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Supplementary Material

Impact of high-severity fire in a Tasmanian dry eucalypt forest

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Appendix 1. Typical remnant dry eucalypt forest in the Tasmanian Midlands, 7 years post-fire

Many eucalypts have recovered via epicormics resprouting, but some individuals were killed. There has been extensive seedling and sapling recruitment, mainly of acacias

Appendix 2. Density by species of live seedlings and trees in long-unburnt and burnt plots

The number of plots (*n*) where the species was present is also listed. Sapling densities were clearly influenced by time since fire, so are shown according to the following three categories: long-unburnt, recently burnt and burnt recovering. Densities for individual species are averaged and analysed only for the plots where the species was present to avoid zero-inflated datasets (analyses of density were performed only on species present at >16 sites). Densities for 'all acacias', 'all eucalypts' and 'all species' were averaged and analysed over all plots, whether or not present in that plot. *w*+ indicates the Akaike weight for the term fire in the presence/absence binomial model set and the density linear model set (only plots where present). Values of *w*+ > 0.73, indicative of a real effect of fire, and the means to which they apply, are shown in bold. 'n.a.' indicates not applicable (present at too few sites)

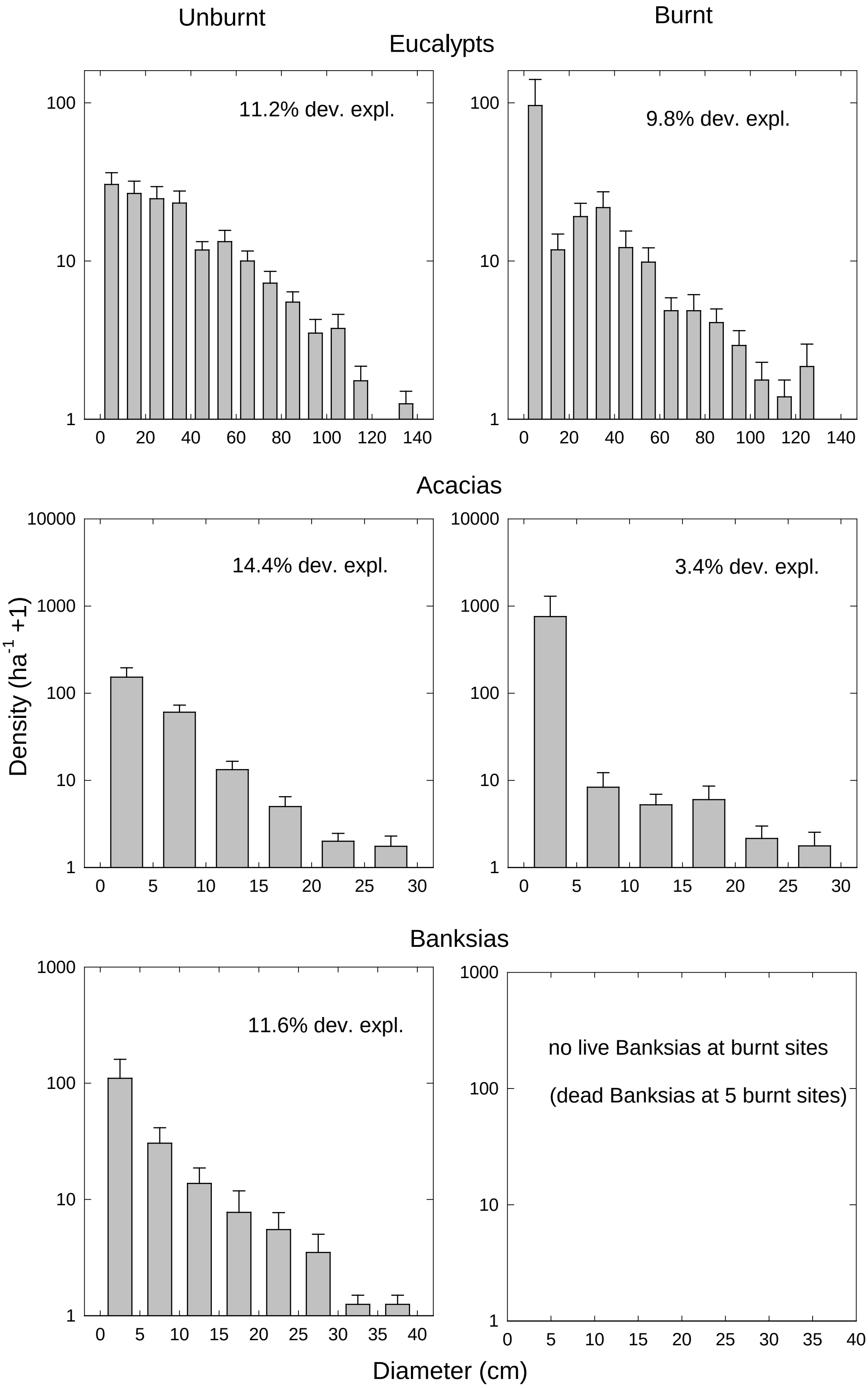
Species	Long-unburnt			Burnt			*w*+ fire	
	n (plots /20)	Density (ha^{-1})	s.e.	*n* (plots /13)	Density (ha^{-1})	s.e.	Presence/ absence	Density
