response to disturbance regimes is comparatively better studied. Unlike many wet sclerophyll forests (Ashton 1981), heathy woodlands and heathlands on the coastal lowlands and ranges, the northern escarpment forests have a significant grassy and herbaceous component in their understorey, which underpins their extensive use for grazing. Unlike most of the semi-arid rangelands, fire regimes are a major force in their ecology and pastoral management. There are several ways in which species can be eliminated through inappropriate burning regimes (Keith 1996; Bradstock *et al.* 1997) and herbivore grazing (Clarke 1999). The difficulty in these forests is that burning and grazing are inextricably linked because of the practice of burning to create green pick for cattle (Lennon 1999).

We hypothesised that disturbances related to the previous grazing management lead to a reduction in the species richness and the population density of woody plants in grassy dells of the temperate forests on the north-eastern edge of the Northern Tablelands escarpment.

This study began in response to new additions being made to the Guy Fawkes River National Park from former grazing leases. The new additions were made as a result of the Regional Forestry Agreement and under the principles of Ecological Sustainable Forestry Management. All of the new additions included in this study were also declared Wilderness Areas. Our aims were to:

1. Document any floristic changes in the woody understorey assemblage as a result of the new management regime;

2. Examine the relationships between vegetation patterns and disturbance associated with historical burning and grazing practices;

3. Account for variation in the vegetation and attribute the variation to a source(s);

4. Conduct a series of treatments to identify the causal mechanisms of changes in species richness and structural diversity in the woody understorey assemblage.

The results of the report are divided into two parts. Part One investigates the variation in the woody understorey vegetation to infer historical impacts of grazing and associated burning. Part Two examines the causal relationships of change in the vegetation and to monitor the effects of alternative management treatments.

## Methodology

### Site Selection

Potential sampling sites with forest type 161a (Round-leaf Gum) and < 10° slope, no entrenched gullies but with a clear drainage line were delineated using topographic maps, forest type maps and field reconnaissance. A subset of 14 potential sites was subjectively selected to represent the full range of variation in elevation and annual rainfall, shown in spatial data layers compiled for the Comprehensive Regional Assessment (New South Wales National Parks & Wildlife Service 1999). Sites ranged in size from approximately 6 to 100 ha and were of varying shapes and patchiness. The placement of samples within each site was determined by measuring a random distance along a drainage line from a randomly selected point. Each random number represented a location for a series of three 20 m × 20 m quadrats along a transect perpendicular to the drainage line. Within each series, one quadrat was placed at the highest point within the catenary depositional zone (e.g. just below outcropping rock), one was placed at the lowest point (adjacent to the drainage line) and one was placed at the midpoint of the topographical gradient. Two series of three quadrats each were sampled on each of the sites selected, except in one case where the site was only large enough to sample one set of the three quadrats. A total of 14 sites and 81 quadrats were sampled.

### Part 1 - Vegetation sampling

The number of individuals of shrub species, woody vines and the large cauducious sedge, *Gahnia* were counted within each quadrat. Juveniles of the woody species were recorded separately from the adult individuals. Juveniles of all species except *Acacia* were defined as those plants that lacked any evidence of reproductive structures from present or previous seasons. The fruits of *Acacia* are generally not held in the canopy for more than one season. Individuals of *Acacia* species that were taller than 1 m (the approximate size of the smallest reproductive plants) were counted as adults irrespective of whether fruits were present.

### Part 1 - Environmental sampling

Environmental variation between samples was minimised by constraining sampling within a narrowly defined topographic envelope. Variation within the sampling envelope was quantified by estimating a set of physical, edaphic and climatic variables. Mean annual rainfall was estimated from the coordinates of each quadrat on a regional rainfall surface interpolated from weather station data using ESOCLIM (Hutchinson 1989). Altitude was estimated from topographic maps. Slope and aspect were estimated in the field using a compass and clinometer. Soil moisture, organic matter, pH and electrical conductivity were estimated from field samples. Ten soil cores were collected from each quadrat and homogenised for analysis. Soil was collected from 0–7 cm depth, and leaf material from the soil surface was excluded. Samples were air-dried for at least 1 week. Soil moisture was calculated from samples dried in the oven at 80°C for 24 h. Percentage loss on ignition (LOI), a measure of organic matter content and hence the long-term moisture status of the soil, was calculated from oven-dried soil (105°C), which was then burnt in a muffle furnace at 400°C for 2 h. Soil solutions were prepared by adding 10 mL of distilled water to 2 g soil and agitating for 1 h. The pH of the solution was measured using an Orion Research SA250 pH meter (Orion Research Inc., Cambridge MA, USA). Electrical conductivity of the soil solution, a measure of dissolved nutrient ions in the soil, was estimated using a β81 conductivity meter on the same samples used to measure soil pH.

Short-term indicators of cattle grazing activity were the presence of and density of cattle dung. The presence and density of cattle dung has proved to be useful for detecting the ecological effects of grazing in other studies (Petit *et al.* 1995; Fensham & Skull 1999; York 1999). The density of cattle dung was estimated at the quadrat level. A similar approach was taken for estimating the use of the area by macropods. Macropod scats were counted in two 5 x 5 m sub-plots within each quadrat.

### Part 1 - Data analysis

Data matrices were constructed for each data set (juvenile plants, adult plants, environment, disturbance and spatial relationship between sites). The environmental matrix included altitude, slope, aspect index (a sine-transformation of half the aspect value in degrees), position on slope (upper, middle or lower), mean annual rainfall, soil pH, soil moisture, organic matter content and electrical conductivity of the soil solution. Variables were coded in the matrices to accommodate non-linear relationships where they might exist. For example, position on slope was coded as three binary variables to indicate presence on the upper, mid or lower slope, rather than a single ordinal variable with three levels. The disturbance matrix included binary variables for presence/absence of dams, cattle tracks, vehicle tracks, fences, yards and cattle dung. Integer variables for density of cattle dung pats and the number of fires recorded were also included. The spatial matrix used the Australian Map Grid references from each plot calculated from 1 : 25000 topographic maps. Variables in the spatial matrix consisted of $x$, $y$, $x^2$, $y^2$, $xy$, $x^2y$, $y^2x$ (after Legendre & Legendre 1998). This was done to quantify the effect of confounding factors associated with spatial variation due to other landscape variables.

