Bryophyte composition in a native grassland community subjected to different long-term fire regimes

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Abstract: The vascular species composition of volcanic plains grassland remnants of western Victoria is strongly tied to management history, with frequently burned remnants often supporting the most diverse native flora relative to grazed and long-unburned remnants. How the fire regime affects the composition of the bryophytic mat, however, has not been documented. I surveyed the moss and liverwort flora of six *Themeda triandra* grasslands subjected to different long-term fire regimes to understand how fire might affect mat composition. A total of 27 non-vascular species (19 mosses and 8 liverworts) were recorded, of which nine species were recorded only from a single location. Non-vascular species contributed 28% of the total diversity observed in this study. The liverwort *Lethocolea pansa* was the most obvious species at all sites, while the mosses *Rosulabryum billardieri* and *Fossombronia intestinalis* were also found at all sites and hence, would appear to be robust to fire at different frequencies. Frequently-burned (1–2 yr interval) grasslands generally had lower mat species richness than longer-unburned sites (4 to >20 yr intervals) and appear to support a subset of the flora (due to the loss of moss species) rather than a distinctly different flora. The preliminary results of this study contrast with the evidence usually found for vascular species, i.e. that frequent fire favours greater native species richness. Hence, the two components of the flora would appear to respond in different ways to fire and this should be considered in the conservation planning for this grassland community. Further field sampling is warranted to confirm the initial trends identified by this study.

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Introduction

Remnant native grasslands on the western volcanic plains, Victoria persist in small areas such as railway verges and cemeteries where domestic stock have been excluded over the last 120 years.These sites have been frequently burned, not for conservation purposes, but to reduce the threat of wild-fire to rural communities (McDougall et al. 1994). The effects of these fire regimes are well known for many plant species (e.g. Stuwe & Parsons 1977, Lunt & Morgan 2002). Frequent fire (e.g. 1–3 year intervals) maintains a species-rich grassland community by mediating the competitive effects of the dominant grass, *Themeda triandra* (Stuwe & Parsons 1977). As time-since-fire increases, the native flora generally becomes depauperate, not successionally different or diverse, i.e. it often represents only a subset of the species that would normally be present in frequently burnt sites (Stuwe & Parsons 1977).

A substantial and largely neglected component of temperate grasslands is the non-vascular species — the mosses and liverworts (= bryophytes), lichens, cyanobacteria, fungi and algae — that carpet the intertussock spaces in a complex mosaic to form a biological soil crust. Scarlett (1994) gives a general account of the biological soil crust of railway reserve *Themeda triandra* grassland remnants in western Victoria, showing that they are dominated by bryophytes rather than lichens and hence, the crust should be more correctly termed a bryophytic mat. Few studies have thoroughly documented the composition of the non-vascular component of grasslands at any site on the volcanic plains in Victoria, and only Morgan and Rollason (1995), who list 32 species for a remnant grassland near Sunbury (comprising 22 mosses and 10 liverworts), have published a non-vascular species list to complement the more usual vascular species list.

The common practice of overlooking non-vascular species in botanical surveys due to their small size and (perceived) difficulties in identification fails to recognise their (a) contribution to local diversity and (b) important ecological role in ecosystems (Eldridge et al. 2003). Including mat species in the species list of a remnant urban grassland in Melbourne, Victoria, for example, increased the known diversity of that remnant by 25% (Morgan & Rollason 1995). Ecologically, biological soil crusts are known to contribute significantly to carbon and nitrogen fixation and soil stabilisation (McKenna-Neuman et al. 1996, Leys & Eldridge 1998), particularly in semi-arid ecosystems, and can both positively and negatively affect germination of native and exotic species in semi-arid and temperate communities (Zamfir 2000, Otsus & Zobel 2004). Biological soil crusts in semi-arid areas are also important indicators of site degradation, often taking long periods (e.g. several decades) to recover after soil disturbance (Belnap 2003).

How non-vascular species have responded to the different fire regimes imposed on volcanic plains grassland remnants of western Victoria over the last century is unknown. All work on the effects of fire on biological soil crusts in eastern Australia has previously been conducted in semi-arid

Table 1. Location of the study sites in western Victoria, their description and long-term burning history.

