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Marsupial response to matrix conversion: Results of a large-scale long-term 'natural experiment' in Australia

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ABSTRACT

We quantified changes in forest-dependent mammal populations when the habitat in which they live remains intact but the surrounding matrix is converted from open grazed land to closed pine plantation forest. This situation is increasingly common as plantations are often established on formerly cultivated or grazed land.
We conducted a large-scale (30 km^2), long-term (14 years) fully controlled and replicated (111 sites) 'natural experiment' in south-eastern Australia. The study focused on the effects of changes occurring in the matrix on mammals which inhabit patches of native *Eucalyptus* woodland.
We found that none of the five target species in our study (two macropods, two possums and a glider) responded negatively to pine plantation establishment. For three species (the sugar glider *Petaurus breviceps*, the red necked wallaby *Macropus rufogriseus* and the swamp wallaby *Wallabia bicolor*) the response to plantation establishment was positive (i.e., increase in colonisation/patch use in sites surrounded by pine plantations) whereas the two possums (the common ringtail possum *Pseudocheirus peregrinus* and the common brushtail possum *Trichosurus vulpecula*) were positively affected by the amount of native tree cover surrounding sites, rather than pine plantation establishment.
We foresee two strong implications of our work for the conservation of mammal species in agricultural areas subject to multiple land-use changes: 1) Our results suggest that converting agricultural land to pine plantations will not affect our target mammalian species negatively; rather, it may facilitate colonisation of remnant patches of native vegetation by some species. 2) Our findings underscore the critical importance of preserving remnant native vegetation within plantations, as it may decrease the risk of local extinction for some species or facilitate the colonisation of new sites for others. Thus, retention of patches of remnant native vegetation should be part of the design of future plantations.

1. Introduction

The conversion of forested and agricultural land to tree plantations is a major driver of global change (Foley et al., 2005). Humans have converted natural forests to forest plantations for thousands of years (e.g., Romans used to convert oak forests to pine plantations for timber production; Ginanni, 1774). However, in the last few decades, there has been an unprecedented global increase in planted forests as the Food and Agriculture Organization recorded a worldwide increase of 5 million hectares/year in the period 2000–2010. This is due to an increased demand for wood and for carbon storage (Jackson et al., 2005; Paquette and Messier, 2010).

A key distinctive feature of tree plantations compared to other types of crops is that they are often extremely large (i.e., covering areas thousands of hectares in size) and need to be managed over long time periods (crop rotation length is usually 7–50 years; Pawson et al., 2013). Consequently, the conversion of agricultural lands to tree plantations can have broad scale and long-lasting impacts on landscapes. How does biodiversity respond to these large-scale and long-term changes? The majority of existing studies have focused on birds, where response to plantations has ranged from positive to negative (Luck and Korodaj, 2008; Mortelliti et al., 2014b; Mortelliti and Lindenmayer, in press; Tomasevic and Estades, 2008; Villard and Haché, 2012). Similarly, the few studies focused on mammals have found complex responses to plantation establishment (Lindenmayer et al., 1999a, 2008; Youngentob et al., 2013), with some studies showing an increase in dispersal and connectivity due to plantation establishment (e.g., Banks et al., 2005; Taylor et al., 2007) and others suggesting an opposite effect (e.g., Lancaster et al., 2011). Previous studies, however, have focused mainly on comparing remnant patches surrounded by

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forest plantations with contiguous non-fragmented areas (i.e., have contrasted forest plantations vs. native forested habitat, Stephens and Wagner, 2007; Youngentob et al., 2013). Other studies have compared different matrix types (e.g., pine plantations vs. others) but have typically focused on single species or have employed an observational approach (e.g., Anderson et al., 2007; Umetsu and Pardini, 2006). Therefore, clear patterns of mammalian responses to the conversion of the agricultural matrix to forest plantations have not yet emerged in the existing literature.

Afforestation of cultivated or grazed land is increasingly common worldwide (Cyranoski, 2007; Sedjo, 1999) and thus empirical evidence to support decision-making is urgently needed. To contribute to filling this knowledge gap we focused our study on the following research question: *What happens to mammal populations when the habitat in which they live remains intact but the surrounding matrix is converted from open grazed land to closed plantation forest?*

Vagility is a key driver of animal responses to land-use changes (Kennedy et al., 2010; Watson et al., 2014), indeed many species of non-volant mammals are limited in their movements and are therefore very sensitive to matrix modifications (Anderson et al., 2007; Gascon et al., 1999; Sozio et al., 2013). The conversion of open agricultural land to a closed plantation environment may thus facilitate the movement of forest-dependent species. Tree plantations may therefore represent an opportunity for keeping landscapes productive for commodities like wood and paper whilst also increasing connectivity between patches of remnant vegetation (Brockerhoff et al., 2008; Tomasevic and Estades, 2008).

To evaluate the effects of matrix conversion on mammals, we conducted a unique large-scale (30 km^2) long-term (14 years) fully controlled and replicated (111 sites) landscape scale 'natural experiment' in south-eastern Australia. The goal of the experiment was to compare mammal populations living within 55 *Eucalyptus* patches surrounded by maturing pine (*Pinus radiata*) plantations (*treatment sites*), with mammal populations living within 56 *Eucalyptus* patches where the surrounding matrix remained unchanged (*control sites*, where the matrix remained pasture).