Canonical correspondence analysis (CCA) was carried out using CANOCO v4.0 (ter Braak & Smilauer 1998). Separate analyses were carried out for the adult and juvenile vegetation matrices to account for the possibility of recent changes in vegetation that may have resulted from less intensive pastoral use during the last decade. Table 1 describes the stepwise analytical procedure implemented to partition variation in each vegetation matrix among sources attributable to disturbance, environment and space and to all pair-wise and three-way combinations.

**Table 1:** Steps and equations for calculating the partitioned variation in Canonical Correspondence Analysis (CCA) of shrub density data. Sums of eigenvalues for various CCAs are given by constants A-H. Components of variation in vegetation matrix are as follows: d- uniquely attributable to disturbance; e- uniquely attributable to environment; s- uniquely attributable to space; de- attributable to disturbance and environment; ds- attributable to disturbance and space; es- attributable to environment and space; des- attributable to disturbance, environment and space; U- unexplained variation (see Figs. 1 & 3 for diagrammatic representation).

| Step | Description of step | Equation |
|---|---|---|
| 1 | Unconstrained CA on vegetation matrix | A=d+e+s+de+ds+es+des+U |
| 2 | CCA on vegetation matrix constrained by disturbance matrix | B=d+de+ds+des |
| 3 | CCA on vegetation matrix constrained by disturbance matrix with combined environment + space matrix as covariable | C=d |
| 4 | CCA on vegetation matrix constrained by disturbance matrix with environment matrix only as covariable | D=d+ds |
| 5 | CCA on vegetation matrix constrained by disturbance matrix with space matrix only as covariable | E=d+de |
| 6 | CCA on vegetation matrix constrained by environment matrix with combined disturbance + space matrix as covariable | F=e |
| 7 | CCA on vegetation matrix constrained by environment matrix with disturbance matrix only as covariable | G=e+es |

| | | |
|---|---|---|
| 8 | Sum of eigenvalues for vegetation matrix constrained by space matrix with combined disturbance + environment matrix as covariable | H=s |
| 9 | Calculate disturbance and environment overlap | de=E–C |
| 10 | Calculate disturbance and space overlap | ds=D-C |
| 11 | Calculate environment and space overlap | es=G-F |
| 12 | Calculate disturbance, environment and space overlap | des=B-(D)-(E-C) |
| 13 | Calculate unexplained variation | U=A–(B)-(F)-(H)-(G-F) |
| 14 | Check additivity of components with other permutations of formulae | |

To determine which species contributed most to the more and less disturbed groups of sites, a SIMPER analysis was carried out in the package PRIMER (Clarke & Gorley 2001). This analysis was carried out on density data for all woody species present as adult and juvenile plants, respectively. A Pearson's correlation coefficient was calculated to determine if there was any correlation between the density of adult and juvenile shrubs.

## Part 2 -Experimental design

Ten study sites of the original 14 (Henderson & Keith 2002) were selected for treatments and further assessment. There were to be four treatments in factorial combinations of grazing and experimental burning. However, in September and October 2000, half of the selected sites were burnt in a wildfire. The experimental design was altered and subsequently only five of the original 14 sites were used for the experimental treatments reported here and the remaining five sites were not used for the initial treatment, although they were fenced. The quadrats were set up with the intent of continuing treatment and ongoing management, which would include both the experimentally burnt (Fig. 2) and wildfire burnt quadrats.

The experimental treatments are as follows, burnt fenced (BF), burnt unfenced (BUF), unburnt fenced (UBF), and unburnt unfenced (UBUF). There were five replicates of each treatment. The unburnt and experimentally burnt and all fencing treatments were randomly allocated to quadrats.

**Table 2.** Burning and fencing treatments.

| | Fenced | Unfenced |
|---|---|---|
| Unburnt | GN1SQ3, GN5SQ5, GN4SQ1, LB3SQ4, GN6SQ4 | GN1SQ1, GN5SQ6, GN4SQ3, LB3SQ5, GN6SQ5 |
| Experimentally burnt | GN1SQ5, GN5SQ2, GN4SQ6, LB3SQ1, GN6SQ2 | GN1SQ4, GN5SQ3, GN4SQ5, LB3SQ3, GN6SQ3 |
| Wildfire burnt | GN8SQ2, GN8SQ6, GN10SQ3, GN10SQ4, GN2SQ4, GN2SQ5, GN11SQ2, GN11SQ4, GN3SQ3, GN3SQ5 | GN8SQ1, GN8SQ5, GN10SQ1, GN10SQ5, GN2SQ1, GN2SQ3, GN11SQ3, GN11SQ5, GN3SQ1, GN3SQ6 |

The fences were erected in January and February 2000, approximately 2 – 3 months after the wildfire and before the experimental fires. The fences measured 24 m x 24 m to include the entire quadrats and to include a 2 m buffer around the entire quadrat perimeter. The fences consisted of 1 m high 20 mm gauge wire netting and a plain wire approximately 20 cm above the netting. The netting is small enough to prevent the entry of small macropods and high enough to prevent the entry of stray domestic stock. It is presumed that larger macropods (e.g. eastern-grey kangaroos) would not enter the fenced quadrats because there was abundant other food on offer. However, to account for the presence of both stock and macropods, scat densities were estimated within 25 $m^2$ quadrats and 400 $m^2$ quadrats for macropods and stock respectively. Scats were removed from the fenced areas to account for the likelihood of re-counting any recent post-fencing scats and to obtain a picture of the level of usage by herbivores. The scat data are not discussed here in this report.

**Part 2 - Data analysis**

Pre-treatment plant densities and species richness were calculated from the data collected in Part One. Post-treatment plant densities and species richness were collected by recording every woody understorey plant in each quadrat. The change in density and species richness was calculated by subtracting the pre- treatment data from the post- treatment data. The changes in plant density or species richness were tested to see if there were significant differences between the treatments. Generalised linear models with a univariate function were used to test for differences between the treatments using SPSS (SPSS Inc. 1999). The mean density of recruits was also tested to determine if there were any differences between the treatments. Once again, univariate generalised linear models were used to test for significant differences between the treatments.

