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Small mammal abundance in Mediterranean *Eucalyptus* plantations: how shrub cover can really make a difference

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ABSTRACT

In the last decades production forests have expanded their range worldwide, and in many regions (e.g., southern Europe) *Eucalyptus* spp. have been the target species used by foresters. However, *Eucalyptus* characteristics and management intensity of its plantations may impose constraints to local wildlife, often considered highly harmful for wildlife. However, although Portugal and Spain encompass the widest *Eucalyptus* production forests in Europe, and the Mediterranean area is a biodiversity hotspot, no study has yet tested specifically the impact of this exotic forest inner structure on rodent's populations. Aiming to evaluate whether this negative influence of *Eucalyptus* stands' on wildlife was associated with any specific structural characteristics of plantations, we tested the effect of plantation's understory structure and homogeneity on small mammal abundance and population structure. Small mammal were live-trapped in autumn and spring in nine sampling sites in *Eucalyptus* plantations in central west Portugal, one km apart. By using a GLMM approach we detected that the percentage of shrub coverage was the main driver of small mammal abundance, although season (autumn) also showed a positive influence. Only for *Crocidura russula* we detected an influence of stands homogeneity in population structure, with a sex-ratio variation according to edge distance. Thus, our study clearly indicates that by maintaining an understory layer within exotic *Eucalypus* plantations, managers may assure that these anthropic environments may still support an abundant small mammal community, thus contributing to the preservation of key ecosystems functions.

1. Introduction

The increasing expansion of areas occupied by production forests, closely associated with a greater consumption of lignocellulosic products (e.g. paper), has enhanced the pressure towards native habitats, thus threatening biodiversity (Abelho and Graça, 1996; Estades and Temple, 1999; Hartley, 2002). In many regions, production forests are often composed by exotic species, and one example of these are the *Eucalyptus* spp. plantations today found worldwide (Stanturf et al., 2013). Its high growth rate, fiber qualities and relatively early flowering make this species monospecific stands one of the highest productivity and profitable forestry systems (Alves et al., 1990, 2012; Calviño-Cancela et al., 2012; Diaz-Balteiro et al., 2009). In 2009 these exotic forests covered more than 20 Mha, throughout America, Africa, Asia and Europe (GIT Forestry Consulting, 2009). In the later region, *Eucalyptus globulus* plantations are mainly concentrated in the Iberian Peninsula, covering more than 1.4 Mha (Flores et al., 2014; GIT Forestry Consulting, 2009), 700.000 ha of which are found in Portugal and represent nowadays the most wide spread forest environment in the country (7.5% of its total area).

Eucalyptus plantations are reported to impose constraints to native wildlife and induce conservation concerns (e.g. Cruz et al., 2015; Timo et al., 2014). Often *Eucalyptus* stands limit not only wildlife species occurrence, but also population abundance and even individual body condition (Martin et al., 2012). The monospecific *Eucalyptus* plantations outcompete other arboreal species (with the exception of those present in fragments of native vegetation associated, for example, to riparian areas – Thomas, 1979), and further affect the diversity and abundance of native understory (Bengtsson et al., 2000; Calviño-Cancela et al., 2012). Moreover, disturbance over native vegetation that survives in such forested environments varies throughout the production cycle (Carneiro et al., 2007) and with management intensity, with

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highest impact associated with intensive management schemes (Bauhus et al., 2001; Calviño-Cancela et al., 2012; Fabião et al., 2002).

Changes imposed to native vegetation by the implementation of *Eucalyptus* stands, have cascading effects upon local wildlife. This may result in less diverse and abundant communities, when compared to native habitats. For example, a study in Australia has shown that the lack of herbaceous and shrub cover in *Eucalyptus* plantations decreased the systems adequacy to support most vertebrates (Hobbs et al., 2003). Small mammal communities living in southeast Brazilian *Eucalyptus* plantations showed lower species richness and abundance than those inhabiting fragments of native vegetation, and mostly composed by generalist species (Martin et al., 2012). These authors also detected a variation in the species composition along the production cycle, with pioneer and more generalist species colonizing the plantation first and more ecologically demanding species only present in later stage stands. Moreover, population abundance and use of plantations may vary according with the rodents' yearly cycle (e.g. reproduction phase, non-reproduction phase, dispersal) and season (Bierman et al., 2006; Takele et al., 2011).

Also for invertebrates the same pattern was detected (Cunningham et al., 2005), with plantations supporting less diversity of insects than native forests, a fact linked to the complexity of the understory found in native forests. However, when compared to other agriculture activities leading to native forest deforestation (e.g. soya plantations, cattle pastures), forested plantations may be considered a regional 'lesser evil' when sustainably managed (Brockerhoff et al., 2008).

To minimize the impact of *Eucalyptus* plantation on biodiversity, several authors have advocated the introduction of discontinuities within plantations, by implementing patches of native vegetation (e.g. Williams, 2015). These patches can increase ecotone areas, with the consequent increase of available niches that may allow species to survive in a plantation dominated landscape. Particularly important are the preservation of wetland areas (Hartley, 2002), especially in Mediterranean environments, where water availability is usually scarce (mainly in summer) and often unpredictable (Blondel et al., 2010). However, there is a lack of evidence of the influence of such schemes in Mediterranean Europe *Eucalyptus* plantations.