We targeted five forest dependent marsupials varying in body size and with contrasting mobility, ranging from arboreal marsupials (the common ringtail possum *Pseudocheirus peregrinus* and the common brushtail possum *Trichosurus vulpecula*) and gliders (the sugar glider *Petaurus breviceps*), to wide-ranging macropods (the red-necked wallaby *Macropus rufogriseus* and the swamp wallaby *Wallabia bicolor*). We predicted that the target mammalian species would display an overall positive response (i.e., increase in patch use or patch colonisation) to the conversion of agricultural land to forest plantations, as the new plantation matrix surrounding the native woodland was expected to provide more sheltered cover (compared to grazed land) for ground-dwelling species and facilitate movement for arboreal species.

2. Methods

2.1. Study area

Our study was conducted in the Nanangroe area (New South Wales, Australia; Fig. 1). The Nanangroe area lies approximately 500 km north-east of Melbourne (coordinates 34°54′–35°4′ and 148°32′–148°18′ E, altitudinal range: 250–750 m a.s.l.), covers approximately 30 km^2 and the region is characterised by hot summers and cool winters (temperate climate). The native vegetation is characterised by open woodlands dominated by white box (*Eucalyptus albens*), red box (*Eucalyptus polyanthemos*), yellow box (*Eucalyptus melliodora*), red stringybark (*Eucalyptus macrorhyncha*) and Blakely's red gum (*Eucalyptus blakleyi*). More than 80% of the original temperate *Eucalyptus* woodland has been cleared for grazing.

2.2. Experimental design

The Nanangroe area hosts a large-scale landscape transformation experiment known as 'the Nanangroe experiment' (Lindenmayer et al., 2001). In 1998 and in 2000 Forest New South Wales established a series of large scale Radiata pine (*P. radiata*) plantations in formerly grazed areas for the purpose of a) timber and pulp production and

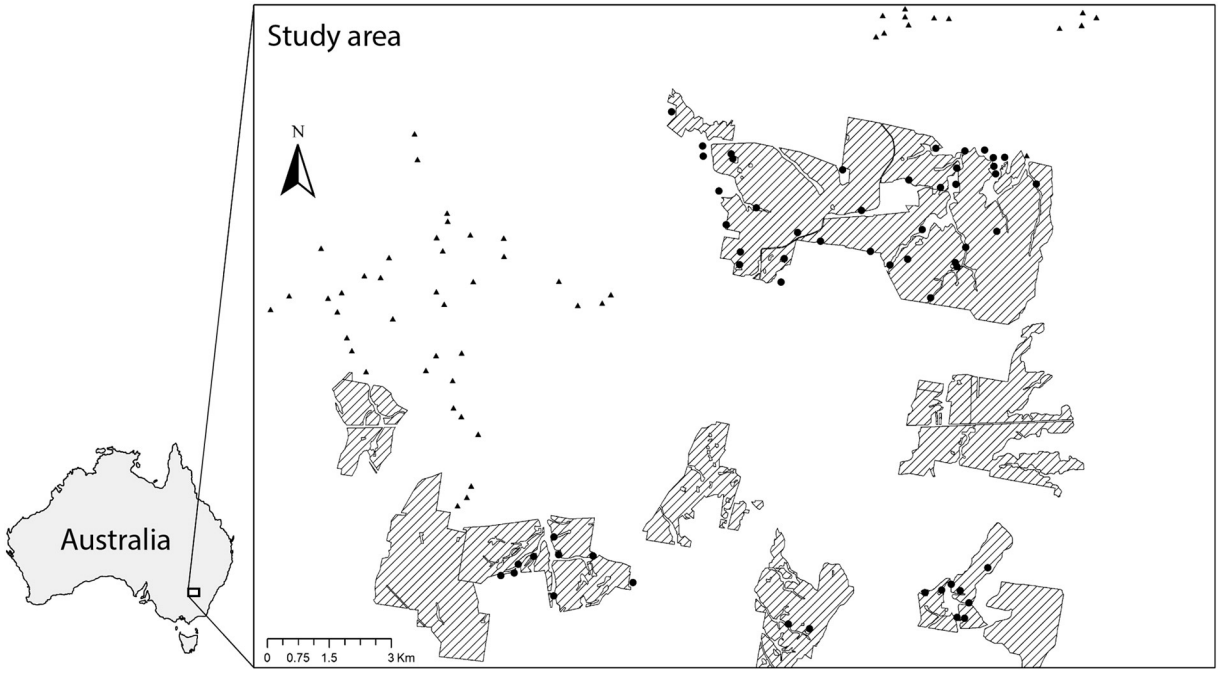

Fig. 1. Map of the study area. Black triangles are control sites (*Eucalyptus* patches surrounded by grazed areas); black circles are treatment sites (*Eucalyptus* patches surrounded by pine *Pinus radiata* plantations). Barred areas are pine plantations.