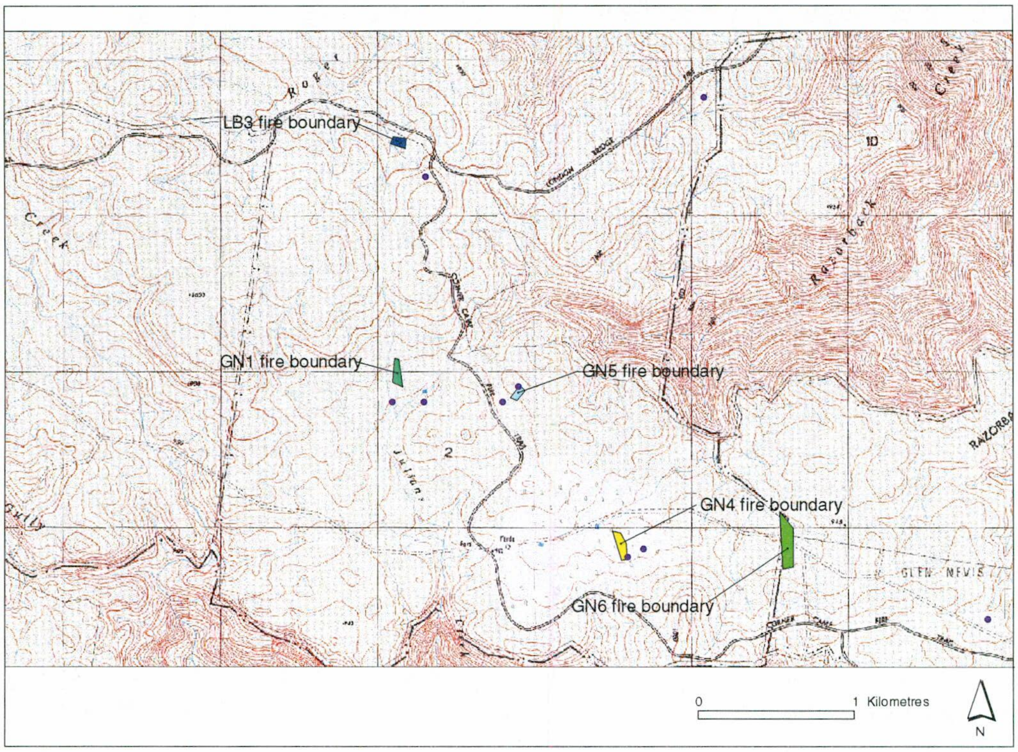


**Figure 2:** Map of experimentally burnt sites within the Guy Fawkes River National Park.

To determine if there were overall floristic differences between the treatments, density data for each species was used in the program PRIMER (Clarke & Gorley 2001). To test for differences between the different disturbance treatments, an analysis of similarity (ANOSIM) was performed. There were two factors (fire and fence) with two levels in each factor (unfenced or fenced and unburnt or burnt).

## Results

### Part 1 – Correlation of historical disturbance indicators with species occurrence

*Species occurrence and disturbance indicators*

Twenty-nine shrub species were encountered in the surveys (Table 3). Most quadrats had less than six shrub species. Only *Leucopogon lanceolatus* and *Allocasuarina littoralis* occurred in more than half of the quadrats. Most species present as juveniles were also present as adults. Species present as juveniles but not as adults were *Acacia melanoxylon*, *Lomatia silaifolia*, *Pittosporum undulatum* and *Synoum glandulosum*. Species that did not occur as juveniles were *Banksia cunninghamii* ssp. *neo-anglica*, *Cyathea australis* and *Swainsona galegifolia*. There was no significant correlation ($r = 0.31$, NS) between the densities of adults and juveniles among the woody species.

All 81 quadrats had at least one disturbance indicator, 51 quadrats had four or more disturbance indicators (and hence qualified as 'more' disturbed) and six quadrats had all possible disturbance indicators. Quadrats with disturbance variables indicating a history of more intensive grazing and more frequent burning generally had fewer woody species ($P < 0.001$; Table 4) and lower population densities of those woody species present ($P < 0.001$; Table 4).

Eigenvalues in the CCA for adult plants indicated a large group of species associated with quadrats with lower disturbance indices. This group contained *Banksia cunninghamii* ssp. A, *B. integrifolia* var. *montana*, *Callistemon citrinus*, *Cyathea australis*, *Cissus hypoglauca*, *Gahnia sieberiana*, *Hibbertia aspera*, *H. scandens*, *Solanum densivestitum*, *Swainsona galegifolia*, *Tasmannia stipitata* and *Trochocarpa laurina*. A second, more widespread group of species contained *Leucopogon lanceolatus* var. *lanceolatus*, *Allocasuarina littoralis* and *Exocarpos strictus*. The SIMPER analysis showed that six of the seven most discriminatory adult species between 'more' and 'less' disturbed quadrats were more abundant in the latter (Table 5). Five of these six species were at least an order of magnitude more abundant in the 'less' disturbed quadrats, including two that were not recorded in the 'more' disturbed quadrats at all. Only *Allocasuarina littoralis* was slightly more abundant in the 'more' disturbed quadrats than the 'less' disturbed quadrats. The juvenile data showed similar patterns (Table 6), with eight of the nine most discriminatory species found at higher densities in the 'less' disturbed quadrats and *A. littoralis* the only species to show the reverse trend.

