Journal of Environmental Management 94 (2012) 125–131

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Does forest fragmentation affect the same way all growth-forms?

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ARTICLE INFO

Article history:
Received 26 October 2010
Received in revised form
12 April 2011
Accepted 14 June 2011
Available online 15 September 2011

Keywords:
Patch size
Degree of isolation
Species traits
Forest specialist species

ABSTRACT

Fragmentation of natural habitats is one of the main causes of the loss of biodiversity. However, all plants do not respond to habitat fragmentation in the same way due to differences in species traits. We studied the effect of patch size and isolation on the biodiversity of vegetation in the mixed-oak forests in the north of the Iberian Peninsula. The aim was to evaluate whether all the growth-forms of vegetation are equally affected by forest fragmentation in order to improve the management strategies to restore this type of vegetation.

This study has shown that the effect of the area and spatial isolation of the patches was not the same for the different growth-forms. Fragmentation had a mainly negative effect on the richness and diversity of forest specialist species, especially ferns and herbaceous growth-forms. Moreover, the presence and/or cover of woodland herbaceous species (such as *Lamiastrum galeobdolon* and *Helleborus viridis*) and of woodland ferns (namely *Asplenium adiantum-nigrum, Asplenium trichomanes, Polystichum setiferum, Dryopteris affinis*) were negatively affected by patch size, possibly due to the reduction of habitat quality. These species have been replaced by more generalist species (such as *Cardamine pratensis*, *Cirsium* sp., *Pulmonaria longifolia* or *Rumex acetosella*) in small patches. Patch isolation had a negative effect on the presence of forest specialist species (namely, *L. galeobdolon*, *Frangula alnus*, *Hypericum androsaemum*, *A. adiantum-nigrum and Athyrium filix-femina*) and favored colonization by more generalist species such as *Cirsium* sp., *Calluna vulgaris*, *Erica arborea* or *Ulex* sp. Thus, in this region special attention should be paid to the conservation of forest specialist species, especially ferns and herbs. In conservation policy focused on forest specialist species, the most valuable species in forest ecosystems, conservation of large forest areas should be promoted.

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1. Introduction

The excessive destruction and fragmentation of natural and semi-natural habitats on the Earth's surface is recognized as one of the principal causes of the loss of wild biodiversity (D'eon and Glenn, 2005; Fischer and Lindenmayer, 2007; Haines-Young, 2009; Harrison and Bruna, 1999; Hobbs, 2000; Meffe and Carroll, 1997; Wilcox and Murphy, 1985; Wood et al., 2000). The effects of habitat fragmentation on biodiversity have been studied for several decades, resulting in a vast literature on this topic. