Biological Conservation 159 (2013) 248–256

Contents lists available at SciVerse ScienceDirect

Biological Conservation

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

Which fire management strategies benefit biodiversity? A landscape-perspective case study using birds in mallee ecosystems of south-eastern Australia

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ARTICLE INFO

Article history:
Received 12 June 2012
Received in revised form 26 November 2012
Accepted 4 December 2012
Available online 22 January 2013

Keywords:
Bird conservation
Fire management
Prescribed burn
Semi-arid
Fire mosaic
Whole-of-landscape design

ABSTRACT

Managing fire regimes for conservation of biodiversity is a global challenge. We examined the responses of birds to fire mosaics (4-km diameter landscapes) comprising different compositions of fire age-classes, and used these results to evaluate the relative value of four contemporary strategies for fire management. These were: (1) promoting a diverse range of age-classes; (2) promoting particular age-classes for fire-sensitive species; (3) preventing reserve-scale wildfire; and (4) burning a fixed percentage (e.g. 5%) of the landscape annually. None of the 28 species examined was positively associated with landscapes with extensive recently burned (<10 years) vegetation. One species was associated with landscapes with a greater diversity of age-classes while two species, including the endangered Black-eared Miner (*Manorina melanotis*), were associated with less diverse landscapes. Landscapes with extensive older (>35 years since fire) vegetation were favoured by three species; while two species preferred those with extensive mid-age (11–35 years since fire) vegetation. Our findings suggest that in semi-arid mallee ecosystems, management that results in large proportions of recently burned vegetation (e.g. by burning 5% of the landscape annually or permitting reserve-scale wildfires), or a high local diversity of age-classes, will negatively affect more bird species than they would aid. Management strategies that promote particular age-classes (i.e. mid-age and older vegetation) are likely to benefit bird species. Species-specific knowledge from a landscape perspective can refine management strategies to assist in defining the characteristics of 'desirable' fire mosaics for maintaining biodiversity.

1. Introduction

Worldwide, fire is an important tool that land managers can use to manipulate vegetation to promote biodiversity (Andersen et al., 2005; Brockett et al., 2001; Fuhlendorf et al., 2006; Parr et al., 2009). Predicting the effects on fauna of different fire management strategies requires knowledge of how biota respond to the landscape properties of fire (Bradstock et al., 2005; Driscoll et al., 2010). Despite widespread advocacy for the creation of diverse mosaics of fire age-classes to maintain biodiversity (e.g. Brockett et al., 2001; Brotons et al., 2004; Brudvig et al., 2007), detailed knowledge of the fire-mediated properties of landscapes (e.g. the extent and mix of fire age-classes) that will best meet the needs of biota is lacking. Indeed, the range of acceptable fire mosaics remains unspecified for any faunal species (Bradstock et al., 2005; Parr and Andersen, 2006) and has rarely been examined empirically (Clarke, 2008; Driscoll et al., 2010). There is an urgent need to fill this knowledge gap because fire management strategies have the potential to produce undesirable, as well as desirable outcomes for fauna (Clarke, 2008).

Different fire management strategies create different fire mosaics. One strategy is to deliver a diverse mosaic of age-classes by applying a burning approach broadly known as 'patch-mosaic burning' (Bradstock et al., 2005; Brockett et al., 2001; Parr and Andersen, 2006). However, the spatial and temporal characteristics of the desired mosaic are rarely specified. This strategy is built on the assumption that a mosaic of patches of differing age-classes (and fire histories) will maintain faunal diversity. Support for this strategy is inferred from research at the site scale that highlights patterns of faunal succession with time-since-fire, in which species exhibit preferences for specific post-fire age-classes (e.g. Fox, 1982; Saab and Powell, 2005).

A second strategy is to deliver at least a minimum area of the particular age-classes required by fire-sensitive threatened taxa (e.g. Brown et al., 2009; Clarke et al., 2005; Thomas et al., 2006a). For example, in mallee ecosystems of south-eastern Australia, a strategy to conserve large areas of older vegetation (e.g.

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http://dx.doi.org/10.1016/j.biocon.2012.12.005

Department of Environment and Heritage, 2008) has resulted from a perception that a group of threatened bird species depend on older vegetation to persist (Woinarski, 1989; Bradstock and Cohn, 2002; Clarke et al., 2005).

A third strategy involves active management to prevent reserve-scale wildfires that convert the entire landscape-management unit into a single age-class (e.g. Burrows, 2008; Fernandez and Botelho, 2003). In practical terms this includes, for example, the use of prescribed burning to create strategic corridors that break up the landscape and prevent fire spread (e.g. Sandell et al., 2006). Beyond this, the actual mix of age-classes has been left to vary naturally through the influence of small-scale wildfires.

A fourth strategy is to burn a fixed percentage of land each year in order to reduce fuel loads and mitigate the threat of wildfires. For example, in forest ecosystems of south-western Western Australia, an annual prescribed burning target of 5–10% has been established since the 1960s (Boer et al., 2009). In the state of Victoria, an annual prescribed burning target of 5% of public land has recently been adopted (Teague et al., 2010).