**Table 3.** Life-history attributes of woody species encountered in quadrat vegetation sampling. Vegetative recovery (VR): N- none; L- lignotuber; S- suckers/stolons. Seed bank (SB): P- persistent soil; T- transient soil; C- canopy. Dispersal (D): W- wide (ingested, wind-buoyant); L- local (passive, myrmecochore). Bud/Fruit height (B/F H): H- above browse height; L- always below browse height. Palatability (P): H- high; M- medium; L- low.

| Species (Vital Attribute Functional Group) | VR | SB | D | B/F H | P |
|---|---|---|---|---|---|
| *Acacia floribunda* (SI) | N | P | L | H | H |
| *Acacia implexa* (ΣI) | S | P | L | H | H |
| *Acacia irrorata* (SI) | N | P | L | H | H |
| *Acacia melanoxylon* (SI) | N | P | L | H | H? |
| *Allocasuarina littoralis* (WT) | N | C | L | H | |
| *Banksia cunninghamii* (CI) | L | C | L | L | |
| *Banksia integrifolia* (WT) | S | T | L | H | L? |
| *Callistemon citrinus* (VI) | L | C | L | H | L? |
| *Cissus hypoglauca* (ΔT) | L | T | W | H | |
| *Cyathea australis* (ΔR) | L | T | W | H | L? |
| *Daviesia latifolia* (ΣI) | N | P | L | L | |
| *Exocarpos strictus* (ΔT) | L? | T | W | L | L |
| *Gahnia sieberiana* (ΔI) | L | P | W | L | H |
| *Hibbertia aspera* (WI) | L | P | L | L | |
| *Hibbertia scandens* (ΔI) | L | P | W | L | |
| *Leptospermum polygalifolium* ssp. *montanum* (VI) | L | C | L | L | M |
| *Leucopogon lanceolatus* (VI) | L | P | W | L | L? |
| *Lomatia silaifolia* (VI) | L | T | L | L | |
| *Ozothamnus diosmifolius* (DI) | N | T? | W | L | |
| *Persoonia oleoides* (SI) | N? | P | L? | L | |
| *Pittosporum undulatum* (DT) | N | T | W | H | |
| *Polyscias sambucifolia* (ΔT) | S | T | W | L | H? |
| *Rapanea howittiana* (ΔT) | L? | T? | W | H | H? |
| *Santalum obtusifolium* (DT) | N | T | W | L | |
| *Solanum densivestitum* (DI) | N | T | W | L | |

| | | | | | |
|---|---|---|---|---|---|
| *Swainsona galegifolia* (ΣI) | N? | P | L | L | L |
| *Synoum glandulosum* (ΔT) | L | T | W | H | |
| *Tasmannia insipida* (ΔT) | S | T | W | L | L |
| *Trochocarpa laurina* (ΔT) | L | P? | W | L | |

**Table 4.** Mean number of woody species (± SEM) and number of woody plants (± SEM) per quadrat for 'more' and 'less' disturbed quadrats

| | 'More' (*n* = 51) | 'Less' (*n* = 30) | *t* value | *P* |
|---|---|---|---|---|
| Mean no. species per quadrat | 4.2 (± 0.3) | 5.9 (± 0.4) | 3.751 | < 0.001 |
| Mean no. plants per quadrat | 36.9 (± 7.1) | 98.2 (± 16.4) | 3.435 | < 0.001 |

**Table 5.** Results of SIMPER analysis for adult shrub species

| Species | Average abundance 'More' disturbed | 'Less' disturbed | % Contribution to difference |
|---|---|---|---|
| *Leucopogon lanceolatus* | 25.3 | 40.7 | 39.0 |
| *Exocarpos strictus* | 2.4 | 25.9 | 17.7 |
| *Hibbertia aspera* | 0 | 11.7 | 7.0 |
| *Hibbertia scandens* | 0.1 | 7.7 | 4.6 |
| *Allocasuarina littoralis* | 2.1 | 1.5 | 3.8 |
| *Acacia irrorata* | 0.3 | 3.8 | 3.1 |
| *Gahnia sieberiana* | 0 | 2.0 | 1.8 |

Average abundance is for shrub density, the percent contribution is the contribution each species makes to the average dissimilarity between the two groups 'more' and 'less' disturbed.

**Table 6.** Results of SIMPER analysis for juvenile shrub species

| Species | Average abundance 'More' disturbed | 'Less' disturbed | % Contribution to difference |
|---|---|---|---|
| *Allocasuarina littoralis* | 36.4 | 13.2 | 36.4 |
| *Leucopogon lanceolatus* | 8.9 | 11.0 | 23.4 |
| *Exocarpos strictus* | 1.7 | 2.7 | 7.7 |
| *Polyscias sambucifolia* | 0.4 | 3.6 | 7.1 |
| *Hibbertia aspera* | 0 | 5.1 | 4.0 |
| *Acacia irrorata* | 0.7 | 1.3 | 3.9 |
| *Hibbertia scandens* | 0.1 | 3.9 | 3.8 |
| *Acacia implexa* | 1.0 | 0.6 | 3.7 |
| *Trochocarpa laurina* | 0 | 1.8 | 2.1 |

Average abundance is for shrub density, the percent contribution is the contribution each species makes to the average dissimilarity between the two groups 'more' and 'less' disturbed.

### *Sources of variation*

Space, environment and disturbance matrices explained 59.3% of the total variation in the mature shrub data, leaving 40.7% unexplained (Fig. 3). The disturbance matrix alone accounted for the largest proportion (25%) of the explained variation in the adult shrub data (Fig. 3). This corresponds to 15% of the total variation. An additional 30% of the total (50% of explained) variation in adult shrubs was correlated with disturbance as well as environmental and/or spatial variation (components de + des + ds; Fig. 3). The combined effects of grazing and burning therefore accounted for between 15 and 45% of total variation or 25–75% of explained variation in the density of adult shrubs. A further 14% of the total variation was attributable to environmental or spatial variation independent of disturbance (components e + es + s; Fig. 3).

