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Prescribed burning reduces the abundance of den sites for a hollow-using mammal in a dry forest ecosystem

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ABSTRACT

Prescribed burning is used in fire-prone environments worldwide to reduce fuel loads and the severity and spread of future wildfires. Forest habitat structures, such as large trees, dead trees and logs are highly flammable, yet also are essential for animal species that require hollows (cavities) as den sites for shelter and reproduction. We examined the effects of experimental prescribed burns on the use of den sites by a small marsupial, the yellow-footed antechinus *Antechinus flavipes*, in south-eastern Australia. Specifically, we radio-tracked individual *A. flavipes* to identify forest habitat structures preferred as den sites and recorded the fate of known den sites following patchy prescribed burns. We found that large living trees and dead trees were used as den sites disproportionately to their relative abundance in the forest. While all marked individuals of *A. flavipes* survived the immediate impacts of patchy prescribed burns, almost a third (16/52) of den sites identified before burning were lost, including 17% of trees (4/23) and 48% of logs (10/21). The vulnerability of den sites to prescribed burns can be attributed to the decay-dependent effect of fire on both trees and logs, whereby, the amount of damage from fire is related to the structure's pre-fire condition (i.e. whether dead or alive, amount of decay). Large trees and large logs are scarce in this dry forest ecosystem and their replacement is likely to take a century or more due to the slow growth rates of trees. The ecological impacts of prescribed burning on habitat structures used by *A. flavipes* and other hollow-using species can be moderated by: (1) carrying out patchy, rather than complete burns; (2) ensuring the inter-fire interval is sufficient to allow time for replenishment of resources; and (3) planning at a regional scale to maintain an appropriate spatial pattern of post-fire age-classes, including areas retained as long-unburned (e.g. > 50 years) in which resources such as deep litter, large logs and dead trees can accumulate.

1. Introduction

Fire is a prominent disturbance process that influences the distribution and abundance of animal species in ecosystems worldwide (Bond et al., 2005). Wildfires, particularly those of high severity, can result in the direct mortality of animals; but the most profound effects are indirect, from changes to the composition and structure of ecosystems and to the availability of habitat resources over time (Driscoll et al., 2010; Smucker et al., 2005; Turner et al., 2003). In the short term, post-fire successional changes may benefit some species (e.g. Brotons et al., 2005; Hutto, 2008), or reduce the abundance of, or locally eliminate, others (e.g. Fox, 1982; Banks et al., 2011a). Long-term changes following fire may determine the distribution and abundance of species over many decades (Haslem et al., 2011; Nimmo et al., 2012).

In fire-prone regions, prescribed burning is widely used by land managers to mitigate the effects of future wildfires (Fernandes and Botelho, 2003; Penman et al., 2011). A common goal of prescribed burning is to modify fuel types and reduce fuel levels to reduce the risk of wildfire to human life and property. It can also be used as a tool to benefit biodiversity; for example, by creating buffers to protect the habitats of sensitive species, or by modifying fuels to reduce the risk of severe fire consuming old-growth structures (Penman et al., 2011; Spies et al., 2006). However, like wildfire, prescribed burning also modifies the availability and abundance of resources used by fauna (Holland et al., 2017).