Trees								
Acacia dealbata	**19**	78	15	**7**	32	4	**0.95**	0.38
Allocasuarina	7	46	15	2	15	4	0.40	n.a.
Banksia marginata	**11**	96	23	**0**	n.a.	n.a.	**1.00**	n.a.
Eucalyptus amygdalina	19	117	17	12	81	16	0.24	0.43
Eucalyptus ovata	0	n.a.	n.a.	1	5.0	n.a.	0.44	n.a.
Eucalyptus pauciflora	3	28	5	0	n.a.	n.a.	0.60	n.a.
Eucalyptus rubida	0	n.a.	n.a.	1	25	n.a.	0.44	n.a.
Eucalyptus viminalis	**17**	26	6	**5**	38	13	**0.94**	0.27
Eucalyptus – unidentified	2	7.5	0.8	1	5.0	n.a.	0.23	n.a.
Exocarpos cupressiformis	3	6.7	0.6	0	n.a.	n.a.	0.60	n.a.
All acacias	**19**	**74**	15	**7**	**16**	5	**0.95**	**0.99**
All eucalypts	20	**138**	17	13	**87**	15	0	**0.80**
All species	20	**283**	24	13	**105**	17	0	**1.00**
Seedlings								
Acacia dealbata	16	**434**	63	13	**2023**	447	0.72	**0.84**
Allocasuarina	1	300	n.a.	0	n.a.	n.a.	0.33	n.a.
Banksia marginata	**9**	575	161	**0**	n.a.	n.a.	**0.99**	n.a.
Eucalyptus amygdalina	16	**175**	38	9	**1931**	739	0.28	**0.99**
Eucalyptus pauciflora	1	75	n.a.	0	n.a.	n.a.	0.33	n.a.
Eucalyptus rubida	0	n.a.	n.a.	1	25	n.a.	0.44	n.a.
Eucalyptus viminalis	6	29	2	3	58	16	0.25	n.a.
Eucalyptus – unidentified	0	n.a.	n.a.	1	950	n.a.	0.44	n.a.
All acacias	16	**348**	69	13	**2747**	747	0.72	**0.95**
All eucalypts	16	152	39	11	2769	1628	0.24	0.65
All species	18	**774**	189	13	**5516**	1876	0.46	**0.89**

Appendix 3. Density by species of saplings in long-unburnt and burnt plots

As for Appendix 2, but for saplings. Results are shown according to three categories of fire history (long-unburnt, recently burnt and recovering) because sapling densities were clearly influenced by time since fire