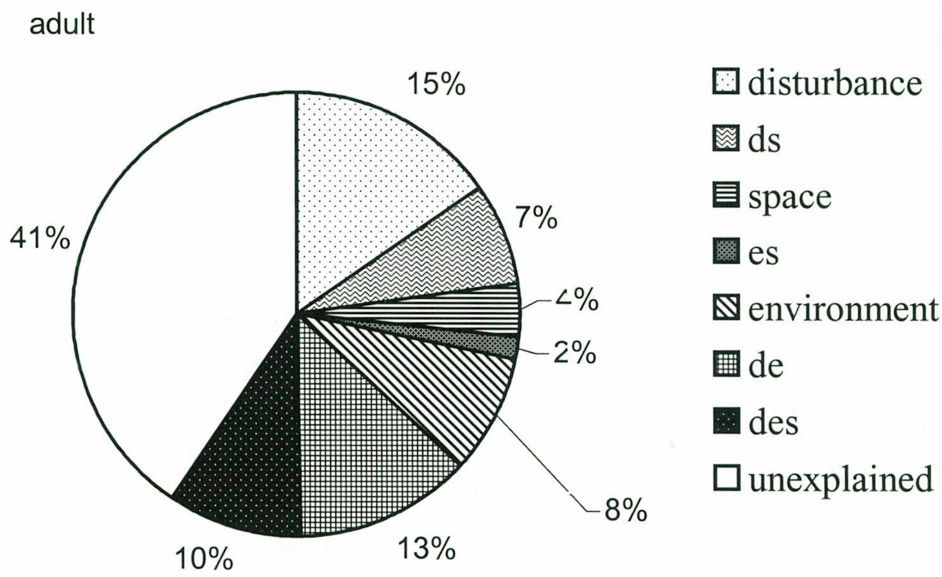


**Figure 3:** percentages of partitioned variation in adult shrub density data for the matrices disturbance, space and environment; ds, disturbance space overlap; es environment space overlap; de disturbance environment overlap; des, disturbance – environment – space overlap. Values are percentages of total variation explained by the data.

## Part 2 – Experimental manipulations

### *Plant density and Species Richness*

Changes in both plant density and species richness were calculated to detect any response due to the treatments. There were no significant differences in plant density (Fig. 4) or species richness (Fig. 5) between the treatments.

*Recruitment*

The density of recruits was recorded and tested to see if there were differences between the treatments imposed. The treatments resulted in no significant differences in the density of recruitment occurring in the quadrats (Fig. 6).

*Floristic composition*

There were no significant differences detected between the treatments using a two-way crossed ANOSIM procedure (between fire R = 0.05, NS; between fence R = 0.012, NS). However, when only one factor, fire, was tested there were differences between the burnt and unburnt floristic compositions (R = 0.06, $P < 0.05$).

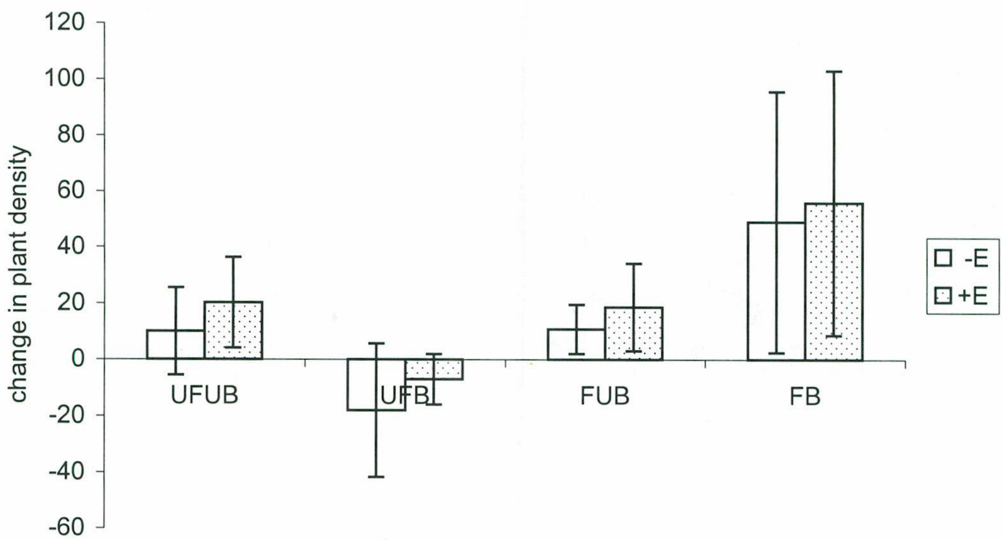


**Figure 4:** Change in mean plant density per quadrat, from pre- to post- treatment, with and without eucalypts (+ E and –E). Treatments are UFUB – unfenced and unburnt, UFB – unfenced and burnt, FUB – fenced and unburnt, FB – fenced and burnt. Bars are standard error, n = 5.

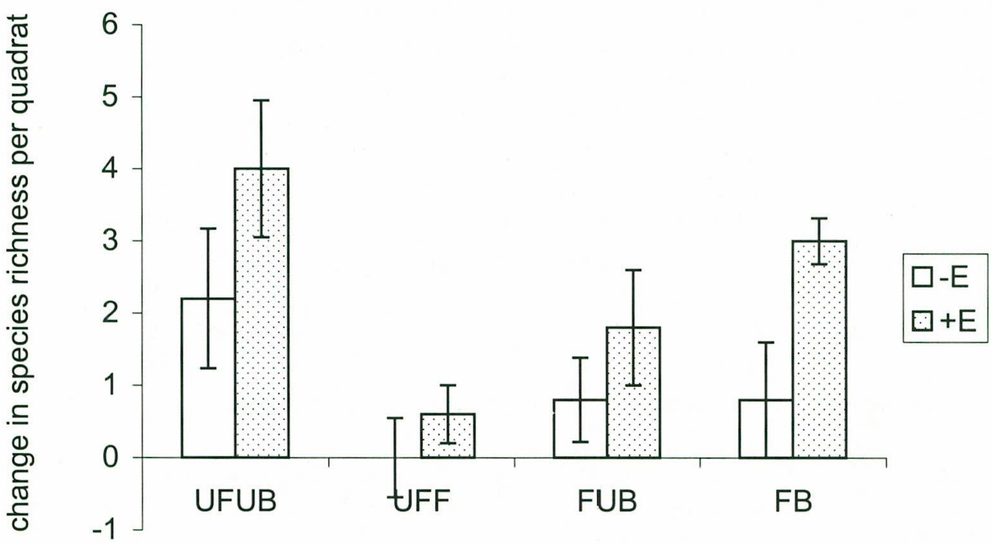


**Figure 5:** Change in mean species richness per quadrat (n = 5) from pre- to post-treatment, with and without eucalypts. Treatments are UFUB – unfenced and unburnt, UFB – unfenced and burnt, FUB – fenced and unburnt, FB – fenced and burnt. –E is without eucalypts and +E with eucalypts. Bars are standard error.

