



# Associations between occupancy and habitat structure can predict avian responses to disturbance: Implications for conservation management



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## ABSTRACT

Increasingly, fire is used as a management tool to mitigate wildfire risk and conserve biodiversity. Use of time since disturbance as a surrogate for faunal occurrence presents an appealing basis for biodiversity conservation; however, successional change in resource availability is often the direct driver of change in animal occurrence rather than time *per se*, and rates of resource development can be highly variable. To facilitate prediction of animal responses to disturbance, we sought to test whether time since fire (TSF) and habitat structure can predict bird occurrence. Time is only expected to predict occurrence if (i) species respond to structural resources and (ii) the abundance of these resources can be predicted by time. We examined the responses of 15 bird species to habitat structure and TSF using a 70-year chronosequence spanning three forest types in southeast Australia. Habitat structure variables predicted the occurrence of 13 species, four of which also responded to TSF. The levels of associations between occurrence, structure and TSF varied among vegetation types but response shapes were generally consistent. The fact that the majority of species did not respond to TSF indicates that TSF is an inappropriate surrogate for avian occurrence in our study system. Further, it is unlikely to be a reliable surrogate for faunal occurrence in forests that exhibit variable rates of post-fire structural development. We suggest that relationships between TSF and structure can provide insight into the capacity of TSF to predict animal occurrence. They will also reveal the extent to which fire can be used as a tool for managing biodiversity, and species likely to benefit or be at risk from particular fire regimes. This is critical given projected increases in the frequency and extent of fire in many regions.

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## 1. Introduction

Fire is a natural source of disturbance and a key driver of ecosystem dynamics (Bond and Keeley, 2005). Increasingly, fire is used as a management tool to mitigate the risk of severe wildfire to human life and assets, and to facilitate biodiversity conservation (Penman et al., 2011). However, the impacts of changing fire regimes on fauna remain poorly understood (Driscoll et al., 2010) and inappropriate fire regimes pose a threat to biodiversity in many regions (Woinarski, 1999; Fuhlendorf et al., 2006; Slik and Van Balen, 2006). Enhanced understanding of fire–fauna relationships is critical given the widespread application of fire under predicted increases in the frequency and severity of wildfire (Stephens et al., 2012; Attiwill and Adams, 2013).

Ecological succession describes the sequential replacement of species following disturbance (Connell and Slatyer, 1977) and provides a theoretical context for evaluating the responses of fauna to fire (e.g. Fox, 1982). Different animal species select habitats at different successional stages, so in principle, the occurrence or abundance of species will change with time since fire (TSF). This pattern of change, often referred to as a fire response curve (Watson et al., 2012), can potentially be identified for all species but habitat generalists (Pons et al., 2012). The use of generalised fire response curves as a basis for fire management is appealing because TSF is simple to measure, and a limited number of fire age classes will provide habitat for a suite of species (Watson et al., 2012). However, attributing fire responses to species requires either long-term studies or data from multiple sites over a spectrum of fire ages (Prodon and Pons, 1993). Furthermore, use of TSF as a surrogate for faunal occurrence might be inadequate because change in habitat structure is often a more important driver of animal community composition than TSF *per se* (Fox, 1982; Monamy and Fox, 2010; Di Stefano et al., 2011).

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Habitat structure influences the availability of food, shelter, nest sites, predation and competition (Brawn et al., 2001) and is frequently associated with animal diversity (MacArthur and MacArthur, 1961; Williams et al., 2002). Differences in post-fire structural development can result from a myriad of interrelated factors including: underlying geology, topography, vegetation type, the soil seed bank, previous land use, and the historic fire regime (e.g. Puerta-Pinero et al., 2012); fire characteristics such as severity and patchiness (e.g. Wang and Kembell, 2005); regional climatic patterns, and weather conditions before, during and after fire (e.g. Arnan et al., 2007). These differences inhibit generalisation of fire–fauna relationships because they generate variability in species' responses to TSF (Lindenmayer et al., 2008b; Jacquet and Prodon, 2009; Monamy and Fox, 2010; Pastro et al., 2013). Explicit recognition of change in habitat structure as the underlying driver of fire–fauna relationships will enhance understanding of variation in the post-fire occurrence of fauna among geographically diverse environments (Barton et al., 2014; Nimmo et al., 2014).

