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Influence of land sharing and land sparing strategies on patterns of vegetation and terrestrial vertebrate richness and occurrence in Australian endangered eucalypt woodlands

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ABSTRACT

Native vegetation placed under an agri-environment scheme (AES) is purported to support greater biodiversity than vegetation managed for intensive livestock grazing, and conservation reserves are purported to support greater biodiversity than land sharing under AES. These predictions underpin financial incentive delivery programs that enable landholders to adopt environmentally friendly agricultural practices. To evaluate these predictions, we established a biodiversity monitoring program in endangered temperate eucalypt woodland communities in southern Australia. We compared vegetation variables and vertebrate species richness and abundance among sites under different land management between 2010 and 2014. Our sites included: (1) woodland remnants on private property recently placed under an AES land management agreement (land sharing), (2) woodland remnants in State conservation reserves as reference areas (land sparing), and (3) woodland remnants used for intensive livestock production as controls. We used hierarchical generalized linear models to examine patterns of biodiversity among management classes and over time. We found conservation reserves were structurally more complex and floristically richer compared to production sites, and AES supported greater cover of native perennial grass. Reptile and amphibian species richness and abundance, and total bird species richness did not differ significantly among management classes, although AES and reference sites supported more birds of conservation concern. Arboreal marsupials were significantly more species rich in conservation reserves than AES. Temporal patterns in vertebrate species richness were related to post-drought climatic conditions. Our findings suggest that strategies involving land sharing under AES are as effective as land sparing (e.g. conservation reserves) for bird conservation, but alternative strategies may be required to enhance habitat for less mobile species such as frogs and reptiles, or species dependant on old growth vegetation such as arboreal marsupials.

1. Introduction

With the global population approaching nine billion people, there is mounting pressure to provide food security while at the same time arrest the decline of biodiversity (Brussaard et al., 2010; Godfray et al., 2010; Chappell and LaValle, 2011; Tscharntke et al., 2012). However, attempts to integrate production and conservation present a major conservation challenge (Tilman et al., 2002; Habel et al., 2015), as approximately 40% of the earth's land is used for agriculture and the estimated rates of biodiversity loss are calculated to be 1,000–10,000 times the pre-human background rate of extinction (Chappell and LaValle, 2011). In recent years, strategies to minimize human impacts on the land include land sharing and land sparing (Fischer et al., 2008; Chappell and LaValle, 2011; Kleijn et al., 2011). The former strategy involves integrating biodiversity conservation and low-yield food production on the same land (Phalan et al., 2011b). An example of this strategy is the European Union's agri-environment scheme, a policy instrument that involves paying farmers to modify agricultural practices to mitigate the negative effects of agricultural intensification on biodiversity (Kleijn et al., 2011; Concepcion et al., 2012). The latter strategy involves separating land for conservation from high-yielding crop land (Fischer et al., 2008). Protected areas are one

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example of this strategy. These areas represent clearly defined geographical spaces that are recognised, dedicated and managed, through legislation, to achieve the long term conservation of nature, associated ecosystem services and cultural values (Dudley et al., 2010). Understanding which of these two strategies can accommodate greater biodiversity in agricultural landscapes around the world remains a key question (Kleijn et al., 2011; Habel et al., 2015).

In 2008, the Australian Government established the Caring for Our Country initiative (Commonwealth of Australia, 2009). This initiative delivered grants to State Government organisations and natural resource management agencies. The North East Catchment Management Authority (NECMA) in Victoria, Australia, was a successful recipient of a grant which funded the project '*Improving landscape scale conservation of threatened grassy woodland ecosystems in the Greater Murray Goulburn catchment*'. The aim of this project was to establish contractual agreements with private landholders to manage approximately 600 ha of endangered grassy woodland vegetation for biodiversity outcomes. This significant financial investment by the Australian Government in threatened native vegetation on private property in south-eastern Australia provided the motivation for this study (Commonwealth of Australia, 2009). This project, governed by NECMA, is analogous to the European Union's agri-environment scheme (AES) (Kleijn and Sutherland, 2003; Whittingham, 2007), which involves paying landholders to adopt environmentally friendly farming practices.

