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Plantations, not farmlands, cause biotic homogenisation of ground-active beetles in south-eastern Australia

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ABSTRACT

Following landscape change, species invasions and extinctions may lead to biotic homogenisation, resulting in increased taxonomic and functional similarity between previously distinct biotas. Biotic homogenisation is more likely to occur in landscapes where the matrix contrasts strongly with native vegetation patches. To test this, we examined the distribution of ground-active beetles in a landscape of remnant *Eucalyptus* open woodland patches where large areas of lower contrast matrix (farmland) are being transformed to high-contrast pine plantations in south-eastern Australia. We sampled beetles from 30 sites including six replicates of five categories; (1) remnants adjacent to farmland, (2) remnants adjacent to plantation, (3) farmland, (4) plantation, and, (5) remnants between pine plantation *and* farmland. Community composition in the pine matrix was similar to native patches embedded in pine (ANOSIM, Global $R = 0.49$, $P < 0.000$), which we suggest is due to biotic homogenisation. Remnant patches with edges of both farmland and pine plantation did not represent an intermediate community composition between patches surrounded by either matrix type, but rather a unique habitat with unique species. Farmland supported the greatest number of individuals ($F = 9.049$, $df = 25$, $P < 0.000$) and species ($F = 5.875$, $df = 25$, $P = 0.002$), even compared to native remnant patches. Our results suggest that matrix transformations can reduce species richness and homogenise within-patch populations. This may increase the risk of species declines in fragmented landscapes where plantations are not only replacing native vegetation patches, but also other matrix types that may better support biodiversity. Our findings are particularly concerning given expanding plantation establishment worldwide.

1. Introduction

Many native species exist in a landscape mosaic that includes native vegetation patches surrounded by human-modified land-cover; the ‘matrix’ (Lindenmayer et al., 2001). Driscoll et al. (2013) defines the matrix as areas where species of conservation interest cannot form sustainable populations. The matrix can significantly impact the colonisation, persistence and survival of patch-associated species by influencing migration (Kuefler et al., 2010), changing abiotic conditions at patch edges (Lindenmayer et al., 2009), and providing resources to patch-associated species and/or non-patch species (Brady et al., 2011; Driscoll et al., 2013). While each of these effects have consequences for individual species and community composition (Driscoll et al., 2013), the ability of the matrix to foster non-patch species can lead to biotic homogenisation (Olden, 2006).

Biotic homogenisation refers to the reduction of species diversity and increase in community similarity between previously distinct biotas (Dormann et al., 2007; Olden et al., 2004). The ‘winners’ of biotic homogenisation are usually generalist species, with rapid dispersal rates and a high tolerance of human-modified landscapes (McKinney and Lockwood, 1999). The ‘losers’ are often habitat specialists, with low dispersal rates, being dependent on areas characterised by low levels of landscape modification (Robertson et al., 2013). These ‘losers’ are vulnerable to external perturbations (Dormann et al., 2007; Olden et al., 2004) and are therefore more likely to suffer from local extinction events. Successful generalist species may further expedite the process of biotic homogenisation by exerting competitive dominance over patch-associated species (Robertson et al., 2013).

Patch-associated species are expected to be less vulnerable to biotic homogenisation if they can also exploit the surrounding matrix (Ekroos et al., 2010). Matrices which share structural

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similarities with habitat patches can increase matrix use and movement for patch-associated species (reviewed in Eycott et al., 2012), which helps protect species against patch isolation and associated extinction risks (Donald and Evans, 2006). For example, species associated with open, grass-dominated native vegetation remnants may perceive agricultural pastures, also having open canopies and grasses, as sub-optimal habitat rather than hostile matrix (Bayne and Hobson, 1998; House et al., 2012; Sweaney et al., submitted for publication). Hence, in some fragmented landscapes, agricultural pastures can be more conducive to edge crossings, dispersal, and resource supplementation than dense closed forest (e.g. Jules and Shahani, 2003; Pita et al., 2007). Structurally similar matrices can support connectivity and persistence of native patch-associated species (Eycott et al., 2012). In these cases, the potential for widespread generalist species to successfully dominate patch-associated species or colonise patches after local extinctions is limited (Ekroos et al., 2010).

In many regions of the world, agricultural matrices are being transformed to tree plantations (Felton et al., 2010b; Kröger, 2012). Simplified landscapes created by the establishment and maintenance of monoculture plantations can cause a loss of habitat specialists and increase in population isolation, thereby increasing vulnerabilities to extinction risks (Dormann et al., 2007; Ekroos et al., 2010). Such landscape transformations may exacerbate and accelerate biotic homogenisation, particularly in areas where the agricultural matrix being replaced was structurally similar to native vegetation remnants.