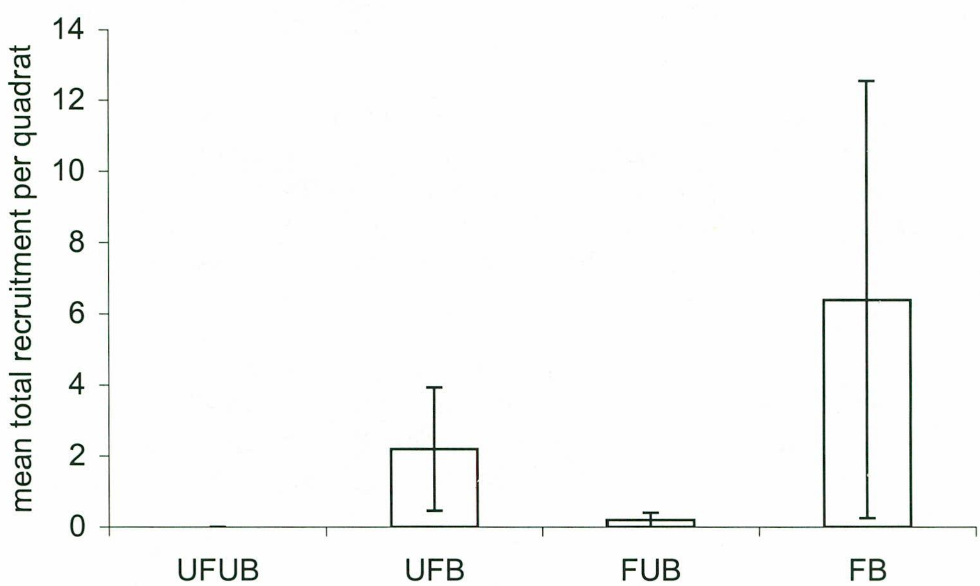


**Figure 6:** Mean total number of recruits per quadrat for each treatment. Treatments are UFUB – unfenced and unburnt, UFB – unfenced and burnt, FUB – fenced and unburnt, FB – fenced and burnt. Bars are standard error, n = 5.

## Management Implications

The first phase of this study produced strong evidence that the disturbances associated with domestic stock grazing have lead to a reduction in the species richness and the plant density of vegetation in the temperate forest understorey. Furthermore, the disturbances have also resulted in different suites of species occurring in the more disturbed than the less disturbed areas. The analyses demonstrated that disturbances associated with cattle grazing account for by far the greatest proportion of the variation in the vegetation. Environmental and spatial attributes accounted for a much smaller proportion of the variation in species assemblages in the understorey.

Inappropriate grazing and burning regimes apparently resulted in the elimination of some species. By maintaining those inappropriate conditions, the chance of a more simplified understorey both in terms of richness and structure is likely.

The species that are eliminated are not able to persist with the grazing and / or burning disturbances. For example, obligate seeders may be eliminated by frequent burning as new individuals are killed before they reach maturity, thus eliminating the next generation; plants that are palatable and therefore vulnerable to grazing would not have the capabilities to attain a reproductive state due to the removal of apical buds (Wahungu *et al.* 1999).

Increases in macropod populations may have occurred through the provision of artificial watering points (ie the dams). By maintaining artificial water points, the macropod populations are likely to have increased relative to 'unwatered' areas. Disturbance that promotes a grassier understorey is likely to favour macropod populations; thus macropod populations may have a twofold effect on the understorey vegetation. Other studies have indicated that native herbivore populations may have a significant negative impact on the age structure and reproductive capabilities of both shrub and tree species (Wahungu *et al.* 1999).

The main influence on the vegetation is not just one fire or one season of grazing, it is the cumulative impacts of these disturbances that shape the species/components of the vegetation. Although each individual low intensity fire itself may not be a major influence on a large proportion of the landscape, the impacts of many of these frequent fires over a long time frame is likely to have a much greater impact than one single fire.

It is quite possible that large elements (eg the two plateaux) of the landscape have been managed in a similar and invariable fashion. The lack of variability in management has resulted in areas with homogeneous structure and florisitcs. Lack of variability has also resulted in few 'reference' sites with which to compare the sites of historical disturbance.

By pushing the system in one, deleterious direction is likely to make 'getting back' to some other state more difficult. That is, the system may have reached another, different steady state that may be unfavourable for elements of the pre-pastoral woody understorey vegetation. The second phase (the experimental manipulations) could not positively confirm that there were any differences in species richness, plant density or recruitment events between the treatments tested. There was the suggestion that some trends were evolving because mean shrub density and recruitment were higher in burnt / fenced relative to burnt / unfenced treatments; however none of the data were significant. The lack of significant treatment response could mean that there are no true treatment response differences or that there has not been enough time to allow for patterns to emerge.

Simply removing the disturbances is unlikely to restore the full component of understorey woody species. This is because:

- Seed banks may not be persistent;
- Dispersal of woody species into disturbed sites is slow or non-existent;
- Sensitive species may be long gone and therefore not present in the sites;
- Time lags associated with macropod grazing may limit recruitment (see earlier point).

The quadrats used in the experimental manipulations were from both groups classified as either 'more' or 'less' disturbed in the correlation study (Part One, Henderson & Keith 2002). This layer of previous disturbance may have also influenced the outcome of the experimental manipulations.

Given that there has only been at most 10 months since the experimental burning, it seems unlikely that any changes due to the experiment would be evident at this early stage. Continuation of experimental treatments and regular monitoring are essential to resolve the effects of management on recovery of the forest understorey. It is likely that treatments and observations will need to be continued over several future fire cycles. Reporting of the continued monitoring could be incorporated into annual State of the Parks and State of the Environment reports.

## Recommendations

1. Reduce herbivory in the forest by:
   - Removing or decommissioning non-essential dams (ie those not used in wildfire fighting). Maintenance of fencing on dams already fenced is likely to prove costly and will be a continual drain on resources into the future.
   - Monitoring macropod populations in response to a reduction in watering points. A before and after study could achieve this with minimal set up. The removal of dams within the Park is unlikely to result in local population extinction, rather a reduction in native herbivore numbers.
   - Removal of all cattle upon detection in the Park and Wilderness Areas. As there are likely to be further additions to the Park, it is not feasible to fence all of the boundaries of the Park; therefore a different approach to the current needs to be taken with the graziers in the area. It is unacceptable that cattle should remain in the Park, given the long period of notice to quit prior to

gazettal. NSW NPWS should dedicate resources to the local Area for the enforcement of stock removal in the Park. A stringent yet fair 'three strikes and you are out' approach could be applied to owners of stray stock.