Site name	Location	Land tenure; size of remnant	Soil features	Annual rainfall (mm)	Alt. (m)	Burning history
Chatsworth Rd (CR)	37°51'S, 143°05'E	Roadside verge; 15 ha	Brown to red-brown clay, pH 6.8	620	195	Burnt annually in late summer since 1950
Victoria Point Rd (VPR)	37°36'S, 142°09'E	Roadside verge; 6 ha	Dark brown clay, pH 6.5	700	250	Burnt every 1–2 yrs in summer for possibly >50 yrs
Doyles Rd (DR)	38º 04'S, 143º 51'E	Roadside verge; 1.5 ha	Dark brown clay; pH 6.5	620	180	Burnt at 1–2 yr intervals in early summer for decades.
Bannockburn (B)	38°02'S, 144°09'E	Railway verge; 3 ha	Brown to red-brown clay; pH 7.1	610	120	Burnt approx. every 3–4 years for last 15-20 yrs
Brewis Rd (BR)	37° 37'S, 142°12'E	Roadside verge; 6 ha	Dark brown to grey clay or clay loam; pH 6.8	700	230	Unburnt for probably much longer than 20 yrs
Rankins Rd (RR)	37°36'S, 143°26'E	Roadside verge; 2 ha	Dark brown clay to clay loam; pH 6.7	630	290	Unburnt for at least 15–20 yrs, probably much longer

ecosystems on sandy soils. Greene et al. (1990) found that annual burning for seven years in a semi-arid woodland completely destroyed the cryptogamic layer, whilst Eldridge and Bradstock (1994) found that frequent fire maintained cryptogamic cover at low levels in a eucalypt shrubland. Are similar effects also occurring in a temperate plant community on clay-rich soils that is likely to have experienced very frequent fire? The aim of this study was to document the composition of the bryophytic mat (specifically the mosses and liverworts) of six native grassland sites that had been subjected to different long-term fire regimes.

Methods

Study sites

The study was conducted on the flat to undulating treeless volcanic plains of western Victoria. The soils are red-brown to grey acidic cracking-clay loams to clays of variable depth on Quaternary basalt (Stuwe & Parsons 1977). The climate is temperate with cool winters (mean minimum temperature of the coldest month (July) is approximately 4°C) and warm summers (mean maximum temperature of the warmest month (January) is approximately 26°C) (Bureau of Meteorology & Walsh 1993). Rainfall is evenly distributed throughout the year, with a slight peak in spring (September), but summer drought is common. A rainfall gradient exists from west (high) to east (low) across the plain.

A tussock grassland community dominated by *Themeda triandra* (Kangaroo Grass) naturally occupied approximately half of the 21 000 km^2 volcanic plain (McDougall et al. 1994). Species from the Asteraceae, Fabaceae, Cyperaceae and Liliaceae are common in the intertussock spaces.

Since European settlement, much of the volcanic plains land-scape has been converted to agriculture and remnants of the original vegetation have been reduced to tiny fragments where stock grazing and pasture improvement have been minimal or absent (McDougall et al. 1994). Disturbance has usually been restricted to frequent burning (i.e. 1–3 yr intervals) in summer by rural fire brigades to reduce the chance of wildfire to local communities (McDougall et al. 1994). Along railway lines, the railway verge was usually burnt, almost annually, in late-spring and early summer to prevent fires igniting from passing steam trains (Stuwe & Parsons 1977).

Floristic composition of sites with different fire histories

The chronosequence method was used to document change in biological soil crust composition with different fire regimes. This method assumes that the grassland sites studied were floristically similar across their range before different management strategies were imposed decades ago. The approach also assumes that the site floras which have subsequently developed are a consequence of the management regime, although chance events, climatic and soil variation undoubtedly also play a major role (McDougall et al. 1994). Caution is therefore warranted when interpreting the effects of fire history on biological soil crust composition, although some of this uncertainty can be reduced by replicating the observations of the management regimes under study by including multiple sites that have been subjected to these 'treatments'.

Six native grasslands dominated by *Themeda triandra* were selected to encompass the range of burning management regimes in the area (i.e. infrequent (i.e. >15 yrs) burning for extended periods (2 sites), annual (3 sites) or 4-yr interval (1 site) fire frequencies that have been perpetuated for decades) (Table 1). Sites were selected on the basis that their management history was well known, that exogenous soil disturbance was minimal and that the vegetation was dominated by native species. Management history was obtained from published and unpublished literature, and from discussions with local fire brigade members.

In August 1998, a single 150 m^2 quadrat was randomly located at each site in visually homogenous vegetation to characterise the non-vascular and vascular species composition. The sites were surveyed using a timed meander search (60 minutes). Moss and liverwort species were

Table 2. Biological soil crust composition of native grassland sites subjected to different long-term fire histories. See Table 1 for explanation of site codes and burning history.

Abundance was estimated in each 150 m² quadrat: + = present as few traces or small colonies; 1 = becoming conspicuous but with low cover; 2 = a prominent feature and cover obvious.

