Manipulating shrub cover on Victorian fuelbreaks to reduce weed invasion

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Summary Fuelbreaks in the Central Highland of Victoria are constructed to provide safe and reliable access for fire suppression and management activities. Fuelbreaks have higher risk of invasion by exotic plants than undisturbed forest and the vegetative condition of fuelbreaks largely determines the abundance and diversity of invasive plants. In particular, there is much lower abundance and diversity of exotic plants when shrub cover is at least 5%, compared to when shrub cover is less than 5%. This study relates the probability that shrub cover is at least 5% to location characteristics. It is found that shrub cover is most likely to be greater than 5% in young forests with lower soil disturbance and lower age since fire. Manipulating shrub cover on fuelbreaks, *via* ongoing management of disturbance, fire and slashing, offers a potential means of minimising exotic invasions on strategic fuelbreaks.

Keywords Bushfire, water catchments, fire, disturbance, exotic plants.

INTRODUCTION

Fuelbreaks are contiguous linear areas 20–50 m wide where almost all woody understorey vegetation and most trees are removed to provide safe and reliable access for strategic fire management operations (MacHunter and Menkhorst 2009**)**.

In the Victorian Central Highlands, severe wild fire is a significant threat to human habitation, natural assets and infrastructure. A network of fuelbreaks has been constructed to provide strategic access to Melbourne's water catchment areas and neighbouring population centres to assist with fire suppression and fire management activities (Mueck *et al*. 2007).

Construction of fuelbreaks involves multiple disturbance forms causing severe disruption to soils and vegetation. Disturbance increases the risk of invasion of exotic plant species (Hobbs 1989, 1991, Sakai *et al*. 2001). In the USA, construction of fuelbreaks facilitates the movement and expansion of weeds and pests (Keeley 2006, Merriam *et al*. 2006) raising concerns that similar processes may operate in temperate sclerophyll vegetation of Victoria.

A study of the factors determining the distribution and abundance of exotic plants on Victorian fuelbreaks identified that low species richness and cover of exotic plants is associated with the 'vegetative state' of the fuelbreak (Adair and Butler 2012). In particular, herbaceous canopy cover <5% and shrub canopy cover >5% were found to be highly influential on the abundance and diversity of exotic plants.

Although the mechanism underlying the association between shrub cover >5% and low cover and richness of exotic plants are unclear, manipulation of shrub cover levels on fuelbreaks may offer a means of suppressing exotic plants, providing the fire management functions of fuelbreaks are not compromised (Adair *et al.* 2012). With this in mind, the present study investigates the relationship between the occurrence of shrub cover >5% at fuelbreak sites and characteristics of those sites.

MATERIALS AND METHODS

One hundred and six sites were randomly selected on Central Highlands Victorian fuelbreaks and sampled for vegetation, topographic and land-use attributes following the methods of Adair *et al*. (2012). In relation to this paper, the canopy cover for shrubs were assigned to cover class categories where [+ = less than 5% cover, 1 = 5–25% cover, 2 = 25–50% cover, 3 = 50–75% cover and 4 = greater than 75% cover].

Statistical analysis The occurrence of shrub cover greater than 5% was characterised by calculating a 0–1 variate that took the values 0 if shrub cover was less than 5% and 1 if shrub cover was greater than 5%. Then, a parsimonious logistic linear model was developed to relate this variate to site characteristics (Table 1). Analysis of deviance X^2 tests were used to select terms for inclusion/exclusion in parsimonious models. Confidence intervals were calculated using the asymptotic normal approximation on the logistic scale, and then back-transforming to the actual number scale.

RESULTS

Thirteen of the 106 sample sites (12%) had shrub cover greater than 5%. There were 74 native species of woody shrub recorded on fuelbreaks, but only 18

Table 1. F and P values for including and excluding terms in the logistic regression model for occurrence of shrub cover greater than 5%.