Species	Long-unburnt			Recently burnt			Recovering			*w*+ Fire	
	n (plots /20)	Density (ha^{-1})	s.e.	*n* (plots /9)	Density (ha^{-1})	s.e.	*n* (plots /4)	Density (ha^{-1})	s.e.	Presence/absence	Density
Acacia dealbata	17	182	44	2	7.5	1.2	4	2460	1557	0.29	0.45
Allocasuarina	2	22	4	0	n.a.	n.a.	0	n.a.	n.a.	0.19	n.a.
Banksia marginata	**9**	254	67	**0**	n.a.	n.a.	**0**	n.a.	n.a.	**0.96**	n.a.
Eucalyptus amygdalina	**13**	**14**	2	**0**	n.a.	n.a.	**4**	**212**	67	**1.00**	**1.00**
Eucalyptus pauciflora	0	n.a.	n.a.	0	n.a.	n.a.	1	15	n.a.	0.43	n.a.
Eucalyptus rubida	0	n.a.	n.a.	1	5.0	n.a.	1	5	n.a.	0.41	n.a.
Eucalyptus viminalis	**7**	9.5	1.2	0	n.a.	n.a.	**3**	77	31	**0.93**	n.a.
Exocarpos cupressiformis	1	5.0	n.a.	0	n.a.	n.a.	0	n.a.	n.a.	n.a.	n.a.
Leptomeria	1	15	n.a.	0	n.a.	n.a.	0	n.a.	n.a.	n.a.	n.a.
All acacias	17	**147**	42	2	**1.7**	1.2	4	**2460**	1557	0.29	**1.00**
All eucalypts	**15**	**12**	3	**1**	**0.6**	0.6	**4**	**274**	95	**0.99**	**1.00**
All species	**18**	**284**	69	**3**	**2.2**	1.2	4	**2734**	1639	**0.97**	**1.00**

Appendix 4. Size-class distributions of live eucalypt, acacia and *Banksia marginata* trees >1.5 m tall in unburnt and burnt plots. Note the different (log) scales on the *y*-axis for the different genera. The percentage deviance explained is for the negative binomial model with diameter as the explanatory variable and site as a random effect.



Appendix 5. Summary of results from the fuel survey, showing mean values for unburnt and burnt transects

Response variables were log-transformed as required to normalise the data. Values of $w_i > 0.73$, indicating support for the fire models (burnt versus unburnt and, for the burnt sites, time since fire) according to linear mixed-effects modelling, are shown in bold. Site was used as a random effect to account for the spatial correlation in the data. Woody.1 to Woody.4 represent the different fractions of woody fuels as follows: Woody.1, 0–6 mm; Woody.2, 6–25 mm; Woody.3, 25–76 mm; and Woody.4, >76 mm

Fuel	Unit	Unburnt	s.e.	Burnt	s.e.	*w*+ (burnt vs unburnt)	*w*+ (time since fire)
Tree height	m	21.5	1.1	21.2	1.3	0.49	0.40
Canopy cover	%	45	4	30	4	**0.93**	0.30
Grass depth	cm	8.0	2.1	5.1	1.1	**0.90**	**0.78**
Litter depth	cm	4.7	0.5	1.4	0.2	**1.00**	0.58
Fuel depth	cm	8.9	2.1	5.8	1.4	**0.94**	**0.75**
Live-grass cover	%	20	3	22	4	**0.95**	0.63
Dead-grass cover	%	27	5	14	3	**1.00**	**1.00**
Live-herb cover	%	7	2	11	3	0.29	0.62
Dead-herb cover	%	0.15	0.15	0.17	0.15	0.25	0.56
Grass load	t ha^{-1}	1.22	0.29	0.96	0.19	**0.99**	**0.92**
Litter load	t ha^{-1}	5.30	0.41	2.27	0.33	**1.00**	0.66
Herbaceous load	t ha^{-1}	0.17	0.05	0.24	0.09	0.29	0.72
Shrub mass	t ha^{-1}	2.11	0.27	3.32	1.18	0.69	**0.86**
Woody.1	t ha^{-1}	0.54	0.05	0.23	0.04	**1.00**	0.65
Woody.2	t ha^{-1}	1.03	0.10	0.46	0.11	**1.00**	0.52
Woody.3	t ha^{-1}	3.45	0.53	1.75	0.33	**0.97**	0.70
Woody.4	t ha^{-1}	9.94	1.96	4.94	1.14	**0.94**	0.67
Woody total	t ha^{-1}	14.97	2.10	7.37	1.41	**1.00**	0.50

