Forest Ecology and Management 318 (2014) 13–20

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

# Avian responses to the diversity and configuration of fire age classes and vegetation types across a rainfall gradient

Holly Sitters[a,*], Fiona J. Christie[a], Julian Di Stefano[a], Matthew Swan[a], Trent Penman[b], Peter C. Collins[a], Alan York[a]

[a] Fire Ecology and Biodiversity Group, Department of Forest and Ecosystem Science, University of Melbourne, Creswick, VIC 3363, Australia
[b] Centre for Environmental Risk Management of Bushfires, School of Biological Sciences, University of Wollongong, Wollongong, NSW 2522, Australia

ARTICLE INFO

*Article history:*
Received 4 November 2013
Received in revised form 7 January 2014
Accepted 7 January 2014
Available online 7 February 2014

*Keywords:*
Conservation
Disturbance
Fire management
Heterogeneity
Patch diversity
Spatial pattern

ABSTRACT

In many regions, planned burns are implemented to reduce fuel loads and mitigate wildfire risk; increasingly, they are also used to achieve conservation outcomes. However, there is uncertainty regarding how best to apply fire to landscapes in order to enhance biodiversity. The assumption that variable fire regimes are conducive to biodiversity conservation is appealing given its basis in landscape ecological theory, which predicts that spatially complex landscapes sustain greater biodiversity. This supposition is often used as a basis for fire management but has rarely been tested in the context of fire. We sought to test predicted positive relationships between bird diversity and both landscape diversity and configuration in the fire-prone Otway Ranges, southeast Australia, where vegetation transitions from treeless heath to tall open eucalypt forest across a rainfall gradient. We used a whole-of-landscape sampling approach, and mapped fire age classes and vegetation types separately within thirty-six 300 ha landscape sampling units. Bird surveys were undertaken at sub-sampling locations during two successive years, and presence-absence data were used to generate landscape-level estimates of species richness and turnover. Generalized linear mixed models, model selection and model averaging were used to investigate how birds responded to landscape diversity and configuration across the rainfall gradient. Species richness was positively associated with age class diversity, age class configuration and vegetation type diversity. Species turnover was positively associated with age class diversity in areas of lower rainfall but exhibited a negative response in areas of higher rainfall. Neither response variable was associated with vegetation type configuration. This study is one of few landscape scale analyses to provide empirical support for the widely held assumption that spatially variable fire regimes can increase the diversity of faunal assemblages. Further, our results demonstrated consistency in responses of species richness to fire-mediated landscape complexity across a rainfall gradient. Managers can potentially increase bird species richness by increasing both the diversity of fire age classes, and the complexity of age class configuration, within relatively small (300 ha) areas.

## 1. Introduction

Fire is a natural component of many ecosystems, and is an agent of disturbance that has multiple direct and indirect impacts on ecological communities (e.g. Smucker et al., 2005). The impact of fire on communities is a function of the fire regime, which describes fire size, frequency, severity, and seasonality (Bond and Keeley, 2005). Urbanisation and climate change have contributed to the modification of fire regimes (Pechony and Shindell, 2010; Brotons et al., 2013) and contemporary fire management policy is compounding change in fire regimes in many regions (e.g. Teague et al., 2010). The main purpose of planned fire is to reduce fuel loads in an attempt to reduce wildfire risk to human life and assets, but increasingly land managers also seek to use planned fire to conserve biodiversity (Penman et al., 2011).

Biodiversity conservation in fire-prone environments presents a challenge for research and management because it is unclear how best to apply planned burns to the landscape (Bradstock et al., 2005). Nevertheless, it is widely assumed that spatially and temporally variable fire regimes benefit biodiversity conservation (Parr and Andersen, 2006). This supposition is appealing because it is founded on landscape ecological theory (Wiens, 1976), which

---

* Corresponding author. Tel.: +61 (0)3 5321 4174.
*E-mail addresses:* hsitters@student.unimelb.edu.au (H. Sitters), fjc@unimelb.edu.au (F.J. Christie), juliands@unimelb.edu.au (J. Di Stefano), mswan@student.unimelb.edu.au (M. Swan), tpenman@uow.edu.au (T. Penman), petercollins129@gmail.com (P.C. Collins), alan.york@unimelb.edu.au (A. York).

http://dx.doi.org/10.1016/j.foreco.2014.01.009
0378-1127/© 2014 Elsevier B.V. All rights reserved.

predicts positive associations between species diversity and environmental heterogeneity (e.g. Smith et al., 2010). A mosaic of fire histories constitutes a mosaic of environmental states, which is generated by differences in the resetting, or partial resetting, of the successional process in time and space (Kleyer et al., 2007).

Although the notion that variable fire regimes benefit biodiversity is grounded in ecological theory, it has rarely been tested (but see Taylor et al., 2012, 2013), and delineation of ideal fire mosaics remains problematic (Driscoll et al., 2010). In the absence of empirical data, planned burns are implemented on the assumption that generating any degree of spatial variation in fire history will benefit biota (Clarke, 2008). The application of planned fire is becoming more common amid forecasted increases in the frequency and severity of wildfire under climate change (Stephens et al., 2012; McCaw, 2013). For example, in the state of Victoria, southeast Australia, a long term program of planned burning on an annual rolling target of 5–8% of public land (equating to a minimum of 385,000 ha per year) was introduced following severe wildfires in 2009 (Attiwill and Adams, 2013). In light of current increases in planned burning and the myriad unknown biodiversity implications, enhanced understanding of the responses of fauna to fire regimes is critical (Bradstock et al., 2010). Birds, for example, are highly responsive to environmental change due to their low birth rates and relatively long life spans, and in Australia more than 50 species of bird are thought to be at risk of extinction from altered fire regimes (Woinarski, 1999). However, despite numerous studies of the effects of fire on birds (for a review see Leidolf and Bissonette, 2009), there is uncertainty regarding the characteristics of planned burns that influence avian diversity.