	F value	Degrees of freedom	P value
Terms Included			
Years since fire	4.50	1	**0.034**
Disturbance class variate	10.11	1	**0.0015**
Age of break grouping	18.31	1	**0.000019**
Terms Excluded that are an expansion of terms in the model			
Square of years since fire	0.33	1	0.57
Any further age of break effect	4.11	3	0.25
Any further disturbance class effect	1.06	3	0.79
Interaction Terms Excluded			
Product of disturbance class variate and years since fire	1.34	1	0.25
Response to disturbance class variate differs with age of break grouping	Not estimable because all forests in 70 year grouping do not have shrubs (<5% cover)		
Response to years since fire variate differs with age of break grouping	Not estimable because all forests in 70 year grouping do not have shrubs (<5% cover)		
Additional Terms Excluded			
EVC name	16.65	17	0.48
Bioregion	2.40	2	0.30
Aspect category	1.67	3	0.64
Slope	0.28	1	0.60
% canopy openness	0.12	1	0.73
Tree height	1.56	1	0.21
Number of trees	0.42	1	0.52
Distance to location	1.33	1	0.25
Distance class to road	4.09	4	0.39
Road access category	3.17	2	0.21
Road class category	0.08	1	0.78
Road type category	1.11	1	0.29
Distance to water course	0.03	1	0.86
Distance to agricultural land	0.02	1	0.90
Distance to private property	0.48	1	0.49
Distance to town centre	1.05	1	0.31
Distance to coupe	0.01	1	0.93
Fire type	0.03	1	0.87
Year since logged	0.93	1	0.34
Break width	0.01	1	0.92
Quadrat size	0.46	2	0.80

species had sampling frequencies >10%. The sample sites in this study differed substantially in vegetation, geographic and land use and pattern variables (Adair and Butler 2012).

The most parsimonious model for occurrence of shrub cover > 5% is of the form (Table 2):
$\text{logit}(p) = \alpha_i + \beta_1$ Disturbancevar $+ \beta_2$ YearsSinceFire

where

- p is the probability that a site has shrub cover >5%,
- logit is the logistic transformation i.e. $\text{logit}(x) = \log_e(x)/(1 + \log_e(x))$,
- α_i is a parameter that differs depending on whether the fuelbreak is 1-4 years old or 70 years old, β_1 and β_2 are single parameters,

- Disturbancevar is a variate that describes the level of ground disturbance on fuelbreaks at sample sites. It takes the values 0, 1, 2, 3, 4 and 5 with 0 being no disturbance and 5 being highly disturbed.

None of the 31 older (about 70 years) fuelbreak sites had shrub cover greater than 5%. The statistical significance for a difference in shrub cover between older and younger (1–4 year) sites, after adjusting for other terms in the model, was $p = 0.00002$. This implies that shrub cover greater than 5% on older fuelbreaks cannot be explained by observed disturbance and time since the last fire.

On younger fuelbreaks, the occurrence of shrub cover >5% declined strongly as the level of disturbance increased from category 2 through to category 5 (Figure 1). There was also a decline in the occurrence of shrub cover >5% as the time since the last fire increased (Figure 2).

DISCUSSION

Post-construction regeneration of shrubs on fuelbreaks can be rapid, but few of the 78 shrub species recorded from fuelbreaks were common on fuelbreaks in any age class category. The most frequent species (*Cassinia aculeata*, *Daviesia ulicifolia*, *Olearia phlogopappa*, *Coprosma quadrifida, Polyscias sambucifolia*) are early seral colonisers of disturbed soils in the region. The level of shrub cover on fuelbreaks varied considerably, with some sites having 50–75 % cover (Adair and Butler 2012), but most sites had relatively low cover levels (<5%).

At least for the younger fuelbreaks (up to 4 years old), the occurrence of shrub cover >5% was strongly negatively associated with soil disturbance i.e. the greater the disturbance, the less shrub cover was present. In contrast, exotic plant richness and abundance (cover) has no relationship with soil disturbance, after adjusting for the 'vegetative state' of fuelbreaks (Adair and Butler 2012). This latter response can alternatively be re-stated as: knowledge about exotic richness and abundance available from 'vegetative state' and disturbance combined is the same as knowledge available from 'vegetative state' alone. An immediate corollary is that if amount of disturbance changes vegetation to a state that is more conducive to higher exotic richness and cover, then this disturbance is likely to increase exotic species and richness. Putting our results of a relationship between shrub cover >5% negatively associated with soil disturbance together with this corollary, suggests that reducing soil disturbance on fuelbreaks could indirectly reduce exotic plant invasions by allowing increased shrub cover.