Appendix 6. Comparison with wet *Eucalyptus delegatensis* forest in the Australian Alps

We had previously measured stand characteristics and fuel loads in burnt and unburnt *E. delegatensis* forest in the Australian Alps in Victoria, according to the same protocol as in the present study (Bowman *et al*. 2014), which afforded the opportunity to directly compare the fire responses of the two forest types. Here, we considered only the plots burnt by a single high-severity fire, excluding those burnt twice in close succession. The fires in the Alps study occurred 6–11 years before our sampling, compared with 0.5–4.5 years in the Midlands, a difference in recovery time that would affect the grassy fuel loads and size and density of regeneration. A few eucalypts had recruited to the 10–20-cm diameter at breast height (DBH) size class in some of the burnt plots in the Alps; hence, our comparison of mature eucalypt density is based on trees larger than 20 cm in DBH.

The influences of fire history (long-unburnt versus recently burnt) and region (Alps versus Midlands) on stand and fuel-load response variables were tested by comparing linear models containing all combinations of fire history and region, including the interaction.

Results

In unburnt forest in the Alps, canopy height was 33 m and canopy cover was 93%, being considerably higher than in the Midlands, and placing it in the tall closed-forest category (Fig. A6.1). Median fire radiative power (FRP) in Alps is 50 MW, and the 95th percentile is 381 MW, considerably higher than the 30 and 136 MW, respectively, in the Midlands. There were strongly supported interactive effects between fire history and region on all demographic variables examined. In unburnt plots, live-stand basal area was almost three times higher in the Alps than in the Midlands (73 versus 25 m2 ha–1), whereas in burnt plots it was lower (Fig. A6.1*b*). While in the Midlands, eucalypts contributed a higher proportion of basal area in burnt than in unburnt plots, the reverse applied in the Alps, where eucalypts contributed 97% of the basal area of unburnt plots, but only 64% in the burnt plots, reflecting high mortality of the dominant eucalypts in the fire, followed by abundant regeneration of acacias as well as eucalypts (Fig. A6.1*c*). In unburnt plots, tree maximum diameter was larger in the Alps than the Midlands (190 cm versus 160 cm DBH), and there was a greater density of eucalypts of all diameter classes (Fig. A6.2*a*). However, fire had a greater impact on density of live mature eucalypts in the Alps (Fig. A6.1*d*), indicated by the much lower eucalypt density in burnt than unburnt plots in all size classes ≥20-cm DBH (Fig. A6.2*b*). (In the 10–20 cm DBH class, there were slightly more eucalypts in burnt than in unburnt plots, presumably as fire-stimulated regeneration started to grow into small trees). The pattern was reversed for juveniles; compared with the Midlands, the Alps had fewer juveniles in unburnt plots and more in burnt plots (Fig. A6.1*e*, *j*). The much greater density of juveniles in burnt plots in the Alps relative to the Midlands is striking (Fig. A6.1*e*, *j*), especially considering the slightly longer time since fire and, hence, presumably greater attrition of germinants, as well as the generally larger size of the juveniles (only 4% of juveniles were <1.5 m high in the Alps, compared with 100% in the Midlands).