In this study, we examined the responses of bird species to fire mosaics (4-km diameter landscapes) that comprised different compositions of age-classes, and then used these results to evaluate the relative value to birds of these four contemporary strategies for fire management (Table 1). The study was undertaken in the fire-prone mallee ecosystem of semi-arid south-eastern Australia. In this system, inappropriate fire regimes are considered a major threat to birds (Woinarski and Recher, 1997). By characterising the types of fire mosaics (i.e. the spatial composition of age-classes) likely to be produced by particular management strategies, it was possible to examine the potential impacts of these strategies on birds (see Table 1). Both the incidence of a species and key landscape properties were sampled at the scale of the 'whole' landscape (sensu Bennett et al., 2006), thereby facilitating landscape-scale inference.

2. Methods

2.1. Study area

The study was undertaken in a 104,000-km^2 region of south-eastern Australia known as the Murray Mallee (Fig. 1). The region is of low elevation and characterised by an undulating dune-swale system. The climate is semi-arid, with hot summers and mild winters which experience mean daily maximum temperatures of 32 °C and 16 °C, respectively. Mean annual rainfall across the region is low (220–330 mm) (data sourced from Australian Bureau of Meteorology).

The most common native vegetation in the region comprises low (<10 m) canopies of multi-stemmed (mallee) *Eucalyptus* species (Bradstock and Cohn, 2002; Fig. 1). We focus on two dominant mallee vegetation types that have been identified and mapped across the region (Haslem et al., 2010): 'triodia mallee' and 'chenopod mallee'. Triodia mallee is characterised by *Eucalyptus socialis* and *E. dumosa* in the canopy and hummock grass (*Triodia scariosa*) in the understory. Chenopod mallee typically comprises *E. gracilis* and *E. oleosa* in the canopy and an understory of shrubs (e.g. *Olearia* spp.) and chenopod species (e.g. *Maireana pentatropis*, *M. pyramidata*).

2.2. Study design

We used Landsat satellite imagery to map the fire history of the study region from 1972 to 2007 (satellite imagery was incomplete prior to 1972) (Avitabile et al., in preparation). Individual fires were first digitised in ENVI 4.2 and then exported to ArcView 9.2 for data checking. We examined management reports and consulted with personnel from natural resource management agencies to assign a precise year of burn to fire patches. Areas burned before 1972 were categorised as 'older' vegetation (>35 years since fire). We used this fire history map of the study region to select 28 study landscapes (4-km diameter circles: 12.5 km^2) along two key gradients; (1) the proportional extent of older vegetation (i.e. >35 years since fire) and (2) the diversity of fire age-classes. The size of landscapes is consistent with the scale of prescribed burning conducted in reserves, and captured the variation in the range of post-fire ages represented in the study region (see Fig. 1). Landscapes were situated at least 2 km apart and all were located in large conservation reserves. Two landscapes were excluded from our analyses as they had a different vegetation type (i.e. heathy mallee: Haslem et al., 2010). Bird responses were examined in the remaining 26 landscapes (Fig. 1).

Table 1
Summary of four strategies of contemporary fire management considered to maintain biodiversity. Each management strategy supports particular fire mosaics that comprise different arrangements of fire age-classes in the landscape. A management strategy is assumed to benefit biodiversity if species prefer the arrangement of age-classes produced by thatstrategy.

Management strategy	Strategy benefits biodiversity where	References
1. Promote diverse age-classes in the landscape	1.1 Different species exhibit preferences for specific (but different) age-classes, such that a range of age-classes in the landscape is required to maintain all species 1.2 One or more species exhibit a preference for landscapes with diverse age-classes	Brockett et al. (2001), Fox (1982), Parr and Andersen (2006) and Saab and Powell (2005)
2. Promote particular age-classes expected to benefit fire-sensitive taxa	2.1 Maintaining extensive areas of selected age-classes does not put other biota at risk (e.g. species with a preference for (i) extensive areas of a specific (but different) age-class or for (ii) areas with diverse age-classes) 2.2 Targeted fire-sensitive species benefit from the promotion of age-class	Black-eared Miner, *Manorinamelanotis* (Clarke et al., 2005); Mallee Emu-wren, *Stipiturusmallee* (Brown et al., 2009); Northern Spotted Owl, *Strixoccidentaliscaurina* (Thomas et al., 2006a)
3. Prevent reserve-scale wildfires	3.1 Refer to 1.1 and 1.2 above 3.2 One or more species exhibit preferences for extensive areas of a particular age-class that is not recently burned vegetation	Burrows (2008), Fernandez and Botelho (2003) and Sandell et al. (2006)
4. Burn a fixed percentage (e.g.5%) of the landscape each year. This strategy results in large amounts of recently burned vegetation in ecosystems with long post-fire recovery periods (e.g. forest ecosystems)	4.1 No species exhibit preferences for extensive areas of older vegetation 4.2 One or more species exhibit preferences for extensive areas of recently burned vegetation	Teague et al., 2010