2. Reduce fire frequency by:

    - Avoiding unplanned fires in the new Park additions for some 10 – 15 years. This recommendation may be difficult if not impossible to achieve given the nature of unplanned fires in this area. The Glen Innes Area and NPWS embark on a multi-agency education program, with aims to encourage the local community and neighbours to prevent and report fires.

    - In addition to fire prevention, NSW NPWS (with other agencies) should prosecute those who disregard fire management practices and are careless with fires on their own or leasehold lands. The terrain in question is rugged and rather inaccessible which makes positioning strategic Hazard Reduction (HR) burns difficult. Also HR burns usually concentrate on property protection rather than remote vegetation protection and there are few if any assets close or on the Park boundary in this section of the Park.

    - Acquisition of sensitive neighbouring properties may alleviate the incidence of unplanned fires in the Park. Some leasehold and freehold neighbouring properties are currently under consideration for acquisition. The properties include gorge country where fires are more likely to enter the Park *and* be difficult to contain. Land acquisition can be expensive and this would not be seen as a priority option beyond those properties under current consideration.

    - Maintaining more accurate fire history records. These records should not only include information on the boundary of the fires, the date of occurrence and the weather conditions, but also some information on the intensity, patchiness and simple measures of fire behaviour. Some of these measures can be made up to 3 months after the passage of the fire. Some of these data can be gathered in a quantitative manner. The use of such data is twofold. Firstly the data would be useful for more informed fire management planning and secondly the data would assist conservation planning and notions of fire thresholds for vegetation communities. Having these data would have strengthened our study and would have been valuable in a management context.

3. Monitoring:

    - NSW NPWS should dedicate resources to a) maintain the experimental exclosures, b) implement burning treatments in 2 – 3 yearly cycles and c) annually monitor and review the trends in response to the treatments.

    - That the experimental quadrats be maintained. As is the case with most ecological studies, the results are usually not gleaned until some time after the experiments commence. That is, long-term studies are more useful for making predictions about the dynamics of taxa to disturbance. Longer-term studies also reduce the likelihood that the observed responses are due purely to chance, unusual climatic conditions and the like. The experimental manipulations in the future could include those plots that were burnt in the 2000 fires and involve a repetition of experimental burning. Maintenance of the unburnt quadrats is also vital.

- That NSW NPWS consider establishing further research into: the impacts of native herbivore grazing; the soil-stored seed banks of areas under previous grazing and burning practices; the restoration and regeneration of areas disturbed by previous grazing and burning practices.

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## Appendices

### Appendix One – Papers published and manuscripts in preparation

Henderson M.K. & Keith D.A. (2002) Correlation of burning and grazing indicators with composition of woody understorey flora of dells in a temperate eucalypt forest. *Aust. Ecol.* **27**, 121 – 31.

There are more manuscripts in preparation.

### Appendix Two – Suggested data to collect from fire scenarios

Example data collection for fire scenarios:

- Scorch height (m), consumption height (m), gradient of fire, direction of burn, % scorch, % burnt (on ground), % scorched but not consumed (on ground), head fire/flank fire, ignition point (source), ignition type;
- Vegetation type, canopy height, % cover, estimated fuel age, estimated fuel load, fuel moisture;
- Temperature at burn time, wind speed, wind direction, humidity;
- Date, time of day of burn, locality, map sheet;
- GPS boundaries.