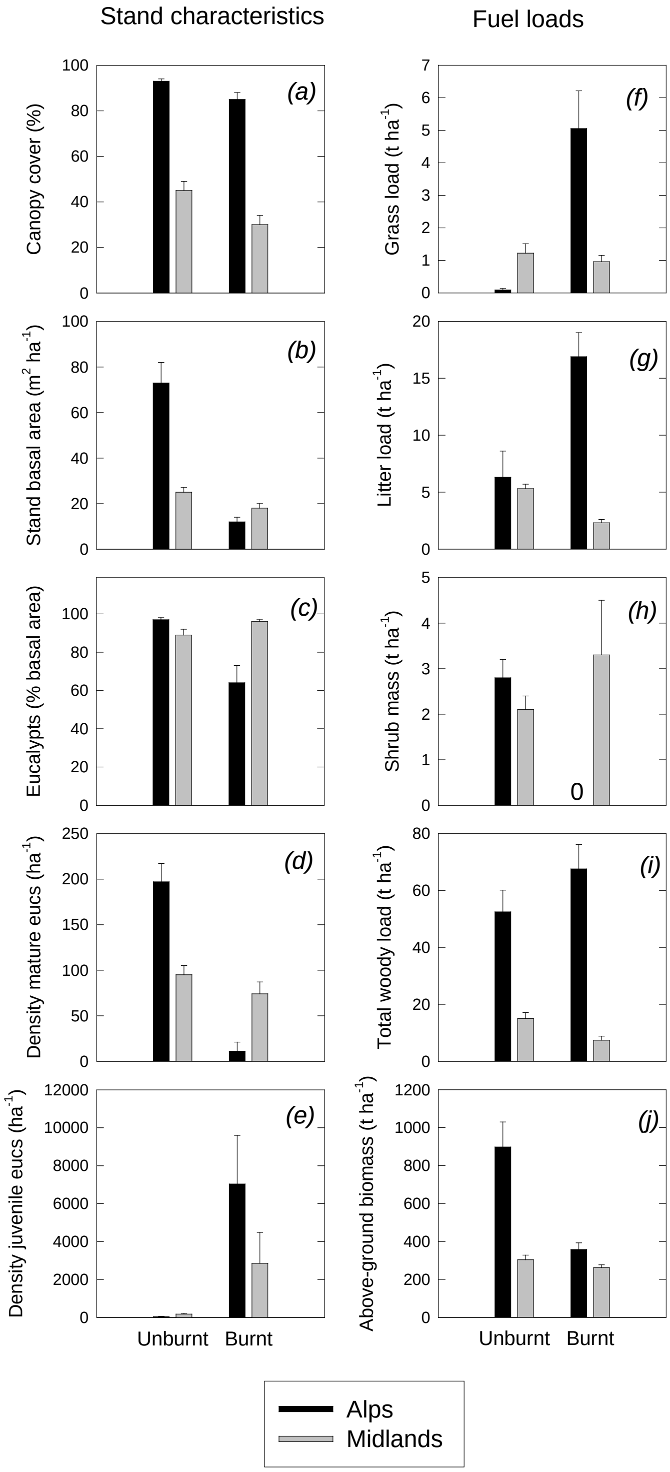


Fig. A6.1. Comparison of stand characteristics and fuel loads of wet eucalypt forest in the Australian Alps and dry eucalypt forest in the Tasmanian Midlands at long-unburnt and recently burnt sites. (*a*) canopy cover; (*b*) live-stand basal area, (*c*) contribution of eucalypts to basal area; (*d*) density of live eucalypts >20-cm diameter at breast height (DBH); (*e*) density of live juvenile eucalypts (saplings and seedlings); (*f*) grass loads (g) litter load; (*h*) shrub mass; (*i*) total woody fuels and (*j*) aboveground biomass of live and standing dead trees. The interaction between 'Fire history' and 'Region' was statistically supported for all attributes except canopy cover, for which 'Fire history' and 'Region' were both important (Table A6.1).