	Sites					
Species	**CR**	**VPR**	**DR**	**B**	**BR**	**RR**
Mosses						
Archidium stellatum	1			1		1
Barbula crinita			1	1	1	1
Bartramia ithyphylla				1		1
Bartramia stricta			2	1		
Breutelia affinis					2	
Bryum dichotomum	1	1	1	1	1	
Campylopus clavatus		1		1	1	1
Fissidens sp.	1			1		1
Fissidens megalotis		1				
Fissidens taylorii	1			1		1
Fissidens tenellus		1				
Gigaspermum repens				+		
Hypnum cupressiforme					2	
Philonotis tenuis		1	1			1
Pleuridium nervosum				1		
Polytrichum juniperinum						1
Rosulabryum billardieri	1	1	1	1	1	1
Totula atrovirens					1	
Triquetrella papillata					1	1
Liverworts						
Anthoceros sp.	1	1				1
Asterella drummondii					1	1
Cephaloziella exiliflora			1			
Chiloscyphus semiteres				1	1	1
Fossombronia intestinalis	1	1	1	1	1	1
Fossombronia sp.	1	1				1
Lethocolea pansa	2	2	2	2	2	2
Riccia bifurca	1	1		1		1
Total No. of Mosses	5	5	6	11	8	10
Total No. of Liverworts	5	5	3	4	4	7
Total Species Richness	**10**	**10**	**9**	**15**	**12**	**17**

searched for between tussocks and on any outcropping rock present. They were then recorded and collected and assigned a nominal abundance value using Watson (1960) as a guide, to illustrate their relative importance (Table 2). Fungi and algae were regrettably ignored while lichens were uncommon. All vascular species present were also recorded and the percent cover of the dominant grass, *Themeda triandra*, was estimated in ten 1 m² quadrats haphazardly placed throughout the larger quadrat. Non-vascular species were identified in the laboratory using a dissecting microscope and voucher specimens retained. Mosses and liverworts were identified using the keys of Scott and Stone (1977) and Catcheside (1980) while nomenclature follows Meagher and Fuhrer (2003).

The relationship between vascular species richness and non-vascular species richness was examined by Spearman rank correlation (Quinn & Keough 2002), as was the relationship between non-vascular richness and mean percent cover of *Themeda triandra*.

Results

A total of 27 bryophytes (Table 2) and 69 vascular species were recorded at the six sites with mosses more common (19 species in total) than liverworts (eight species in total). Hence, non-vascular species contributed 28% of the diversity observed in this study. Bryophytic mat species richness was low at all sites (9–17 species per quadrat) and lower in sites burnt annually (mean 9.7 species per quadrat) than sites burnt at 4–20 year intervals (mean 14.7 species per quadrat). The liverwort *Lethocolea pansa* was found at every site and was also the most conspicuous non-vascular species (by cover) at all sites. The mosses *Rosulsabryum billardieri* and *Fossombronia intestinalis* were also found in all grasslands. Nine soil mat species, eight of which were mosses, were recorded from a single site (Table 2). Fifty percent of these 'singleton' mosses were found in the two unburnt sites. Frequently burnt sites appear to support a subset of the longer-unburnt non-vascular flora rather than a distinctly different flora (Table 2). This simplification results mostly from losses in mosses with increasing frequency of fire (Table 2). The liverwort *Chiloscyphus semiteres* was also conspicuously absent from sites burnt more frequently than every 3–4 years (Table 2).

No significant correlation was found between non-vascular and total vascular species richness ($r = 0.055$, $p = 0.913$). Non-vascular species richness was strongly associated, however, with mean percent cover of *Themeda triandra* ($r = 0.925$, $p = 0.008$, Fig. 1).

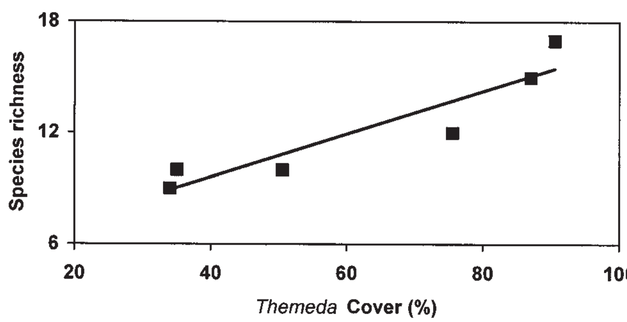

Fig. 1. Relationship between the cover (%) of the dominant grass *(Themeda triandra)* and the number of bryophytic mat species sampled from six grasslands in western Victoria.

Discussion

This preliminary study suggests that frequent fire may reduce the number of mat-forming species (specifically mosses) found in the intertussock spaces of *Themeda*-dominated grasslands on the volcanic plains of western Victoria. Moss richness was higher in longer unburned areas, suggesting that mosses do not survive repeated fire at short return intervals. This may be due to the effects of fire *per se* consuming plants or the post-fire environment which may be much drier. By contrast, liverworts were found at all sites, often at high cover, suggesting a greater resilience to fire.