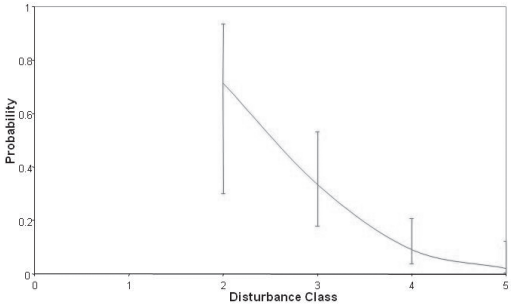

Figure 1. Effect of disturbance class on the probability of occurrence of shrub cover greater than 5% at 1 to 4 year old sites, after adjusting for the effect of years since fire on the logistic scale. Results are presented at the average value of years since fire for 1 to 4 year old sites. The disturbance class categories are 0 = no observable ground disturbance, 1 = low levels of ground disturbance, mostly natural, 2 = light to moderate ground disturbance but restricted in distribution, 3 = ground disturbance over most of quadrat but deep, fresh or gross disturbance absent, 4 = overturned soil present, rutting, mounding, or soil removal present and occasional to moderate, 5 = high levels of soil rutting, mounding, or removal and present over much of the site. Error bars are 95% confidence intervals.

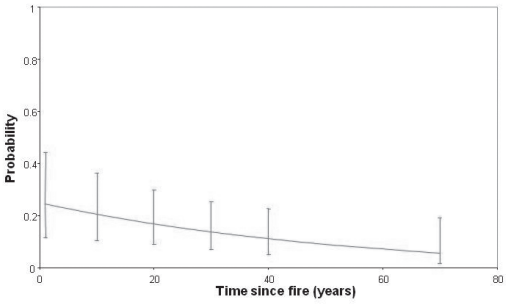

Figure 2. Effects of years since fire on the probability of occurrence of shrub cover greater than 5%, after adjusting for the effects of disturbance class on the logistic scale. Results are presented at the average value of the disturbance class variate since fire for 1 to 4 year old sites. Error bars are 95% confidence intervals.

Aside from initial fuelbreak construction activities, disturbance on fuelbreaks is largely generated by illegal off-road traffic, which can be intense in areas where access is not restricted. Soil churning, rutting and erosion are typical on more disturbed breaks and

clearly have degrading impacts on vegetation. Our results indicate, that in younger firebreaks, even a moderate reduction in disturbance could provide a strong response in the occurrence of shrub cover >5%, and consequently a large reduction in exotic plant richness and abundance.

Another apparent requirement to achieve shrub cover > 5% is to limit the time since the last fire. This is not surprising since most of the common shrubs on Central Highlands fuelbreaks proliferate following fire and reach maximum densities and cover within 10 or so years, before declining. The association we have detected suggests that fire may be a useful indirect method of manipulating shrub cover to minimise exotic plant abundance and richness on fuelbreaks. These considerations should be included in fuel management programs for the region.

The level of shrub cover on fuelbreaks is undoubtedly influenced by slashing frequencies, a factor we were not able to incorporate into model constructions. Fuelbreaks are slashed every one to few years to reduce the biomass and therefore combustible matter on fuelbreaks. This influence, together with the effects of soil disturbance and age since last fire, suggests that it may be possible to manage fuelbreaks in a manner to achieve shrub cover >5%, and consequently lower levels of exotic plant diversity and abundance.

There was a large effect of fuelbreak age on shrub cover >5%, even after allowing for the effects of soil disturbance and age since fire. This effect led to a zero occurrence of shrub occurrence >5% for those fuelbreaks set up after the 1939 fires. However, we suggest that the most likely reason for this otherwise unexplained age effect is a long history of slashing, which selects against shrub development, historical disturbance and fire suppression. None of the variables measured in our study can account for these factors.

Fuelbreaks are constructed to provide safe and reliable access for strategic fire management operations (MacHunter and Menkhorst 2009**)**. Although shrub cover is managed with these important objectives in mind, manipulation of shrub cover may also provide a means of suppressing exotic invasions on fuelbreaks. Slashing, disturbance management and fire management are likely to be important tools in this process. The prescriptions that meet both fuel and weed management requirements need development and validation.

ACKNOWLEDGMENTS

We thank Sarita Kulkarni for preparing data for analysis. The Office of Land and Fire (Department of Sustainability and Environment) provided the financial support for this project.

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