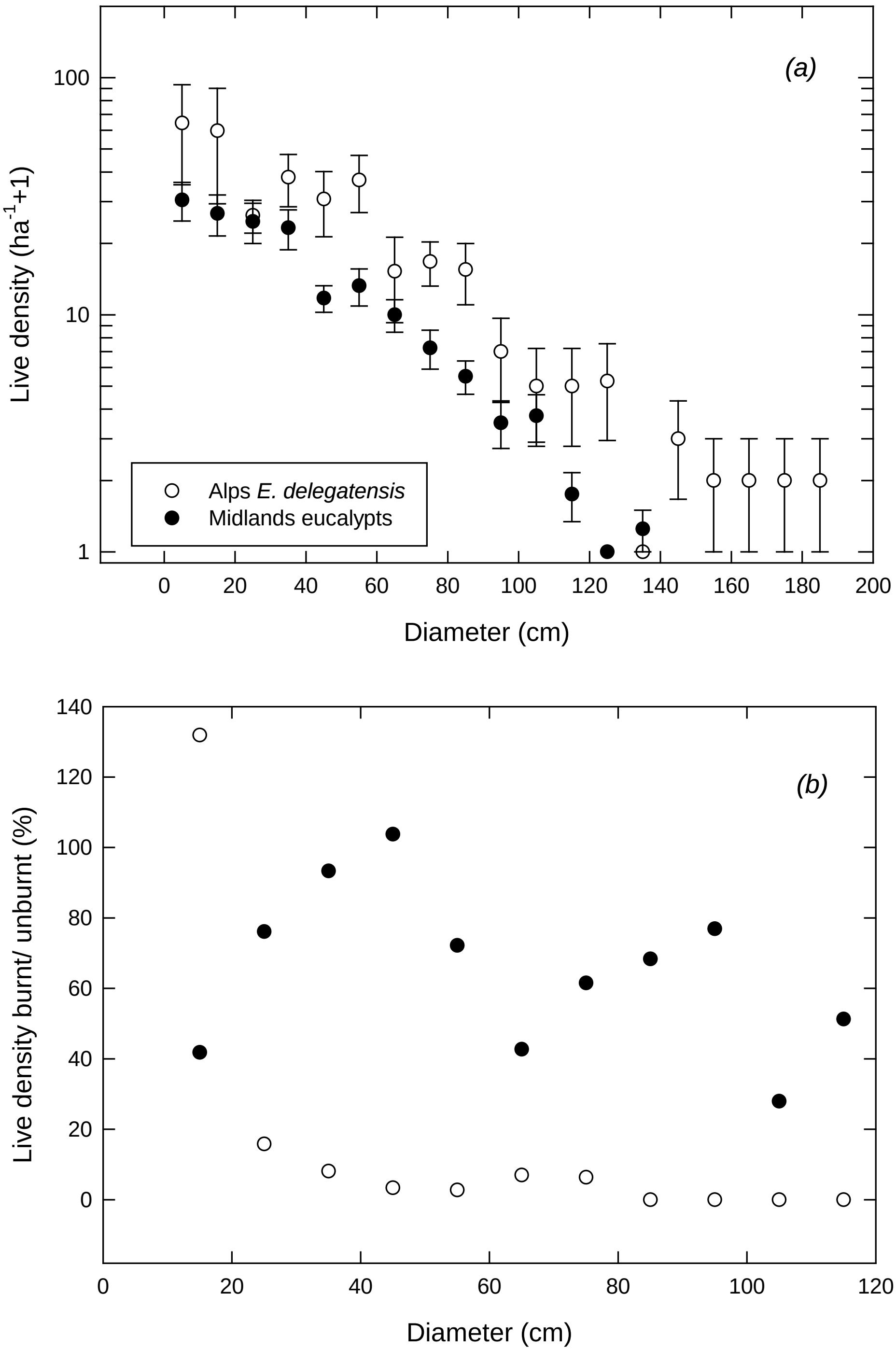


Fig. A6.2. (*a*) A comparison of eucalypt stand structures in unburnt wet *Eucalyptus delegatensis* forest in the Australian Alps and dry eucalypt forest in the Tasmanian Midlands. Trees were binned into 10-cm-diameter classes; bars represent standard errors. (*b*) Density of live eucalypt stems in burnt plots as a percentage of density in long-unburnt plots. Measurements in the Alps were made as much as 11 years after fire, and the some of the resulting regeneration had grown to >10-cm diameter at breast height (DBH); thus, there was a high burnt to unburnt percentage for the 10–20-cm DBH class in the Alps.

