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Earthworm composition, diversity and biomass under three land use systems in south-eastern Australia

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ABSTRACT

In south-eastern Australia, strips of planted native trees and shrubs (shelterbelts) are frequently established to restore ecosystem services altered by agriculture. Despite their wide use, little is known about the effects of establishing shelterbelts on soil macro invertebrates, especially earthworms, which are of major importance in soil processes. We assessed earthworm composition, diversity and biomass in three land use systems: native shelterbelts dominated by *Acacia* and *Eucalyptus* species, agricultural pastures and native remnant woodland fragments dominated by *Eucalyptus blakelyi* and/or *Eucalyptus melliodora*. Earthworm communities differed significantly among systems, with abundance, biomass and diversity greatest under pasture. Within shelterbelts we saw a shift from high earthworm biomass and density to low with increasing time after establishment. Soil edaphic variables did not correlate strongly with earthworm biomass or density, but were correlated with earthworm community composition. Overall the introduction of native woody vegetation was associated with a decline in density and biomass of earthworms, including a decrease in the relative abundance of exotic species. As such shelterbelts can be used to promote native earthworm relative abundance, which may be important for local diversity, soil function and landscape connectivity.

1. Introduction

In response to a growing awareness of the need to conserve local biodiversity and reduce land degradation, the use of native plant species for ecological restoration has been widely implemented in Australian agricultural landscapes (Cleugh et al., 2002; Hobbs, 1993). One method of re-introducing woody species into agricultural land is through the planting of shelterbelts, which are strips of planted native trees and shrubs (Cleugh et al., 2002). The restoration and addition of shelterbelts to agricultural landscapes provides various ecosystem services including increased landscape connectivity, increased productivity and reduced erosion (Bird, 1998; Bird et al., 1993; Cleugh et al., 2002). Nevertheless, little information is available on the effects of restoration on local earthworm communities, despite the known role of earthworms as regulators of nutrient cycling, water infiltration and cycling of organic matter (Edwards, 2004; Lee, 1985).

The impact of agricultural practices on the abundance and diversity of earthworms, and in turn their influences on soil properties and plant production, is well studied worldwide (Edwards, 2004; Lee, 1985). This includes Australia, where exotic earthworms, notably Lumbricidae, have been studied in detail (Baker, 1998a, 2004). In southern Australia, the documented effects of exotic earthworm species on agricultural soils include influences on soil structure (Chan and Barchia, 2007), nutrient availability (Baker, 2007; Baker et al., 2003a), soil organic matter and lime burial (Baker et al., 1999, 1998; Chan et al., 2004), and beneficial microorganisms (Doube et al., 1994; Stephens and Davoren, 1997; Stephens et al., 1993).

Disturbance associated with agricultural practices in southern Australia is allied with reduced native earthworm abundance and invasion by exotic earthworm species, in particular European *Aporrectodea* species (Chan and Barchia, 2007; Chan and Heenan, 2006). However, our understanding of the ecological role of native species, especially the most common family of Megascolecidae remains poor (Baker et al., 2003b, 1997; Chan, 2004), although, it has been shown that native species of *Spenceriella* and *Gemascolex* (Megascolecidae) are inferior in improving soil structure, water infiltration, burial of surface dung and plant production compared with exotic Lumbricidae such as *Aporrectodea caligonosa*,*Aporrectodea trapezoides* and *Aporrectodea longa* (Baker, 1998a; Baker et al., 2003b; Blakemore, 1997). Common exotics, *A. calignosa*, *A.*

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trapezoides and *Aporrectodea rosea* in southern Australia are regarded as endogeic species (Lee, 1985). They feed on the organic matter in the mineral horizons.

Ecological relationships between native and exotic species in an Australian context are not well understood. In southern New South Wales, Baker (2004) found no correlation between the abundance of native and exotic earthworms. Contrary to this, in Western Victoria, native earthworms were generally absent where exotic species exceeded 400 individuals m^{-2}. In this case it is possible that competitive interactions were occurring between exotic and native species similar to that shown experimentally by Dalby et al. (1998a) for two exotic species, where removal of food, destruction of habitat and consumption of cocoons by *A. longa* reduced the abundance and biomass of *Microscolex dubius*. Similarly Didham et al. (2007) argued that habitat modification alters ecological interactions (including competition) between invasive and native species. Changes in land use can alter preferential feeding on different quality litter by earthworms, and this can in turn influence community composition and altered soil edaphic properties (Rajapaksha et al., 2013b). For example, the invasion of *A. trapezoides* and displacement of native *Argilophilus* species in areas converted to livestock grazing in California was facilitated by the rapid growth and reproduction rate of *A. trapezoides* in these altered systems (Winsome et al., 2006). However, in less productive natural grasslands, *A. trapezoides* failed to acquire enough resources to maintain its rapid growth rates or reach reproductive maturity. Further to this, in South Australia, Dalby et al. (1998b) concluded that the European lumbricid, *A. longa*, was able to survive and grow in woodland soil, but did not reproduce.

