Post-fire litter accumulation under mallee canopies in south-western NSW

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Abstract

Fire management is an important issue for landholders in mallee areas. Relationships between eucalypt litter fuel loads and fire intensity are well researched, but basic information on fuel re-accumulation after fire is lacking. We compared differences in litter bed size beneath mallee trees with increasing time since fire, and related tree dimensions to litter bed size across a short spectrum (3, 13 and >30 years) of time since fire. As expected, all tree and litter dimensions increased significantly with time since fire with the exception of litter density. Litter density (kg m^{-3}) was significantly greater 13 years after fire than 30 years after fire. This is likely due to changes in litter composition with increasing time since fire. Canopy area was the best predictor of litter bed area (R^2=0.73) and volume (R^2 = 0.81). Our data confirm that relationships identified between crown size and litter bed size are upheld in recently burnt mallee communities.

Introduction

The mallee eucalypt community is particularly well adapted to cycles of fire (Whittaker *et al.* 1979) and fire management is an important issue for landholders in mallee areas (Bradstock and Cohn 2002). The discontinuous canopy of mallee results in a highly variable spatial arrangements of surface litter, which is concentrated around individual plants (Bradstock and Gill 1993; McElhinny *et al.* 2010). Litter cover alone is often insufficient to sustain spreading fires, though fuel loads of litter may determine fire intensity and the rate of fire spread (Bradstock and Cohn 2002). Basic information on the rate of fuel re-accumulation after fire is however lacking (Bradstock and Gill 1993; Bradstock *et al.* 2010).

Although general trends exist between crown cover and litter bed size (Bradstock and Gill 1993, Bradstock and Cohn 2002), there are few data on empirical changes to litter bed dimensions as a function of time since fire. In this study we investigate how time since fire affects litter bed size beneath mallee Eucalypt trees. Additionally, we relate tree dimensions to litter bed size across a short spectrum of time since fire.

Methods

The study was conducted in dune mallee at the Australian Wildlife Conservancy's Scotia Sanctuary in south-western NSW in January 2010. We sampled two areas burnt under equivalent high intensity fire in the summer of 2006/2007 (3 years since fire) and 1996/1997 (13 years since fire); and one control area (>30 years since fire). In each area we established four sites (blocks) and sampled three trees in each block. We also measured tree height, two canopy diameters (to calculate elliptical canopy area), number of stems, and diameter of the largest stem (measured 10 cm above the ground surface). A sample of litter was collected in a circular quadrat of 0.03 m^2 at each tree, dried at 60°C and weighed.

Around each tree, we established six transects extending from the base of the tree to the edge of the continuous litter bed. Along each transect we measured litter bed length and depth and three locations (tree base, mid-canopy, canopy edge). Litter area was calculated from the sum of six partial ellipses derived from the litter cover. Litter volume was calculated from the sum of six volumes of litter depth. Volumes were calculated by the cylindrical shells method by fitting a quadratic curve (R^2>0.99) to the three depths at each transect and solving for transect length.

We used a nested analysis of variance to determine differences between burn sites for all tree and litter dimensions. Measurements were $\log_{10}$ or square-root transformed where required to meet the assumptions of ANOVA. We used quadratic regressions to determine the line of best fit for the relationship between tree dimensions and litter bed dimensions across all sites.

Results

There were significant differences in tree and litter dimensions among all three times since fire (Table 1). Trees were significantly taller, with a greater canopy area, and had fewer stems with larger stem diameters with increasing time since fire. Litter dimensions also increased with time since fire, with significantly longer litter bed length, larger litter area and greater litter volume. The total litter density (kg m^{-3}) peaked at 13 years since fire (Table 1). Litter depth decreased significantly with distance from the tree, while the depth of litter significantly increased with time since fire (time since fire by location interaction: $F_{4,606}$= 248.32, P< 0.001, Table 1). Additionally, the depth of litter was unevenly distributed around each tree (Transect effect: $F_{24, 606}$= 248.32, P<0.001).

Canopy area explained 73% of the variation in litter area (Litter Area = 0.0003*canopy $areas^2$ + 0.1025*canopy area + 0.2529; $F_{2,33}$= 43.99; P<0.001; R^2=0.73) and 81% of litter volume ($F_{2,33}$= 69.42; P<0.001; R^2=0.81; Fig. 1). The diameter of the largest stem was the best predictor of the litter bed length (litter length = –0.0487*stem $diameter^2$ + 5.3636*canopy area – 4.2171; $F_{2,33}$= 41.02; P<0.001; r^2=0.713). Litter density was best predicted by average transect length (Litter density = 0.4478*average transect length + 7.062; $F_{1,34}$= 64.82; P<0.001; R^2=0.66).

Table 1. Mean (± SE) tree and litter dimensions for each burn site. Different superscripts indicate significant differences between burns at P<0.05 using Fisher's LSD test.