We examined the distribution and abundance of ground-active beetles in a fragmented landscape in south-eastern (SE) Australia. Here, patches of *Eucalyptus* open woodland are surrounded by agricultural pastures (established almost two centuries ago) and extensive areas of pine plantations (established 1998), including areas where the two matrix types meet (Lindenmayer et al., 2008a). Previous research in this study area has shown that butterflies were often found in farmland, but were completely absent in pine plantations (Sweaney et al., submitted for publication). These results suggested that pine plantations constitute a high-contrast matrix for patch-associated species, which may make populations in patches surrounded by pine susceptible to biotic homogenisation.

Ground-active beetles are an ecologically important group in most ecosystems (Gibb et al., 2006b; Werner and Raffa, 2000) and are expected to also be sensitive to matrix transformation (Gaublomme et al., 2008). This sensitivity to environmental change may affect beetles differently depending on their ecological traits and/or functional group (Hyvärinen et al., 2009). For example, winged beetle species may be more abundant in recently disturbed areas as they can quickly colonise these sites compared to flightless species (Hart, 1998; Moretti et al., 2004), while larger-bodied species are often found to be negatively affected by disturbances (Ribera et al., 2001). Alterations to beetle communities and the loss of particular suites of species with certain ecological traits (such as body size and the presence of wings) and/or from different functional groups (such as trophic groups) can have major implications for food web stability and overall ecosystem function and integrity (Naeem et al., 1994; Ulanowicz, 1996). However, research examining biotic homogenisation and changes to ecological traits and functional groups in areas undergoing landscape transformation is limited (Ekroos et al., 2010), and represents a concerning knowledge gap in the literature.

To address this knowledge gap, we sought to determine if taxonomic and functional similarities between ground-active beetles in the matrix and native vegetation remnants was greater in areas where agricultural pastures had been transformed to pine plantations. We examined overall community composition, as well as the abundance and species richness of ground-active beetles and groups of beetles with various traits (body size, wing presence and trophic group). We expected that, because pine plantations in our study area contrast more strongly with eucalypt patches compared to agricultural pastures, ground-active beetle populations in patches surrounded by pine will show more signs of biotic homogenisation than patches adjacent to farmland.

Given that most of the world's new plantations are established on former agricultural pastures (Felton et al., 2010a), understanding species' responses to matrix transformations from agriculture to plantation is critical to successful biodiversity conservation and the effective management of plantations. This is particularly important given expectations that plantations will expand globally from 230 million ha to over 300 million ha by 2020 (FAO, 2010).

2. Materials and methods

2.1. Study area

This investigation was conducted at 'Nanangroe', 10–20 km south-east of Jugiong in NSW Australia (Lindenmayer et al., 2001; Fig. 1). Historically, the area consisted of extensive stands of temperate *Eucalyptus* open woodlands. Approximately 85% has been cleared for agriculture over the past 170 years (Lindenmayer et al., 2008b). In 1998, large areas of Nanangroe were converted to *Pinus radiata* plantations (Lindenmayer et al., 2008b). Prior to plantation establishment, 52 *Eucalyptus* woodland patches were selected for exemption from conversion (Lindenmayer et al., 2001). These remnant patches are relatively small fragments (most are <5 ha), surrounded by a matrix of agricultural pastures and dense pine plantations, including areas where the two matrices meet (Lindenmayer et al., 2001, Fig. 1). In Australia, closed forests (such as pine plantations) and open-woodlands are markedly different vegetation types, characterised by distinct differences in tree and canopy height and spacing, as well as a raft of other clear distinctions (Specht and Specht, 1999).

2.2. Study Sites

We selected 30 study sites, including six replicates of five different site categories; (1) woodland patch adjacent to both pine plantation and farmland (referred to as 'PwB' i.e. patches with *both* types of edge), (2) farmland matrix ('F'), (3) woodland patch adjacent to farmland ('PF'), (4) woodland patch adjacent to dense pine plantation ('PPi'), and, (5) pine matrix ('Pi') (Fig. 1).

Pine plantations ('Pi' sites) in Nanangroe are thinned every 12–15 years and clearfelled after 25 years (Lindenmayer et al., 2008b). At the time of our study, the pine plantation was mature (>12 years old) and densely stocked (i.e. had not been thinned). The ground cover of all pine matrix sites was comprised almost exclusively of fallen pine needles.

The agricultural pastures ('F' sites) studied are subject to fertilizer application, chemical spraying, and intensive grazing by domestic livestock (Lindenmayer, 2009). Our farmland sites supported sparse clusters of woodland trees and shrubs. Farmlands also were characterised by several species of native and introduced grasses.

Eucalyptus open woodland patches ('PwB', 'PF' and 'PPi') are dominated by an overstorey of several species of eucalypt; yellow box (*Eucalyptus melliodora*), white box (*Eucalyptus albens*), Blakely's red gum (*Eucalyptus blakelyi*) and to a lesser extent red stringybark (Fischer et al., 2008). Over-storey trees are widely spaced, and tree canopies rarely touch. The understorey and ground cover are simple, in part a characteristic of grassy open woodlands and also a result of grazing pressure from domestic livestock (Prober and Thiele, 1995). Shrubs and tall native grasses are uncommon