## Appendix Three – Quadrat environmental and treatment data

| Quadrat number | Easting | Northing | Elevation (m) | Fire history | Evidence of fire | Disturbance class | Treatment |
|---|---|---|---|---|---|---|---|
| GN1SQ1 | 418300 | 6690800 | 960 | 1 | Y | M | UFUB |
| GN1SQ2 | 418300 | 6690800 | 960 | 1 | Y | M | N |
| GN1SQ3 | 418300 | 6690800 | 960 | 1 | Y | M | FUB |
| GN1SQ4 | 418100 | 6690800 | 960 | 1 | Y | M | UFB |
| GN1SQ5 | 418100 | 6690800 | 960 | 1 | Y | M | FB |
| GN1SQ6 | 418100 | 6690800 | 960 | 1 | Y | M | N |
| GN5SQ1 | 418900 | 6690900 | 960 | 1 | Y | M | N |
| GN5SQ2 | 418900 | 6690900 | 960 | 1 | Y | M | FB |
| GN5SQ3 | 418900 | 6690900 | 960 | 1 | Y | M | UFB |
| GN5SQ4 | 418800 | 6690800 | 960 | 1 | Y | M | N |
| GN5SQ5 | 418800 | 6690800 | 960 | 1 | Y | M | FUB |
| GN5SQ6 | 418800 | 6690800 | 960 | 1 | Y | M | UFUB |
| GN7SQ1 | 422100 | 6689200 | 950 | 1 | Y | M | N |
| GN7SQ2 | 422100 | 6689200 | 950 | 1 | Y | M | N |
| GN7SQ3 | 422100 | 6689200 | 950 | 1 | Y | M | N |
| GN7SQ4 | 421900 | 6689400 | 940 | 1 | Y | M | N |
| GN7SQ5 | 421900 | 6689400 | 940 | 1 | Y | M | N |
| GN7SQ6 | 421900 | 6689400 | 940 | 2 | Y | M | N |
| GN8SQ1 | 422400 | 6688900 | 940 | 2 | Y | M | UFWF |
| GN8SQ2 | 422400 | 6688900 | 940 | 2 | Y | M | FWF |
| GN8SQ3 | 422400 | 6688900 | 940 | 2 | Y | M | N |
| GN8SQ4 | 422300 | 6688850 | 940 | 3 | Y | M | N |
| GN8SQ5 | 422300 | 6688850 | 940 | 3 | Y | M | UFWF |
| GN8SQ6 | 422300 | 6688850 | 940 | 3 | Y | M | FWF |
| GN9SQ1 | 424480 | 6688100 | 960 | 0 | Y | L | N |
| GN9SQ2 | 424480 | 6688100 | 960 | 0 | Y | L | N |
| GN9SQ3 | 424480 | 6688100 | 960 | 0 | Y | L | N |
| GN9SQ4 | 424600 | 6688600 | 950 | 0 | Y | L | N |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| GN9SQ5 | 424600 | 6688600 | 950 | 0 | Y | L | N |
| GN9SQ6 | 424600 | 6688600 | 950 | 0 | Y | L | N |
| GN10SQ1 | 424400 | 6687200 | 960 | 2 | Y | L | UFWF |
| GN10SQ2 | 424400 | 6687200 | 960 | 2 | Y | L | N |
| GN10SQ3 | 424400 | 6687200 | 960 | 2 | Y | L | FWF |
| GN10SQ4 | 424250 | 6687180 | 970 | 2 | Y | L | FWF |
| GN10SQ5 | 424250 | 6687180 | 970 | 2 | Y | L | UFWF |
| GN10SQ6 | 424250 | 6687180 | 970 | 2 | Y | L | N |
| GN4SQ1 | 419700 | 6689850 | 940 | 1 | Y | M | FUB |
| GN4SQ2 | 419700 | 6689850 | 940 | 1 | Y | M | N |
| GN4SQ3 | 419700 | 6689850 | 940 | 1 | Y | M | UFUB |
| GN4SQ4 | 419600 | 6689800 | 940 | 1 | Y | M | N |
| GN4SQ5 | 419600 | 6689800 | 940 | 1 | Y | M | UFB |
| GN4SQ6 | 419600 | 6689800 | 940 | 1 | Y | M | FB |
| LB2SQ1 | 420600 | 6693850 | 950 | 0 | Y | L | N |
| LB2SQ2 | 420600 | 6693850 | 950 | 0 | Y | L | N |
| LB2SQ4 | 420600 | 6689750 | 960 | 1 | Y | L | N |
| LB3SQ1 | 418100 | 6692100 | 970 | 1 | Y | M | FB |
| LB3SQ2 | 418100 | 6692100 | 970 | 1 | Y | M | N |
| LB3SQ3 | 418100 | 6692100 | 970 | 1 | Y | M | UFB |
| LB3SQ4 | 418000 | 6691900 | 970 | 1 | Y | M | FUB |
| LB3SQ5 | 418000 | 6691900 | 970 | 1 | Y | M | UFUB |
| LB3SQ6 | 418000 | 6691900 | 980 | 1 | Y | M | N |
| LB1SQ1 | 424500 | 6698950 | 970 | 2 | Y | L | N |
| LB1SQ2 | 424500 | 6698950 | 970 | 2 | Y | L | N |
| LB1SQ3 | 424500 | 6698950 | 970 | 2 | Y | L | N |
| LB1SQ4 | 423950 | 6698850 | 975 | 2 | Y | L | N |
| LB1SQ5 | 423950 | 6698850 | 975 | 2 | Y | L | N |
| LB1SQ6 | 423950 | 6698850 | 975 | 2 | Y | L | N |
| GN6SQ1 | 420750 | 6689900 | 935 | 1 | Y | M | N |
| GN6SQ2 | 420750 | 6689900 | 935 | 1 | Y | M | FB |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| GN6SQ3 | 420750 | 6689900 | 935 | 1 | Y | M | UFB |
| GN6SQ4 | 420850 | 6689900 | 940 | 1 | Y | M | FUB |
| GN6SQ5 | 420850 | 6689900 | 940 | 1 | Y | M | UFUB |
| GN6SQ6 | 420850 | 6689900 | 940 | 1 | Y | M | N |
| GN2SQ1 | 424600 | 6688900 | 935 | 1 | Y | L | UFWF |
| GN2SQ2 | 424600 | 6688900 | 935 | 1 | Y | L | N |
| GN2SQ3 | 424600 | 6688900 | 935 | 1 | Y | L | UFWF |
| GN2SQ4 | 425600 | 6689200 | 980 | 1 | Y | M | FWF |
| GN2SQ5 | 425600 | 6689200 | 980 | 1 | Y | M | FWF |
| GN2SQ6 | 425600 | 6689200 | 980 | 1 | Y | M | N |
| GN11SQ1 | 425200 | 6687500 | 995 | 3 | Y | M | N |
| GN11SQ2 | 425200 | 6687500 | 995 | 3 | Y | M | FWF |
| GN11SQ3 | 425200 | 6687500 | 995 | 3 | Y | M | UFWF |
| GN11SQ4 | 425200 | 6687700 | 990 | 3 | Y | M | FWF |
| GN11SQ5 | 425200 | 6687700 | 990 | 3 | Y | M | UFWF |
| GN11SQ6 | 425200 | 6687700 | 990 | 3 | Y | M | N |
| GN3SQ1 | 423050 | 6688775 | 935 | 0 | Y | M | UFWF |
| GN3SQ2 | 423050 | 6688775 | 935 | 0 | Y | M | N |
| GN3SQ3 | 423050 | 6688775 | 935 | 0 | Y | M | FWF |
| GN3SQ4 | 422750 | 6689000 | 950 | 0 | Y | M | N |
| GN3SQ5 | 422750 | 6689000 | 950 | 0 | Y | M | FWF |
| GN3SQ6 | 422750 | 6689000 | 950 | 0 | Y | M | UFWF |

Fire history - the number of recorded fires that area has experienced (digital data from NSW NPWS & SFNSW); Evidence of fire - scorching on trees and charcoal on ground present (Yes / No); Disturbance class - 'm' more, 'l' less; Treatment - UFUB unfenced unburnt, FUB fenced unburnt, UFB unfenced burnt, FB fenced burnt, UFWF unfenced wildfire, FWF fenced wildfire, N not used. NB: It is now thought that LB3 should be classed as less rather than more disturbed.

| Borrower | Location | Date borrowed | Returned |
|---|---|---|---|
| Jodie Saville | Dubbo | 16/9/02. | ✓ |
| LAURIE PASCO | ROC SYDNEY REGION | 8/10/03 | ✓ |
| | | | |
| | | | |

| BORROWER | Location | Date borrowed | |
| --- | --- | --- | --- |
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DATE DUE

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