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Acacia shrubs respond positively to high severity wildfire: Implications for conservation and fuel hazard management

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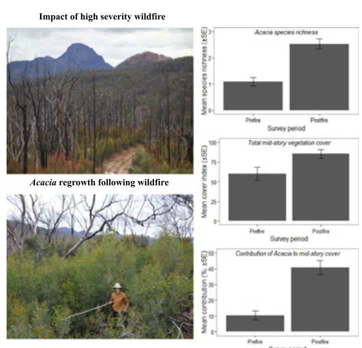
HIGHLIGHTS

- Impacts of fire severity on flora-dynamics and subsequent fuel hazard are poorly understood.
- High severity fire did not initiate a state-change shift for dominant *Acacia* shrubs.
- Rather, vigorous *Acacia* regrowth increased fuel hazard for ~20 years.
- Prescribed burning following fire will mitigate this increased hazard.
- However its widespread application will compromise biodiversity.

GRAPHICAL ABSTRACT



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ABSTRACT

High severity wildfires pose threats to human assets, but are also perceived to impact vegetation communities because a small number of species may become dominant immediately after fire. However there are considerable gaps in our knowledge about species-specific responses of plants to different fire severities, and how this influences fuel hazard in the short and long-term. Here we conduct a floristic survey at sites before and two years after a wildfire of unprecedented size and severity in the Warrumbungle National Park (Australia) to explore relationships between post-fire growth of a fire responsive shrub genera (*Acacia*), total mid-story vegetation cover, fire severity and fuel hazard. We then survey 129 plots surrounding the park to assess relationships between mid-story vegetation cover and time-since-fire. *Acacia* species richness and cover were 2.3 and 4.3 times greater at plots after than before the fire. However the same common dominant species were present throughout the study. Mid-story vegetation cover was 1.5 times greater after than before the wildfire, and *Acacia* species contribution to mid-story cover increased from 10 to 40%. *Acacia* species richness was not affected by fire severity, however strong positive associations were observed between *Acacia* and total mid-story vegetation cover and severity. Our analysis of mid-story vegetation recovery showed that cover was similarly high between 2 and 30 years post-fire, then decreased until 52 years. Collectively, our results suggest that *Acacia* species are extremely resilient to high severity wildfire and drive short to mid-term increases in fuel hazard. Our results are discussed in relation to fire regime management from the twin perspectives of conserving biodiversity and mitigating human losses due to wildfire.

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1. Introduction

The interplay between fire and vegetation is complex and important to understand, from the twin perspectives of managing risk to human assets and maintaining biodiversity. Large, severe wildfires pose particular risks to human assets but are also often perceived to impact biodiversity because they consume a large proportion of the vegetation and a small number of species may become dominant for some time after fire (Gill, 2005; DellaSala and Hanson, 2015). Contrary to this perception, ecological research has shown that plant diversity often increases after fire, and that recovery for most species is rapid (Huston et al., 2003; Pausas et al., 2004; Andersen et al., 2005). However, vegetation dynamics and species-specific responses to wildfire are strongly influenced by fire severity (a measure of biological impact related to fire intensity; Moreno and Oechel, 1991; Morrison, 2002; Ooi et al., 2006; Keeley, 2009), fire frequency (the number of fires) and inter-fire interval (the time between fires; Gill, 1975; Ooi et al., 2006). The spatial patterns of these fire regime characteristics also influence vegetation dynamics at the landscape-scale. Given this, the persistence of species in these landscapes is dependent on their species-specific responses to different attributes of fire regimes (i.e. fire severity, fire frequency, fire interval). To further complicate matters, reduced fuel loads in recently burnt areas protect human assets from subsequent fire for some years, but the degree of this protection depends on the amount of fuel reduction and the rate of vegetation regrowth, both of which are probably affected by the severity of fire. There are considerable gaps in our knowledge about how fire severity influences plant species responses to fire and hence also how it influences subsequent fire hazard.

Fuel load is one of the most important determinants of many aspects of fire behaviour including the likelihood of ignition, rates-of-spread (the rate of forward propagation of fire) and fire line severity (the severity of the fire front; Noble et al., 1980; Bradstock, 2010; Bradstock et al., 2010). Surface (i.e. litter from leaves and twigs <6 mm diameter) and near-surface fuels (low lying vegetation connected to the ground) are particularly important because these elements facilitate fire ignition and are required to sustain fire spread (Walker, 1981; Raison, 1983; Gould et al., 2008). However, fires are at their most severe when the entire forest vegetation is alight from the ground to crown canopy (Gill et al., 1987). Litter and near-surface fuels cannot alone facilitate flame transfer to the canopy crown without a well-developed mid-story (the shrub layer, also called elevated fuel) to connect flames from the surface to the crown (Cheney et al., 1992; Gould et al., 2008). Consequently, consideration of mid-story fuels is necessary to understand vegetation responses to fire, and to improve our ability to predict fire behaviour and manage fuel loads.