The exception was *Chiloscyphus semiteres;* this species was absent from annually burnt sites but found elsewhere. The preliminary data therefore suggest that differences in bryophytic mats after fire are mostly the result of the slow recovery of the mosses as has been found in other ecosystems (Johansen et al. 1984). Management practices would therefore appear to be potentially important influences on mat composition in grasslands as they may impact on recolonization patterns. Changes in fire regimes are likely to have the most effect on the non-vascular flora and should be considered in conservation planning. In particular, sites that go from being infrequently- to frequently-burnt may lose aspects of the moss and liverwort flora (Greene et al. 1990, Hilty et al. 2004). Detailed surveying of the biological soil crust at a range of temperate grassland sites with different fire frequencies is necessary to determine whether these initial trends are supported. An important analogous question is whether grassland sites currently experiencing high fire frequencies can recover bryophtic mats with a reduction in their fire frequency. This is completely unknown and worthy of future study.

The effects of fire on bryophytic mat diversity reported here, however, have some similarity with the findings of studies conducted on biological soil crusts in semi-arid rangelands. Eldridge and Bradstock (1994) found that moss cover declined after annual fire on aeolian sands and that their recovery may take many years, if not decades. Where fire is very frequent, only algae were present. Similarly, Johansen et al. (1984) report the slow recovery of mosses after fire in desert rangelands in Utah, USA, such that five years after fire, recovery was not complete either in terms of biomass or composition.

Some differences in the response to fire of temperate grassland soil mats relative to semi-arid biological crusts, however, are also obvious. While single fire events have been reported to reduce the abundance of liverworts in some habitats (e.g. Florida rosemary scrub (Menges & Kohfeldt 1995) and desert rangelands (Johansen et al. 1984)), liverworts were common at all sites in the present study regardless of fire frequency. *Lethocolea pansa* was one of the conspicuous and dominant species at all sites, suggesting that responses of bryophytic mats to fire may be species-specific. Additionally, frequent fire has probably been a feature of temperate grasslands in south-eastern Australia for centuries (Lunt & Morgan 2002) and hence, fire-sensitive crust species are likely to have been eliminated there long ago unlike many of the less frequently burnt semi-arid communities where much of the biological crust research has been conducted (Eldridge 2003).

No simple linear relationship was observed between vascular and non-vascular species richness in this study. Species-rich grasslands in southern Victoria generally occur in areas ungrazed by stock where fire is sufficiently frequent (i.e. 1–3 yr intervals) to prevent competitive exclusion (for space, light, water, nutrients) by the dominant tussock grasses (Lunt & Morgan 2002). By contrast, the richest bryophytic mats observed in the present study occurred where fire was less frequent and hence, sufficient time elapsed between fire events for the slow recolonisation of species and/or development of microsite conditions conducive to bryophytes. These areas often support lower vascular species richness. Dominant grass (*Themeda*) cover is highest in the longer unburned sites and this canopy cover may provide shade and protection from desiccation for many non-vascular species such as *Triquetrella papillata* (Eldridge et al. 2000), although deep shading and litter deposition for extended periods can reduce their cover (Scarlett 1994). Interestingly, biological crust cover also declines in long unburned mallee shrublands due to increases in litter (Eldridge & Bradstock 1994) and in ungrazed disclimax native grassland (Eldridge et al. 2000).

The vascular and non-vascular flora of the temperate grasslands in the present study recover from fire at considerably different timescales. While frequent fire favours vascular species richness due to resprouting of the bud and tuber bank (Lunt & Morgan 2002), such fire regimes do not enable maximal species diversity of bryophytic mat species to develop. This difference should be given some consideration when conservation planning for temperate grasslands is undertaken. Clearly, it will be almost impossible to maximize both vascular and non-vascular species richness using a single fire regime. A range of fire regimes is warranted across the range of grassland remnants that persist to conserve the greatest range of vascular and non-vascular flora. Using a range of fire regimes across the landscape has been acknowledged as important for vascular species conservation (Scarlett & Parsons 1982). However, non-annual fire regimes are necessary to promote rare legumes and some shrub species and it appears that non-vascular species richness will also benefit greatly by maintaining longer fire-free intervals. The complete absence of fire (or disturbance *per se*), however, is likely to lead to declines in richness of both non-vascular (Eldridge et al. 2000) and vascular species (Stuwe & Parsons 1977). While the findings presented here should be considered preliminary, it appears that greater attention to bryophytic mat diversity, ecology and function is warranted in native temperate grasslands.

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