There were also strong interactive effects of fire history and region on fuel loads (Fig. A6.1). Although differences in the patterns of the finer fuels (grass and litter) could reflect the different times since fire, the effects of fire on loads of woody fuels would be likely to persist for many years, and are more likely to reflect inherent differences between the regions. In the Alps, grass loads were very low in unburnt plots, but were 56 times higher in unburnt transects, whereas in the Midlands there was slightly less grass in the burnt than unburnt transects (Fig. A6.1*f*). Similarly, in the Alps litter loads were higher after fire, but in the Midlands they were lower (Fig. A6.1*g*). No shrubs were found in burnt transects in the Alps, and there was little difference in shrub load between burnt and unburnt transects in the Midlands (Fig. A6.1*h*). There was much more woody fuel in the Alps than in the Midlands, and it increased slightly after fire, whereas it decreased slightly in the Midlands (Fig. A6.1*i*). There was a large difference between burnt and unburnt sites in aboveground tree biomass in the Alps, but not in the Midlands (Fig. A6.1*j*).

Table A6.1. Summary of statistical support for models describing stand structure

Linear models describing stand-structure variables in relation to region (Alps versus Midlands) and fire history (long-unburnt versus recently burnt). Site was a random effect to account for spatial correlation. Delta Akaike information criterion for small sample sizes (AICc) and Akaike weight of the model (w_i) for the top model are in bold. k is the number of parameters in the model; delta AICc is the difference between AICc of that model and the best model (which has the lowest AICc); a w_i of <0.01 indicates virtually no support for the model, and of 1.0 indicates full support. Data are presented in Fig. A6.1. BA, basal area

Stand structure	k	Canopy cover		Live BA		Eucalypts (%BA)		Density ≥ 20 cm		Juvenile density	
		Delta AICc	w_i	Delta AICc	w_i	Delta AICc	w_i	Delta AICc	w_i	Delta AICc	w_i
Region × Fire	4	1.1	0.36	**0.0**	**1.00**	**0.0**	**1.00**	**0.0**	**1.00**	**0.0**	**0.99**
Region + Fire	3	**0.0**	**0.63**	31.8	<0.01	19.5	<0.01	44.3	<0.01	11.3	<0.01
Region	2	7.2	0.02	52.8	<0.01	20.5	<0.01	65.9	<0.01	27.4	<0.01
Fire	2	49.7	<0.01	45.4	<0.01	21.8	<0.01	50.3	<0.01	9.0	0.01
Null	1	54.3	<0.01	59.0	<0.01	23.5	<0.01	71.3	<0.01	25.2	<0.01

Table A6.2. Summary of statistical support for models describing fuel-load variables

Linear mixed-effects models describing fuel loads in relation to region (Alps versus Midlands) and fire history (long-unburnt versus recently burnt). Site was a random effect to account for spatial correlation. Delta Akaike information criterion for small sample sizes (AICc) and Akaike weight of the model (w_i) for the top model are in bold. k is the number of parameters in the model; delta AICc is the difference between AICc of that model and the best model (which has the lowest AICc); a w_i of <0.01 indicates virtually no support for the model, and of 1.0 indicates full support. Data are presented in Fig. A6.1

Fuel load	k	Grass load		Litter load		Shrub mass		Total woody fuels		Aboveground tree biomass	
		Delta AICc	w_i	Delta AICc	w_i	Delta AICc	w_i	Delta AICc	w_i	Delta AICc	w_i
Region × Fire	4	**0.0**	**1.00**	**0.0**	**1.00**	**0.0**	**0.78**	**0.0**	**0.99**	**0.00**	**1.00**
Region + Fire	3	30.1	<0.01	28.6	<0.01	3.4	0.14	9.5	0.01	10.8	<0.01
Region	2	28.7	<0.01	26.6	<0.01	16.2	<0.01	12.3	<0.01	21.3	<0.01
Fire	2	28.2	<0.01	27.4	<0.01	4.6	0.08	54.7	<0.01	37.6	<0.01
Null	1	26.9	<0.01	25.4	<0.01	16.8	<0.01	59.9	<0.01	40.9	<0.01

Reference

Bowman DMJS, Murphy BP, Neyland DLJ, Williamson GJ, Prior LD (2014) Abrupt fire regime change may cause landscape-wide loss of mature obligate seeder forests. *Global Change Biology* **20**, 1008–1015. doi:10.1111/gcb.12433