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Prescribed burning impacts avian diversity and disadvantages woodland-specialist birds unless long-unburnt habitat is retained[☆]

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ABSTRACT

Prescribed burning is a commonly adopted fire-management strategy that attempts to protect human life and assets by removing accumulated, flammable biomass. Heterogeneous burning patterns are often favoured in an attempt to balance fuel-reduction and biodiversity goals under the 'pyrodiversity begets biodiversity' paradigm. Using comprehensive spatiotemporal monitoring data, we quantified the impacts of fire on bird assemblages in the peri-urban temperate woodlands of the Mount Lofty Ranges, South Australia, where the frequency of prescribed burning is increasing. After accounting for regional trends and site effects, sites burnt 20 years previously accommodated 15% fewer birds than unburnt sites, while sites burnt in the preceding year had 22% fewer birds. Fire also modified bird assemblages, favouring generalists and ground-feeding species. Of 60 species considered, 37% were both declining and negatively impacted by recent burning, while burning reinforced increasing trends in 30% of species, particularly large, common birds (e.g., magpies, ravens, wattlebirds). Simulations of avian alpha-, beta- and gamma-diversity under different fire-management scenarios predicted higher avian diversity for scenarios that retained unburnt woodlands relative to those that managed all sites. Relative to a no-fire scenario, for example, burning sites once every 10 years was simulated to reduce the abundance of woodland generalists by 7% and woodland specialists by 10%, while retaining some long-unburnt woodland ameliorated these effects. There is a trade-off between fuel-reduction burning and conservation goals; to maximise avian diversity and avert the replacement of woodland bird species with generalists, fire-management planning should preserve long-unburnt woodland habitat.

1. Introduction

Fire is a major disturbance process that has structured global biomes, and the control of fire by humans has inevitable ecological consequences (Bowman et al., 2016). Following prevalent fire suppression in many landscapes during much of last century, the accumulation of flammable biomass and increased risk of high-intensity wildfires led to new fire-management practices (Backer et al., 2004; Schoennagel et al., 2004) including low-intensity "prescribed" burning to reduce fuel loads (Parr and Andersen, 2006; Taylor et al., 2012). Simultaneously, greater recognition of fire as a natural and ecologically important disturbance (Allen et al., 2002) contributed to the development of patch mosaic burning strategies that sought to maximise or restore lost biodiversity by generating a mosaic of different fire histories across a landscape (Brockett et al., 2001; Parr and Andersen, 2006). The central assumption of this approach, that "pyrodiversity begets biodiversity" (Martin and Sapsis, 1992), traces back to the intermediate disturbance hypothesis (IDH) which asserts that biodiversity is maximised at moderate levels of disturbance because a range of successional stages will accommodate more species (Connell, 1978).

The contribution of ecologists to fire-management planning processes is hampered by controversy surrounding the efficacy of

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heterogeneous burning patterns (Parr and Andersen, 2006) which, in theory, should increase γ-diversity (the total species diversity across a landscape) and β-diversity (species "turnover"), while having positive or negative impacts on α-diversity (the mean diversity per site or habitat). However, empirical support for these effects is equivocal and the response of diversity metrics to fire appears to be taxon-specific (Lindenmayer et al., 2016; Pastro et al., 2011; Pastro et al., 2014; Velle et al., 2014; Whelan et al., 2002). Further, burning regimes that increase γ-, β- and/or α-diversity might be considered inappropriate when rare or threatened species are disadvantaged. In such cases, fire ecologists could aim to optimise different metrics such as the geometric mean of the species' abundances (GMA), a multiplicative index that is equally sensitive to variation in the abundance of common species as rare species (Giljohann et al., 2015; Kelly et al., 2015).

The imperative to use prescribed burning in conservation reserves is increasing as urban fringe development brings suburbia closer to protected areas (Gueneralp and Seto, 2013), and as wildfire risk increases due to more frequent extreme heat events under climate change (Westerling and Bryant, 2008; Wotton et al., 2010). However, a major challenge is to ensure that prescribed burning does not impact biodiversity negatively (Clarke, 2008; Giljohann et al., 2015; Kelly et al., 2015). Birds are conspicuous, easily monitored, and are often used as a flagship taxon in biodiversity studies (Lawton et al., 1998). Birds with specific habitat and foraging requirements respond differently to fire - some species persist in burnt areas or readily move into them, while others recolonise from source populations at different stages of vegetation succession after burning (Christensen et al., 1985; Loyn and McNabb, 2015; Russell et al., 2009). However, some bird species require or prefer habitats that have had little or no exposure to fire for extended periods (Berry et al., 2015; Kelly et al., 2015). Urban development in Australia has favoured non-native, predatory, nectarivorous and/or large native birds (Catterall et al., 2010; French et al., 2005) at the expense of small 'specialist' species, insectivores, and understorey and tree-cavity nesters (Ikin et al., 2014). There is an urgent need for data to guide fire management in habitat refuges that support such species (Clarke, 2008; Woinarski, 1999), particularly given that high-frequency prescribed burning can, at least initially, create open and structurally simple habitats that might favour the same birds that proliferate in urban and peri-urban environments.