Attribute	3 years		13 years		+30 years		$F_{2,9}$	P
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Tree height (m)	1.50	0.07[a]	2.21	0.08[b]	9.13	0.78[c]	248.32	<0.001
Canopy area (m^2)	3.64	0.31[a]	10.27	0.85[b]	66.61	9.22[c]	127.78	<0.001
No. of stems	22.17	1.49[a]	11.75	0.52[b]	6.16	0.76[c]	51.52	<0.001
Stem diameter (cm)	6.08	0.47[a]	13.29	0.71[b]	50.42	3.54[c]	261.91	<0.001
Litter bed length (m)	0.13	0.01[a]	0.75	0.03[b]	1.32	0.09[c]	40.69	<0.001
Litter area (m^2)	0.05	0.01[a]	1.86	0.30[b]	5.68	0.92[c]	25.89	<0.001
Litter volume (m^3)	0.001	0.0003[a]	0.028	0.005[b]	0.24	0.05[c]	28.02	<0.001
Litter density (kg m^{-3})	92.0	20.54[a]	156.6	64.4[b]	69.6	7.29[a]	5.30	<0.001
Litter depth (cm)								
• Base	1.52	0.13[a]	5.04	0.25[b]	4.17	0.30[c]	81.97	<0.001
• Mid	1.10	0.10[d]	1.71	0.11[e]	3.50	0.23[f]		
• Edge	0.58	0.00[g]	0.63	0.06[g]	1.04	0.10[d]		

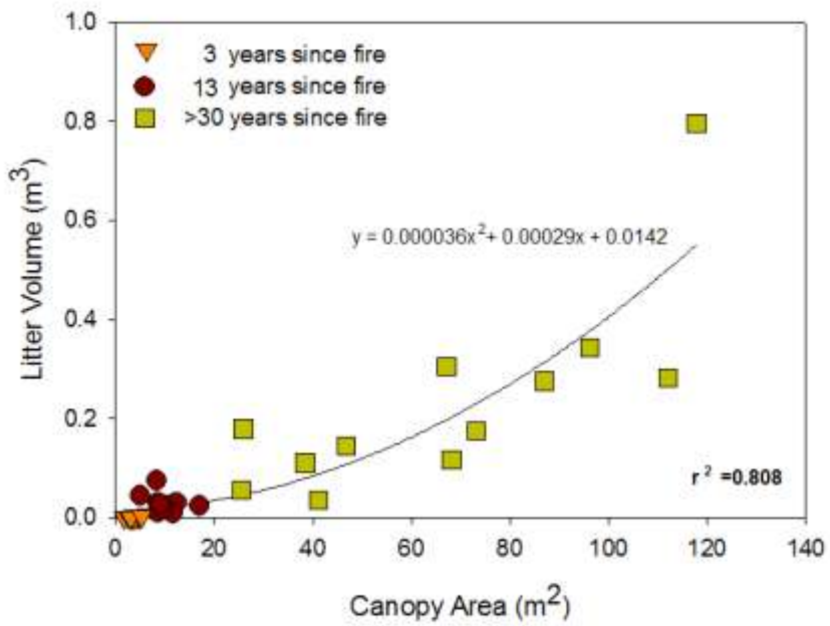

Fig.1. Litter volume (m^3) in relation to canopy area (m^2) for all sites. Regression equation shown, where y= litter volume (m^3) and x= canopy area (m^2).

Discussion

We found that litter density did not increase linearly with time since fire. This is likely due to changes in litter composition, potentially from variations in decomposition rate between litter components, or from a greater proportion of litter accumulating as suspended material in large trees (Bradstock and Gill 1993). Litter depth significantly decreased with distance from the base of the tree and was highly variable around each individual tree. Similar observations have been reported elsewhere (e.g. Bradstock and Gill 1993). More importantly, we found an overall increase in litter depth with time since fire. Previous studies have found that canopy dimensions are proportional to the length of the litter bed below the canopy (McElhinny *et al.* 2010). However, unlike single-stemmed trees, mallee has an irregular growth form, so the deepest part of a mallee canopy may not be directly above the stem base. This may explain our highly variable litter depths both around each tree, and across times since fire.

The diameter of the largest stem was the best predictor of litter bed length, and litter bed length was the best predictor of litter density. Similarly McElhinny *et al.* (2010) found tree diameter at breast height to be a better predictor of litter load than tree basal area. Overall tree size and litter bed size increased proportionally with time since fire. Existing trends between canopy area and both litter area and volumes were upheld across a variety of tress sizes, irrespective of fire history. In general strong relationships exist between surface litter load and the volume (and area) of a tree crown as litter will shed onto a surface area proportional to canopy size in scattered tree ecosystems (McElhinny *et al.* 2010). We have demonstrated that such relationships are upheld in recently burnt dune mallee.

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