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Response of wood-inhabiting fungal community to fragmentation in a beech forest landscape

N. ABREGO[a,b,*,1], I. SALCEDO[a,1]

[a]Dept. Plant Biology and Ecology (Botany), Fac. of Science and Technology, University of the Basque Country (UPV/EHU), P.O. Box 644, E-48080 Bilbao, Spain

[b]Dept. of Biological and Environmental Science, P.O. Box 35, FI-40014, University of Jyväskylä, Finland

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ABSTRACT

Fragmentation of natural habitats has become one of the main causes of the loss of biodiversity. To assess the effects of forest fragmentation on wood-inhabiting fungal community in a beech-dominated landscape, 15 differently shaped beech forest fragments were examined in northern Spain. This work covers all the wood-inhabiting macromycetes, including Basidiomycota and Ascomycota. A modelling approach was used to examine the predictability of the fungal community in a fragmented beech forest landscape. In the beech forest patches, a large proportion of edge, low tree densities and low levels of variety of woody debris caused a decrease of wood-inhabiting fungal richness. The fungal community composition proved complex to model due to its specific traits: it is made up of many species, most of which are rare, and each fungal group responds differently to environmental variables. Nevertheless, the dead wood availability and the exposure to light significantly affected the fungal community composition.

Introduction

Fragmentation causes the natural habitat to break into smaller and more isolated patches. The principal consequences of such habitat transformation include reduction in patch size, decreased connectivity between patches and increased proportion of edge-effected habitats (Saunders et al., 1991). Habitat loss due to fragmentation is one of the greatest threats to species worldwide (Hanski, 2005; World Resources Institute, 2005). Habitat loss, fragmentation and degradation processes usually occur together, which often makes it difficult to assess the individual effects of each factor (St-Laurent et al., 2009). However, it is known that landscape fragmentation has direct consequences for spatial population dynamics, mainly because of increased edge effects (Fischer and Lindenmayer, 2007). Indeed, fragmentation of the landscape causes changes in the physical fluxes of radiation, wind

* *Corresponding author*. Dept. Plant Biology and Ecology (Botany), Fac. of Science and Technology, University of the Basque Country (UPV/EHU), P.O. Box 644, E-48080 Bilbao, Spain.
E-mail address: nerea.abrego@ehu.es (N. Abrego).
[1] Tel.: +34 946015355; fax: +34 94 601 3500.
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and water especially at edges, which affects species composition and nutrient cycling processes (Saunders et al., 1991).

Not all organisms respond in the same way to habitat fragmentation effects, and those with low dispersal capability and specialised habitat requirements are known to be especially vulnerable (Henle et al., 2004). Wood-inhabiting fungi suffer particularly from habitat loss, due to the large-scale reduction in dead wood caused by forest management (e.g. Penttilä et al., 2004; Siitonen, 2012; Abrego and Salcedo, 2013), and are known to respond to fragmentation, as species richness and the occurrence of some species have been shown to be affected by patch isolation and size (Berglund and Jonsson, 2001; Penttilä et al., 2006; Laaksonen et al., 2008; Berglund et al., 2009; Nordén et al., 2013). Indeed, the occurrence of wood-inhabiting fungi is known to depend on habitat availability on a landscape scale (Ódor et al., 2006). Thus, the break-up of forests into small patches causes the loss of their principal habitat, dead wood, from the matrix. Similarly, increased solar radiation and wind at the edges of patches of forest change the physical conditions of the habitat, affecting the occurrence of wood-inhabiting fungal species (Siitonen et al., 2005) and communities (Crockatt, 2012). There are few studies which have examined the likelihood of species occurrence at resource level to determine the response of individual species to fragmentation (Berglund et al., 2009; Nordén et al., 2013). The main results of these studies suggest that red-listed species require well connected natural forests, whereas some generalist species which become more abundant in fragmented surroundings (Berglund and Jonsson, 2008; Nordén et al., 2013) are better adapted to forest edges (Siitonen et al., 2005).

Although there have been several studies that have tried to assess the effects of forest fragmentation on wood-inhabiting fungal species, some groups of fungi have not yet been studied. Most of those studies have selected certain species of particular interest on Red Lists (e.g. Sverdrup-Thygeson and Lindenmayer, 2003; Berglund and Jonsson, 2008; Laaksonen et al., 2008) and have been carried out in boreal forests. The species chosen for such studies are normally easily identifiable red-listed wood-inhabiting fungal species, which mainly fruit on coarse dead wood. In particular, species of the Ascomycota phylum and most of the corticioid and lignicolous agaricoid species have been overlooked in such ecological studies. The principal reasons for neglecting those species groups are that many of them develop tiny ephemeral sporocarps that are laborious to identify and present high detectability variation that complicates the community assessment (Halme and Kotiaho, 2012).

In southern European beech forests very little is known about the threatened wood-inhabiting fungal species, and forest characteristics are very different from other European beech forests (Brunet et al., 2010). Actually, the beech forests from these regions are close to their southern limit of distribution, and therefore the climatic conditions and floristic composition differ from the central European ones. In line with the way in which the forests have been managed in northern Spain, beech forests have been exploited for wood extraction, applying techniques such as thinning and selective cutting, which has simplified the biological and structural complexity of most forests. This type of forest management has also decreased the volume of dead wood and the variety of woody debris types in beech forests (Abrego and Salcedo, 2013). At the landscape level, the beech forests of northern Spain have been fragmented due to the expansion of grasslands for cattle grazing in ancient times.

In the present study we use a large species dataset (including Basidiomycota and Ascomycota) collected from several beech forest patches in northern Spain to examine how forest fragment characteristics affect wood-inhabiting fungal species. We analyse response to the effects of beech forest fragmentation at three levels: overall fungal richness, the whole fungal community and specific wood-inhabiting fungal groups. We use a modelling approach to test the predictability of each level in each forest fragment and each plot sampled. The specific objectives of the study are to: (1) measure the impact of beech forest fragmentation on wood-inhabiting fungal richness and community structure; (2) create statistical models to predict wood-inhabiting fungal richness and community composition based on the environmental and spatial variables of different-shaped beech forest fragments; and (3) analyse the responses of the different wood-inhabiting fungal groups to environmental variables in forest fragments.

Materials and methods

Study area

The study area considered here is an area of *Saxifrago hirsutae–Fagetum sylvaticae* S. acidophilous beech forest type (Loidi and Báscones, 1995) in northern Navarre (northern Spain). This area has a temperate climate with an annual mean precipitation of 1 500–2 000 mm and a mean temperature of 10–13 °C. In this territory, beech forest is the main vegetation type, covering most of the forest area. These forests are dominated by beech trees (*Fagus sylvatica*), though other tree species also occur occasionally (e.g. *Quercus robur*, *Castanea sativa* and *Ilex aquifolium*).

Although most of the territory is covered by beech forest, its structure and natural complexity have been altered by the local land use practices. The original beech forest area was reduced in ancient times for providing grassland for cattle grazing, and in general, the remaining beech forest patches are heavily managed by thinning for firewood. Most forest patches are quite small, the smallest being around 32 ha, while a few are large the biggest measuring around 14 000 ha. The biggest forest patches are irregular in shape, with many edges, while some medium size patches are more compact in shape (Fig 1). The study area chosen can thus be considered to have characteristics that make it suitable for the study of forest fragmentation effects: forest partition occurred because of the same type of management of grasslands, the expansion of grassland occurred in ancient times and there are a great many forest patches. For this study, each forest patch is considered as one forest fragment (Fig 1).

Design of the study

Considering the different beech forest patches from the northern Navarre, a nested mixed model was used for data