Fire can affect animal populations indirectly by altering habitat

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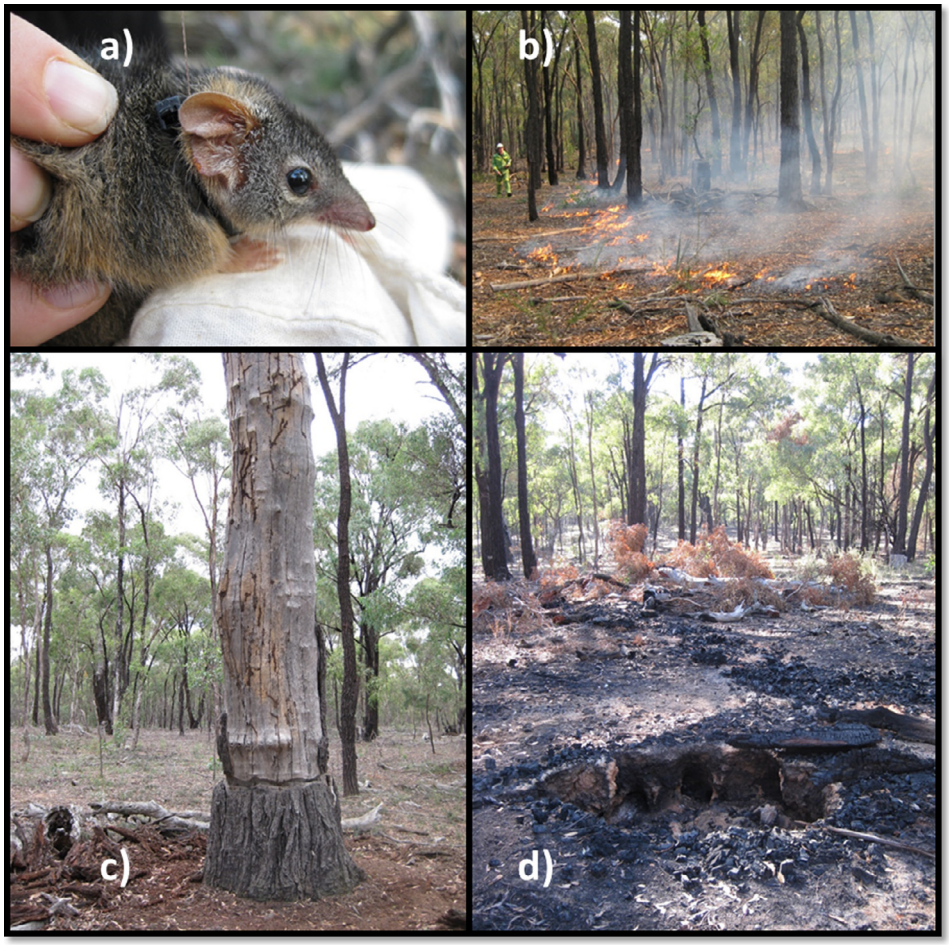

Fig. 1. Photo panel of: (a) the study species, *Antechinus flavipes;* (b) a prescribed burn; (c) a large dead tree (> 60 cm diameter) used by *A. flavipes* as a den site before burning (surrounded by small trees and a sparse understorey typical of the forest); and (d) the same location post-burn where the den tree has been consumed. The unburned tree canopy in the background shows this was a low-intensity burn.

structural resources such as breeding sites. In forest ecosystems, for example, hollows (cavities) and crevices that occur in live and dead trees, in logs and in stumps, are used for breeding by many species (Gibbons and Lindenmayer, 2002; Kunz and Lumsden, 2003; Newton, 1994; van der Hoek et al., 2017). Hollows and crevices also serve other functions, including providing refuge from predators, ameliorating environmental conditions, and facilitating social interactions (Gibbons and Lindenmayer, 2002; Lazenby-Cohen, 1991). The loss of such resources can affect the survival and reproductive success of individuals and the density of local populations. For example, the availability of suitable hollows is known to influence the abundance of hollow-nesting birds (Aitken and Martin, 2012; Cockle et al., 2011; Newton, 1994) and arboreal marsupials (Gibbons and Lindenmayer, 2002).

Here, we investigated the effect of experimental prescribed burns on the use of den sites for refuge and breeding by a small marsupial, the yellow-footed antechinus *Antechinus flavipes*, in a dry forest ecosystem in south-eastern Australia. Before European settlement in the mid 19th century, 'box-ironbark' eucalypt forests covered ~1.5 million ha of northern Victoria (ECC, 2001). Intensive gold-mining, agriculture and logging have reduced these forests to ~25% of their original extent (ECC, 2001; Lawrence and Bellette, 2010). The remaining forests are fragmented and highly modified. Large, hollow-bearing trees (≥ 60 cm diameter) once dominated the landscape (Newman, 1961), but typically now comprise < 1% of trees in the forest (ECC, 2001; Holland et al., 2017). Prescribed burning is employed in these forests to reduce ground fuels.

Populations of *A. flavipes* potentially are vulnerable to prescribed burning if the resources they use as den sites for refuge and breeding are consumed by fire. Further, this species (and other *Antechinus* species) have a distinctive life-history strategy that may increase their vulnerability to the timing and effects of prescribed burns. There is a complete die-off of males after an annual mating season in winter, leaving a population of pregnant females that require suitable den sites to rear their young (Dickman, 1980; Menkhorst, 1995). We addressed four questions in this study:

(1) what types of habitat structures does *A. flavipes* use as den sites?
(2) do individuals preferentially select certain habitat structures as den sites compared to their availability in the landscape?
(3) does prescribed burning affect the persistence of den sites used by *A. flavipes*?
(4) do individuals of *A. flavipes* alter their use of habitat structures as den sites following prescribed burning?

2. Methods

2.1. Study area

The Heathcote-Graytown National Park and Redcastle-Graytown State Forest form a contiguous forested area of ~40 000 ha, in north-central Victoria, Australia. The topography is undulating (elevation ~150–370 m) and soils generally are shallow and infertile with poor water-holding capacity (Muir et al., 1995). The area experiences hot, dry summers and mild winter months. Mean daily maximum