



Refuges for birds in fire-prone landscapes: The influence of fire severity and fire history on the distribution of forest birds



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ABSTRACT

Unburnt patches within a fire boundary may act as refuges for fauna, facilitating their survival and persistence within fire-prone landscapes. Unburnt patches can arise due to various processes, including topographic variation, fire behaviour, and fuel reduction from recent burning. However, the value of unburnt patches of differing characteristics to the post-fire persistence of faunal communities has rarely been examined. In this study, we examined the relative importance of fire history and severity in predicting the occurrence of birds in a burnt forest landscape. We conducted surveys in mixed eucalypt forest of south-east Australia, 2–3 years after a high intensity, landscape-scale wildfire (>200,000 ha). Sites ($n = 91$) were selected to encompass fire severity ranging from unburnt patches to stands of crown-burnt forest. Fire history prior to the wildfire was defined as short (<3 years) or long (>20 years) time-since-fire. Unburnt patches of long time-since-fire were important avian refuges, harbouring 20–40% more species, up to 56% more individuals and an assemblage that was distinct from that at all sites burnt by the wildfire, including low severity ground fire. No difference in species richness or composition was detected between sites in unburnt patches of short or long time-since-fire; but bird abundance was ~20% lower in patches of short time-since-fire. Unburnt and ground-burnt patches of short time-since-fire provided habitat for more species and had distinct assemblages from that of severely burnt sites. For sites severely burnt in the wildfire, there was no difference in avifaunal richness, abundance or composition between those burnt twice in rapid succession and those not burnt for >20 years. Together, these results highlight: (1) the particular importance of unburnt vegetation remaining within fire-affected areas as faunal refuges, and (2) the potential for recent planned burns to contribute to refuge habitat if it avoids severe burning in a subsequent wildfire.

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1. Introduction

Fire is an important agent of change in many systems globally (Bond and Keeley, 2005). Fire can result in substantial mortality of the existing fauna (Silveira et al., 1999; Lyon et al., 2000; Sanz-Aguilar et al., 2011), especially in the case of large intense wildfires (Newsome et al., 1975; Silveira et al., 1999). Despite this, the most significant impact on fauna often occurs after a fire through loss of habitat and food, and increased predation (Whelan et al., 2002). Requirements for resources that are scarce or unavailable post-fire can place species at risk of reduced fecundity (Brooker and Rowley, 1991) or local extinction (Baker, 1997; Recher et al., 2009). Accordingly, unburnt patches that remain within a fire

boundary may have value as faunal refuges that provide immediate shelter and resources for long-term persistence and recovery of animal populations (Whelan et al., 2002; Robinson et al., 2013). Persistence and recovery of populations within a fire boundary are likely to be especially important in the case of large fires for which mortality is often high and distance to outside source populations may be great relative to a species' dispersal ability (Turner et al., 1998; Whelan et al., 2002; Brown et al., 2009).

All fires, even large intense events, typically result in some unburnt or less severely burnt areas remaining (Schoennagel et al., 2008); these areas are sometimes referred to as residuals (Schieck and Hobson, 2000), fire skips or isolates (Stuart-Smith et al., 2002). The processes, either stochastic or deterministic, that contribute to fire heterogeneity differ in the type of habitat that is left unburnt. For example, natural variation in topography and fuel barriers (such as rocky scree, rivers) may afford protection from multiple fire events (Mackey et al., 2002; Bradstock et al., 2005; Burton et al., 2008). Vegetation remaining in such locations may be much

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older than that in the surrounding landscape (Burton et al., 2008) and floristically distinct (Clarke, 2002), and therefore harbour fauna not found in the broader fire-prone landscape (Gandhi et al., 2001). Unburnt patches may also arise when fuel reduction from recent burning prevents a patch from being burnt in a subsequent fire (Bradstock et al., 2005). Such patches are characterised by early successional age-classes but, depending on the severity of the prior fire, may contain important habitat components (Bradstock et al., 2005; Pereoglou et al., 2013).

Patches that remain unburnt in fire-prone landscapes are expected to become increasingly important under current predictions of climate change (McKenzie et al., 2004). Weather conditions that contribute to large, high intensity fire events are expected to be more frequent in fire-prone regions such as south-east Australia (Hasson et al., 2009) and north-west USA (McKenzie et al., 2004), resulting in greater coverage and frequency of fire. Land managers may be able to minimise the severity and extent of wildfire through prescribed burning, and creating unburnt patches within or adjacent to the fire boundary (Burrows and Wardell-Johnson, 2004). On the other hand, extreme weather conditions may lead to recently fuel-reduced areas burning again in a subsequent wildfire, resulting in adverse changes to faunal habitats due to short fire intervals (Agee, 1993; Whelan et al., 2002). Indeed, the effects of short fire intervals can push vegetation communities towards new states, that cater for a different faunal assemblage (Fontaine et al., 2009).