Acacia is a diverse genus of shrubs and trees common throughout Australia. Many *Acacia* species have long-lived soil seedbanks which require fire to stimulate germination (Ooi et al., 2014; Clarke et al., 2015). These 'physically dormant' *Acacia* species often persist in long unburnt areas not as adult plants, but as viable seeds within a soil seedbank (Gill, 1981; Auld, 1986). Soil seedbank 'stores' can be extremely abundant if adult plants consistently produce seed before senescence, especially in long unburnt areas. These seedbank stores can initiate mass germination events following fire (Gill, 1975; Keeley, 1995), and subsequent increases in recruitment may increase fuel hazard (the potential for fuel loads to sustain fire) because the canopy of *Acacia* regrowth is dense and well connected both vertically and horizontally, often over large areas.

In January 2013 a large high severity wildfire burnt 90% of Warrumbungle National Park in the central-west of New South Wales, Australia. This fire was remarkable in a number of respects. Firstly, it was the first fire of such extent and severity in the 60 year recorded fire history of the park (most of the park was unburnt in that time). Secondly, a large rainfall event immediately following the fire led to extensive soil erosion. Thirdly, widespread regrowth of a number of *Acacia* species occurred following the wildfire, including in areas where *Acacias* were not prominent prior to the fire. As a consequence there was some concern that this regrowth may have caused: 1) medium or long-term changes in the vegetation community and 2) elevated fuel hazard. Gordon et al. (2015) quantified spatial patterns of mid-story vegetation regrowth throughout Warrumbungle National Park following the 2013 wildfire and assessed relationships between this regrowth and fire severity. They found that mid-story regrowth was dense in discrete patches, and particularly so in areas burnt at high severity, probably due to a strong response by a variety of *Acacia* species.

Here we quantify how *Acacia* species composition (the relative abundance of different species), species richness (the number of species), species cover (the area of ground covered by the canopy when viewed from above), species dominance (the most common species) and total mid-story vegetation cover (the sum of species cover values within the mid-story) has changed as a consequence of the 2013 wildfire. We then assess relationships between the magnitude of the post-fire responses of *Acacia* species richness, *Acacia* cover and total mid-story vegetation cover with fire severity. Finally, we assess longer-term trends in mid-story recovery (and hence fuel hazard) following fire using a space-for-time substitution study for the broader region. To do this we use data from floristic surveys conducted before and after the 2013 wildfire within the park and following other fires in the broader region in the past 20 years. The aim of the research was to predict *Acacia* dynamics and fuel hazard over a period characterising the lifespan of most *Acacia* species (~10–15 years for early succession species, 30–50 years for most species; CSIRO, Australian Biological Resources Study, 2005).

Considering existing knowledge of the life history of *Acacia*, and the observed dense regrowth following the wildfire (Gordon et al. 2015), we test the following hypotheses:

1) There will be a net gain in *Acacia* species richness and no loss of species due to the fire.
2) Mid-story vegetation cover will be higher post-fire than pre-fire, mostly due to *Acacia*.
3) Responses of *Acacia* and mid-story vegetation will be strongest where fire severity is high rather than low.
4) Over a longer time period (20–30 years) mid-story cover will decline due to self-thinning and senescence.
5) Consequently, mid-story fuel hazard will follow a peaked relationship post-fire, being highest at intermediate fuel ages.

2. Materials and methods

2.1. Study area

The study was conducted in Warrumbungle National Park (31.29°S, 149.01°E; 233.1 km^2 area; Fig. 1) 36 km west of Coonabarabran, central New South Wales. The park has a topographically diverse landscape with steep volcanic mountains (Warrumbungle Volcanic Complex: basalt, dolerite, andesite, tristanite, trachyte; New South Wales Office of Environment and Heritage, unpublished data) rising to 1206 m above sea level and sedimentary river flats (Pilliga Sandstone, Purlawaugh Formation and Keelindi Beds: sandstone, siltstone and mudstone) laying 400–500 m above sea level. Average annual rainfall at Coonabarabran – which is the closest long-term weather station to the park – is 750.7 mm (134 years of data; Australian Bureau of Meteorology) and rainfall decreases east-west due to orographic effects of the mountain range. Mean monthly maximum temperatures at Coonabarabran range from 31.7 °C in January to 14.8 °C in July. Prior to the 2013 wildfire, most of the park (~70%) had been unburnt since at least 1970.

The majority of Warrumbungle National Park is vegetated by dry sclerophyll open forests with a grass/shrub understorey. A vegetation survey of the park by Hunter (2008) identified nine vegetation communities. For simplicity, we have grouped these nine communities into six