Whilst biodiversity in protected areas is relatively well studied and monitored, many AES have been criticized for their lack of monitoring and evaluation (Kleijn and Sutherland, 2003; Tscharntke et al., 2005; Whittingham, 2007; Kleijn et al., 2011; Concepcion et al., 2012). Furthermore, the majority of studies that have examined the effectiveness of AES involve investigations on invertebrates (Fuentes-Montemayor et al., 2011; Holland et al., 2012, 2014; Delattre et al., 2013; Wood et al., 2015) or birds (Baker et al., 2012; Lindenmayer et al., 2012a; MacDonald et al., 2012; Prince et al., 2012; Hiron et al., 2013; Bright et al., 2015). This is, in part, because of the ease in which these taxa can be studied (Whittingham, 2011). By contrast, studies on mammals (Broughton et al., 2014) and ectothermic vertebrates are scarce and represent a key knowledge gap in the ecological literature on agri-environmental schemes (Lindenmayer et al., 2012b; Michael et al., 2014) and would add valuable information to the land sparing versus land sharing debate (Kleijn et al., 2011; Habel et al., 2015).

We sought to address the question of whether the strategies of land sharing versus land gazetted for conservation (land sparing) had complimentary vegetation patterns and richness of vertebrate fauna in endangered eucalypt woodland communities. In doing so, we explored two questions that underpin biodiversity conservation in commodity production landscapes: (1) Does native vegetation placed under AES support greater vertebrate species richness and abundance than vegetation managed for primary production outcomes? (2) Do conservation reserves support greater vertebrate species richness and abundance than sites under AES? Remnant vegetation placed under a management agreement has the potential to support good quality native vegetation and high levels of biodiversity (Lindenmayer et al., 2012a; Michael et al., 2014). We postulated that management interventions such as reducing livestock grazing pressure, controlling weeds of National significance and restricting the removal of fallen timber are likely to result in improved native vegetation structure and condition, which in turn, may lead to improved habitat values and positive biodiversity outcomes. We also predicted that there would be a significant difference in vegetation structure and measures of vertebrate diversity between sites managed for production outcomes, sites placed under management agreements in 2010 (AES) and conservation reserves, in accordance with differences in land use history and past disturbance regimes. With these two above questions in mind, we aimed to evaluate the effectiveness of land sharing and land sparing strategies in conserving and improving woodland biodiversity.

2. Methods

2.1. Study area

Our study was conducted in the North East and Goulburn Broken catchment management areas of Victoria. This region is bordered by the Murray River in the north, the township of Merton in the south (36° 58′ 42″ S 145° 42′ 33″ E), Wises Creek Flora Reserve in the east (36° 03′ 17″ S 147° 12′ 58″ E) and the township of Locksley in the west (36° 49′ 06″ S 145° 18′ 31″ E) (Fig. 1). The predominant type of native vegetation in our study region is temperate eucalypt woodland, of which, over 85% has been cleared for agriculture and livestock grazing (Hobbs and Yates, 2000). The remaining stands off fragmented vegetation include several endangered grassy woodland communities listed under the *Environment Protection Biodiversity Conservation Act 1999*. The two endangered woodland communities in our study area include Box Gum Grassy Woodland dominated by white box *Eucalyptus albens*, yellow box *Eucalyptus melliodora* and Blakely's red gum *Eucalyptus blakelyi*; and Buloke Woodland dominated by Buloke *Allocasuarina luehmannii* and grey box *Eucalyptus microcarpa*. The quality and quantity of remnant vegetation in our study area varies according to land use history and past clearing, with most remnant vegetation occurring on hillsides or along drainage lines. Sites with minimal livestock grazing pressure are dominated by native grasses and forbs, whereas intensive production sites with a history of fertilizer use are dominated by exotic annual grasses and broad-leaved weeds.

2.2. Experimental design

Under the Australian Government's Caring for Our Country initiative, the North East and Goulburn Broken Catchment Management Authority (CMA) received a grant to improve and protect 580 ha of endangered grassy woodland vegetation. Expressions of interest were advertised and eligible landholders received funds and entered into management agreements to undertake conservation actions such weed control and fencing native vegetation to exclude or reduce livestock grazing pressure during the spring and summer months.

In April 2010, 13 discrete landscape units (paddocks containing threatened native vegetation) that ranged in size from 9–200 ha (mean = 53 ha) were placed under a management agreement (agri-environment scheme) and selected for biophysical monitoring. New fences were constructed where necessary and new grazing regimes were adopted before biophysical surveys were conducted. These areas were selected based on attaining benchmark vegetation condition criteria, such that structurally diverse and floristically rich sites were targeted over poorer condition sites. A single 200 m long transect (monitoring site) was placed randomly within patches of native vegetation at a minimum distance of 50 m from the edge of the remnant. These sites were paired with native vegetation managed for production purposes (control) on the same property to account for inter-farm differences in management practices. Control sites were selected to approximate the same vegetation type as AES but differed in having below benchmark vegetation condition scores. In addition to these paired sites, we selected the nearest conservation reserve/ roadside reserve (protected area) within 15 km of the same