In order to understand how faunal communities persist in fire-prone landscapes, we investigated the value to birds of unburnt or ground-burnt patches within the fire boundary of a major wildfire (>200,000 ha), and the relevance of fire history prior to the major fire. Our research was undertaken 2–3 years after the Kilmore East-Murrindindi Fire complex in the foothill forests of Victoria, south-east Australia. These fires began on 7th February 2009 on what became known as Black Saturday. Due to their devastating impact on human life and property, a subsequent inquiry (Teague et al., 2010) recommended that prescribed burning in the state of Victoria be increased from an annual average of 1.7% to a minimum annual rolling target of 5% of public land, with the objective of reducing the recurrence and severity of large wildfires. However, the ecological implications of this new policy are unclear. High levels of prescribed fire may reduce the severity and extent of

future fires, and sites where fuel has been reduced by prescribed burning may burn less severely when a major fire occurs (Burrows and Wardell-Johnson, 2004). Conversely, high levels of prescribed fire may also result in a decrease in the extent of suitable habitat for certain animal species that remain in the broader landscape after the major fire (Penman et al., 2007).

We examined the role of residual habitat within a fire boundary by addressing three hypotheses (Table 1) and illustrating our predictions (Fig. 1). First, we hypothesise that unburnt, or ground-burnt only (with canopy still intact), patches within the fire boundary act as refuges for birds. This hypothesis predicts that in unburnt, or ground burnt, patches there will be greater species richness and abundance of birds, and an assemblage that is distinct from that in more severely burnt patches; but similar richness, abundance and composition to sites in continuous forest outside the fire boundary. Second, that among patches of equal fire severity in the 2009 wildfire, those that experienced no fire in the 20 years preceding Black Saturday will have greater species richness and abundance and a different assemblage from patches that were burnt during the three years prior to Black Saturday. This hypothesis predicts that (a) unburnt patches of long time-since-fire (TSF) are better refuges than those of short TSF; and b) patches of long fire interval but burnt by the wildfire provide better habitat than patches burnt twice in rapid succession (short interval). The third hypothesis predicts that patches burnt in the three years preceding Black Saturday (short interval), that escaped severe fire during the wildfire, will have greater species richness and abundance and differing composition than more severely burnt patches of long fire interval (>20 years).

2. Methods

2.1. Study area

On 7th February 2009, two independent fires began burning in the central highlands of Victoria, approximately 100 km north of Melbourne, Australia (Teague et al., 2010). These fires converged to form the Kilmore East-Murrindindi fire complex (Price and Bradstock, 2012); a major fire that burnt 228,000 ha of forest, with fire severities ranging from extreme crown burn through to low

Table 1
Planned comparisons of the relationship between birds and fire treatments, based on *a priori* hypotheses and predictions.

Hypotheses and predictions	Planned comparison
1. Unburnt, or ground burnt, patches are refuges for birds within burned landscapes	Within each class of short and long TSF (or interval) prior to the 2009 fire:
(a) Unburnt patches have similar species richness, abundance and composition to reference sites outside the fire boundary	• Unburnt compared with reference
(b) Unburnt, or ground burnt, patches have greater species richness, abundance and a distinctive composition compared with more severely burnt patches	• Unburnt compared with: ground burnt, crown scorch, crown burnt
	• Ground burnt compared with: crown scorch, crown burnt
2. Within a given severity class, patches of long TSF (or interval) provide better habitat than patches of short TSF (or interval)	Within each severity class:
(a) Unburnt patches of long TSF have greater species richness, abundance and a distinctive composition compared with unburnt patches of short TSF	• Long TSF (or interval) compared with short TSF (or interval)
(b) Patches burnt by the wildfire of long fire interval have greater species richness, abundance and distinctive composition compared with patches burnt twice in rapid succession (short interval)	
3. Patches recently burnt prior to Black Saturday that subsequently escaped the wildfire (or were ground burnt) provide better habitat than more severely burnt vegetation of long fire interval	Unburnt of short TSF compared with:
(a) Unburnt, or ground burnt, patches of short TSF (or interval) have greater species richness and abundance and distinctive composition compared with more severely burnt patches of long fire interval	• Ground burnt of long interval
	• Crown scorch of long interval
	• Crown burnt of long interval
	Ground burnt of short interval compared with:
	• Crown scorch of long interval
	• Crown burnt of long interval

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