We examined interrelationships between TSF, habitat structure and the occurrence of birds to test whether TSF and structure can predict avian occurrence. We used a 70-year chronosequence that spanned a moisture gradient comprising three vegetation types (tall mixed woodland, foothills forest and wet forest) in the state of Victoria, southeast Australia, where planned burns are implemented on an annual rolling target of at least 5% of public land (equivalent to 385,000 ha per year) (Attwill and Adams, 2013). Initially, we examined the influence of TSF on attributes of habitat structure. Second, we investigated the influence of habitat structure variables on bird species' occurrence, and finally we explored the relationship between species' occurrence and time since fire. We expected the responses of individual bird species to correspond to one of three alternative pathways, which synthesise faunal responses to habitat structure and disturbance reported in the literature (Fig. 1):

- (a) species associated with structural attributes affected by fire would respond to TSF;

- (b) species that respond to structural attributes unaffected or weakly affected by fire would exhibit null responses to TSF; and  
(c) species that are not associated with structure would not respond to TSF.

TSF can affect fauna directly, for example through mortality or emigration (Fig. 1; Driscoll et al., 2010), but we focus on the indirect responses of birds to TSF over decade-long time periods. If most species in the system follow pathway (a), TSF would be a suitable surrogate for species' occurrence, and generalised fire response curves could be used to guide the management of fire for biodiversity. Conversely, if most species follow pathways (b) or (c), TSF would be an inadequate surrogate for species' occurrence, which may instead be predicted by attributes of habitat structure.

## 2. Material and methods

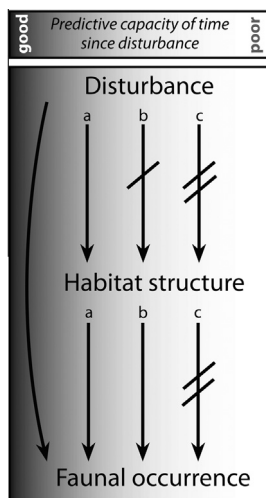
### 2.1. Study area

The study area covered 50,000 ha of the Otway Ranges in south-east Australia (38°29'S, 143°53'E; Fig. 2), where the climate is generally mild (mean annual minimum and maximum temperatures are 10.5 °C and 18.2 °C) and there is a gradient in mean annual rainfall ranging from 661 mm in the northeast to 1259 mm in the southwest (Bureau of Meteorology, 2013). The northeast of the study area is low-lying (30–270 m a.s.l.) and vegetation comprises dry forests and heathy woodlands of messmate (*Eucalyptus obliqua*), brown stringybark (*Eucalyptus baxteri*) and red stringybark (*Eucalyptus macrorhyncha*) (Department of Sustainability and Environment, 2012). Low, undulating landscapes transition to more complex topography at higher elevations in the southwest (200–650 m a.s.l.), where vegetation is predominantly wet sclerophyll forests of mountain grey gum (*Eucalyptus cytellocarpa*), Tasmanian blue gum (*Eucalyptus globulus*), messmate (*E. obliqua*), narrow-leaved peppermint (*Eucalyptus radiata*), and manna gum (*Eucalyptus viminalis*).

### 2.2. Study design and data collection

This study was part of an investigation of the impact of fire mosaics on flora and fauna, thus sites were positioned within 100-ha landscapes (Fig. 2). Landscape centre points were at least 3 km apart where possible, and locations within 3 km of urban areas were excluded because they are subject to frequent prescribed burning. Five sites were placed in each landscape using a restricted random protocol. Sites were placed at least 200 m apart and, to facilitate access, 50–300 m from roads. At each site, a 100-m transect was established along a randomly selected bearing such that it did not extend back towards the road. One-hundred-and-fifty sites were surveyed in total; 135 sites during the first year (2010) and an additional 15 sites were surveyed during the second year (2011).

Bird surveys were conducted two times each year during spring, once within four hours of sunrise and once within three hours of sunset. Surveys involved two 10-min point interval counts at the 20- and 80-m marks of each transect (Bibby et al., 1994; Lindenmayer et al., 2008a) and were undertaken by five observers. Individual detections were recorded as seen, heard or flying over, and assigned to one of two distance classes (0–50 m and >50 m) from the point of observation. Distance markers along transects were used to estimate the distances of detections. Surveys were carried out on days of fine weather (no rain or strong wind) between late September and early December, which is the breeding season for most species and overlaps the time when most



**Fig. 1.** Relationships between disturbance, habitat structure and faunal species' occurrence. Arrows imply associations between variables (slashes indicate relationships are weak or absent), and paler shading reflects attenuation in the capacity of time since disturbance to predict faunal occurrence. Species respond to time since disturbance if they are associated with an element of habitat structure that is affected by disturbance (pathway a); they do not respond to time since disturbance if associated with an attribute of structure that is weakly related or unrelated to disturbance (pathway b). Species that do not respond to habitat structure do not respond to time since disturbance (pathway c). Species can respond to time since disturbance directly, for example through mortality or emigration.

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