These management pressures apply in the fragmented woodlands of the Mount Lofty Ranges of South Australia, a national biodiversity hotspot (Department of the Environment, 2015) that lies directly adjacent to the city of Adelaide (population c. 1.3 million). Approximately 90% of native vegetation has been cleared from the ranges since European arrival in the mid 1800's (Westphal et al., 2003) and, although some bird species are now locally extinct (Ford et al., 2001), remnant woodland ecosystems still provide an important refuge for avian biodiversity. However, there is a time-lag between habitat loss and species loss, and the abundance of many small-bodied, specialist birds continues to decline in favour of large-bodied generalist species (Szabo et al., 2011). Prescribed burning in the Mount Lofty Ranges to avert dangerous, high-intensity bushfires has also increased in frequency over the last decade (Fig. 1), a management response to loss of human life in wildfires in other parts of Australia (Bardsley et al., 2015; Gibbons et al., 2012). In 2012, the South Australian Government adopted a target to burn 5% of all public woodlands annually in high-risk areas (DEWNR, 2014), which necessitated additional burning in the Conservation Land Management Zones. The consequences of this response for avian diversity are poorly understood; however, frequent low-intensity fires could reinforce population declines in species that require a complex understorey habitat (Ford et al., 2001).

Fire management in the Mount Lofty Ranges has created a mosaic of different post-fire vegetation age classes, whilst retaining some vegetation patches that have never been burnt in recorded history (Fig. 1). Simultaneously, the Mount Lofty Ranges woodland bird monitoring programme has comprehensively monitored avian abundance and diversity at 151 woodland sites. Using this unique, spatially replicated and longitudinal dataset, we investigated the long-term responses of avian abundance and diversity to disturbance by fire that are so difficult to address with short-term experimental studies (Driscoll et al., 2010). Using multinomial diversity models fitted to the data, we also simulated α-, γ- and β-diversity under different fire-management scenarios. We predicted that avian diversity metrics should be improved at intermediate levels of fire disturbance, but maximised by management scenarios that retained some long-unburnt woodland habitat.

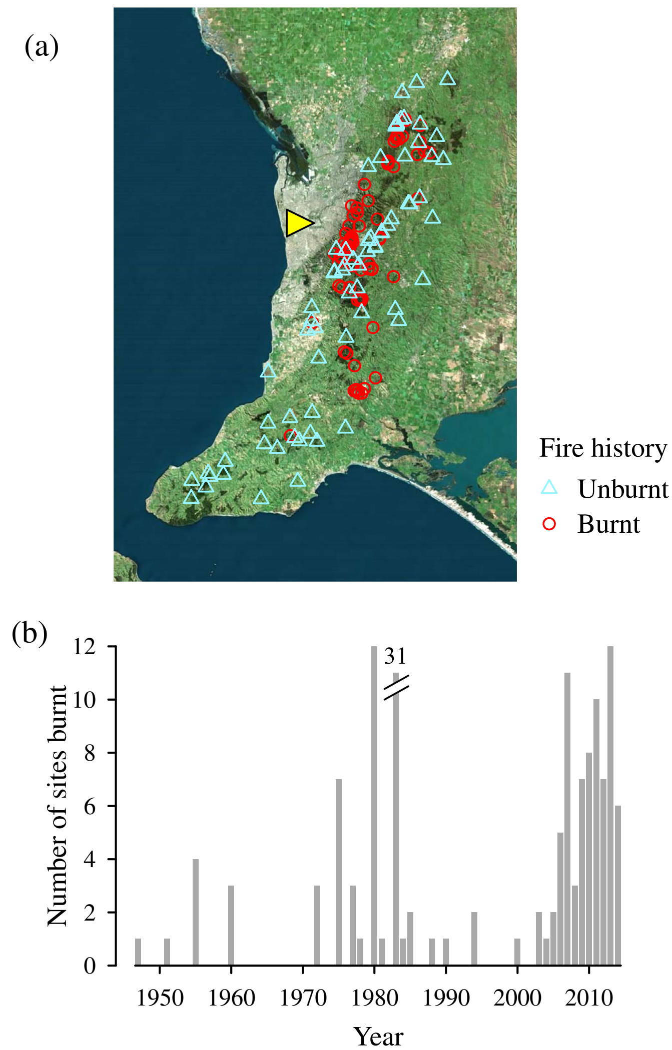

Fig. 1. (a) Bird survey sites in the Mount Lofty Ranges, South Australia, showing sites that have (n = 81) and have not (n = 70) been burnt in recorded history. The central business district of the city of Adelaide is marked with a yellow arrow. (b) The number of survey sites burnt in each year since 1947, illustrating the increased frequency of prescribed burning over the last decade. In 1983, 31 sites were burnt during the 'Ash Wednesday' bushfires. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2. Materials and methods

2.1. Survey methodology and species selection

Avian diversity in the Mount Lofty Ranges has been surveyed annually since 2001 across a core set of 151 sites (Fig. 1a). Each site consists of a 2-ha woodland plot dominated by stringybarks (*Eucalyptus obliqua*) (83 sites) or pink gum/blue gum (*Eucalyptus fasciculosa/leucoxylon*) (68 sites). Sites are surveyed 3 times per year during Austral spring and early summer, using a standard 20-min timed search, during