The principal aim of this research was to test theorised relationships between forest bird diversity and landscape spatial pattern complexity within the fire-prone Otway Ranges of southeast Australia (Fig. 1). In this region, a rainfall gradient generates stark contrasts in vegetation type, from treeless heath to tall open eucalypt forest. We quantified landscape-level estimates of bird species richness and spatial turnover (beta diversity) by pooling site-based observations. We sought to examine how avian response variables are influenced by (i) fire-mediated spatial pattern, which is subject to control by land managers, and (ii) spatial pattern in vegetation type, which remains relatively static. We differentiated between these two influences by mapping fire age class and vegetation type separately, and tested two predictions about the responses of bird diversity to the observed spatial patterns.

Our first prediction pertained to landscape diversity. In accordance with landscape ecological theory (Wiens, 1976), we expected bird species richness and turnover to respond positively to patch diversity, quantified separately in terms of fire age class and vegetation type. Vegetation types are characterised by distinct structural and floristic elements; they thus constitute different environmental states, and are expected to support different species (Pino et al., 2000; Atauri and de Lucio, 2001). Secondly, we sought to investigate the influence of landscape configuration on avifauna. We anticipated a positive relationship between bird diversity and the complexity of patch configuration (i.e. a higher mean perimeter-to-area ratio), again quantified separately in terms of fire age class and vegetation type. To our knowledge, the influence of fire age class configuration on biodiversity is unstudied, but reports of associations between faunal species richness and patch configuration within fragmented landscapes abound. For example, positive associations between species diversity and edge habitat between adjacent patches have been reported, and are attributed to the unique habitat provided by the edge zone (Zurita et al., 2012). It is plausible that landscapes composed of a complex configuration of patches therefore support greater avian diversity because edge habitats constitute distinct environmental states.

## 2. Material and methods

### 2.1. Study area

The study was conducted in a 59,000 ha section of the Otway Ranges (the Great Otway National Park and Forest Park), southeast Australia (Fig. 1), where the climate is mild (mean annual minimum and maximum temperatures are 10.5 °C and 18.2 °C) (Bureau of Meteorology, 2012). The far northeast of the study area is dry (mean annual precipitation 661 mm) and low-lying (30–270 m a.s.l.). Heathland characterised by a low, dense shrub layer transitions to dry forests and heathy woodlands of messmate (*Eucalyptus obliqua*), brown stringybark (*Eucalyptus baxteri*) and red stringybark (*Eucalyptus macrorhyncha*) further southwest, where undulating landscapes merge with more complex topography at higher altitudes (200–650 m a.s.l) (Department of Sustainability and Environment, 2012). The southwest of the study area is wet (mean annual precipitation 1259 mm; Bureau of Meteorology, 2012) and is characterised by wet sclerophyll forest of mountain grey gum (*Eucalyptus cypellocarpa*), Tasmanian blue gum (*Eucalyptus globulus*) and manna gum (*Eucalyptus viminalis*).

Several wildfires have occurred in the study area since 1939 and planned fire has been applied regularly since 1982. Planned burns typically cover areas of <400 ha and are implemented during spring and autumn (Department of Environment and Primary Industries, 2013). They involve the application of low severity fire in a patchy manner, such that 30–70% of the treated area remains unburnt. Low severity planned fire consumes understory and midstory vegetation, and rarely reaches the canopy (Penman et al., 2007).

### 2.2. Study design

We selected landscape-scale sampling units by stratifying the study area into five regions representing dominant vegetation categories across the rainfall gradient (heathland, tall mixed forest, foothills forest, forby forest and wet forest). Within each region, areas were identified that were and were not planned for burning by the land management agencies during the course of the study. This was done to ensure that selected landscapes captured an adequate representation of younger age classes because old vegetation resulting from large wildfires is widespread in the study area. Landscapes were selected using 500 random points such that there was approximately equal representation in areas scheduled for planned burning and those which were not, within each region. We also ensured that within each region, landscapes contained a gradient of spatial pattern complexity with respect to fire age class and vegetation type. Landscape centre points were located at least 3 km apart where possible, and locations within 3 km of urban areas were excluded because they are subject to frequent planned burning. Thirty-two landscapes were selected in year one (2010) and four additional landscapes were selected the following year, resulting in a total of 36 landscapes in year two (2011).

For the purpose of site establishment, we delineated landscapes of 100 ha (1.13 km diameter) because this spatial extent is commensurate with the scale at which fire management is practised in the region (Department of Environment and Primary Industries, 2013). Further, we considered this size appropriate for a study of forest birds because it contains multiple territories for most of the species expected to occur in the area (for example, territory sizes for superb fairy-wren (*Malurus cyaneus*) and rufous whistler (*Pachycephala rufiventris*) are 0.8–2.6 ha (Nias, 1984) and 1.2–4.2 ha (Bridges, 1994), respectively).

We used a restricted random protocol to position five sites in each 100 ha landscape (Fig. 1), ensuring that at least one site was