The particular focus of this study was to improve understanding of how earthworm communities are altered by the restoration of agricultural land via planting native shelterbelts. We hypothesised that: (1) earthworm community composition and diversity were different under pastures, shelterbelts and native remnants; and (2) earthworm communities within shelterbelt habitats by chronosequence would show trajectories that converge toward those observed in local native remnants.

2. Methods

2.1. Study site and design

The study sites were located near Murrumbateman in New South Wales, Australia (34°57′0″S, 149°01′0″E). The region is predominantly agricultural land dominated by grazing. The climate is temperate, with warm to hot summers and cool winters. The average annual rainfall is 927 mm (Australian Bureau of Meterology, 2014). Rainfall is higher in spring to summer with October and November being slightly wetter than other times. Rainfall is lowest within the winter months of June and July.

Nine sites in total were selected. Six sites consisted of 2 parallel transects per plot, one within a shelterbelt established on old pastoral land and the other within an adjacent grazed pasture (Fig. 1). Another three sites were selected within three native remnant woodlands. At each native remnant site a single transect was sampled. These native remnants were small (approximately 1 ha) fragments which had various levels of disturbance. The native remnants all had an overstory of native tree species, predominantly *Eucalyptus blakelyi* and/or *Eucalyptus melliodora*. The level of understory disturbance varied within and between the native remnant patches in particular due to grazing, thus exotic pasture species were typically present to varying degrees in native remnants.

The six shelterbelt transects were separated into three age classes: 0–5 years since establishment (young), 5–15 years (middle aged), 15+ years (old), with two (replicate) transects in each age class. This provided a chronosequence. At the time of establishment, each shelterbelt had been direct sown with a seed mix of tree and shrub species endemic to the Murrumbateman area. The primary trees used were a mix of *Acacia* and *Eucalyptus* species. The dominant *Eucalyptus* species within the seed mix consisted of *E. mannifera*, *E. blakelyi*, *E. viminalis* and *E. melliodora*, the dominant *Acacia* species were, *A. mearnsii*, *A. cardiophylla*, *A. decurrens* and *A. rubida*.

All transects were situated within a radius of 12 km, thus limiting environmental variability between sites. All sites were located on mid to lower slopes. Each transect was 90 m long. Shelterbelt width varied from 4 to 8 tree rows wide. Transects were centered through each shelter belt, to minimise any possible edge effects. In the pastures, transects were positioned parallel, approximately 15 m away from the edge of the shelterbelt (Fig. 1). Transects within native remnants were positioned in the middle of the native remnant patch. Ten sample points were set along each transect at 10 m spacings. Paired transects (shelterbelt and pasture) within each site were sampled at the same time. Earthworms were collected at these sample points in late July in both 2012 and 2013. This timing ensured maximum surface activity of the earthworms and thus the most efficient collection (Baker et al., 1992a,b,b).

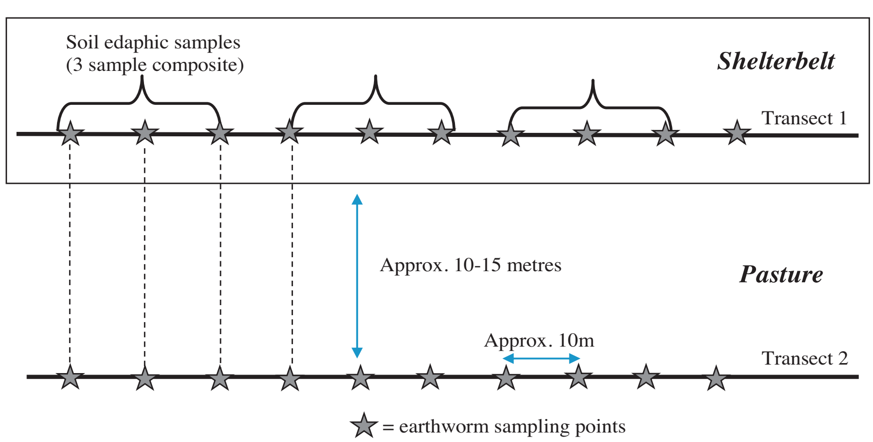

Fig. 1. Experimental design for replicated field sites. Each site contained one transect in each of the shelterbelt and pasture. Ten sample points for earthworms and three (composite) sample points for soil edaphic properties were established along each transect. The design was replicated over six sites (shelterbelts = 6 transects, pastures = 6 transects). Sampling in native remnants was similar, but consisted of 1 transect per site. The design was replicated over three native remnant sites (native remnants = 3 transects).