In the present study we aimed to test if the deleterious effects of *Eucalyptus* plantations reported for wildlife are associated with any specific structure characteristic of the plantation's habitat, which could be shaped by management actions. In Mediterranean Europe, no study has tested the effect of *Eucalyptus* plantations inner structure on small mammals abundance (but see Teixeira et al., 2017). Thus, we tested the effects of under canopy layers (e.g. shrub, herbs) and plantations homogeneity (e.g. distance to roads, ecotones and water sources) on wildlife abundance, using small mammals as models. Small mammals where chosen because they have an important functional role in ecosystems, directly influencing vegetation cover (e.g. as seed dispersers/predators; Perea et al., 2012), soil composition (e.g. burrowing activities; Sieg, 1988) and predator food webs (e.g. snakes, raptors/owls, carnivores; Macdonald, 1983; Rosalino et al., 2011; Sieg, 1988). They are often considered good ecological indicators, including that of sustainable forest management (e.g., Pearce and Venier, 2005), since they respond rapidly to disturbances due to their short generation times, r-life strategy (Jacob et al., 2008; Martin and Palumbi, 1993) and sensitivity to micro-habitat changes (e.g. Rocha et al., 2011).

Using a *Eucalyptus* plantation with a low-intensity management, we tested four hypotheses: (1) shrub cover variations influence small mammals' abundance (i.e. areas with higher understory cover will support higher small mammals abundance, due to more food and shelter availability; e.g. Rosalino et al., 2011); (2) Small mammal abundance is mainly determined by the distance to ecotone areas (e.g. Sekgororoane and Dilworth, 1995), or (3) to wetland patches (e.g. Rosalino et al., 2009); and (4) population fluctuations are mainly determined by the species seasonal life cycles variation.

2. Material and methods

2.1. Study area

This study was carried out at an *Eucalyptus* plantation within Companhia das Lezírias, S.A., the largest Portuguese farmstead, with an agrosilvopastoral area of approximately 18.000 ha, located in western Portugal (38°47′56.39″N, 8°53′36.48″W). This region is dominated by a flat plain, characterized by a Temperate Mediterranean Climate, with dry and hot summers and mild but rainy winters, with an average annual temperature that reach 16.3 °C and mean annual rainfall of 700 mm (Gonçalves et al., 2012).

The *Eucalyptus globulus* plantation occupies an area of approximately 476 ha limited, at its eastern edge, by a paved road (N118). The planted stands size ranged from 3 ha to 55 ha, separated from each other by dirt paths. Although tree's age varied among stands, most of them were covered with mature trees averaging 20 m of height. This plantation had a higher understory biomass when compared to intensively managed *Eucalyptus* plantations, commonly characterized by the almost complete absence of shrubs and herbs (Calviño-Cancela et al., 2012; Cerveira et al., 1999; Hobbs et al., 2003; Lindenmayer and Hobbs, 2004). This was the result of a low intensive management that allowed the establishment of native understory species, namely heathers (*Calluna vulgaris*, *Erica* sp.), gorse-heaths (*Ulex australis*, *Stauracanthus genistoides*), rock-roses (*Cistus salvifolius*, *Halimium calycinum*), sunroses (*Halimium halimifolium*), genistas (*Genista triacanthos*), French lavenders (*Lavandula stoechas*), narrow-leaved mock privets (*Phillyrea angustifolia*), mastic trees (*Pistacia lentiscus*) and rosemaries (*Rosmarinus officinalis*).

The surrounding area, mostly covered by cork oak savannah-type woodlands, holds a diverse community of terrestrial vertebrates (Gonçalves et al., 2012), including at least eight small mammal species, namely the European hedgehog (*Erinaceus europaeus*), the greater white-toothed shrew (*Crocidura russula*), the Iberian mole (*Talpa occidentalis*), the Cabrera vole (*Microtus cabrerae*), pine voles (*Microtus* sp.), the wood mouse (*Apodemus sylvaticus*), the brown rat (*Rattus norvegicus*) and the Western Mediterranean mouse (*Mus spretus*).

2.2. Sampling design

The sampling design was based on small mammals live-trapping in a 4 km^2 grid, consisting of 9 sampling sites spaced 1 km from each other within the *Eucalyptus* plantation (Fig. 1). At each sampling site a grid of 25 trapping points was defined (5 × 5; 1600 m^2), with traps spaced 10 m apart.

2.3. Animal capture and handling

We used a capture-mark-recapture approach (Gurnell and Flowerdew, 2006) to estimate small mammals occurrence and abundance. As potentially co-occurring species show diverse eco-morphological characteristics, at each trapping point we set three types of traps (two models of Sherman box traps – 38 × 10 × 12 cm and 23 × 8 × 9 cm, and a pitfall trap – size 14 × 14 × 17 cm) to assure a broad representation of the local small mammal community (Dizney et al., 2008). The Sherman traps were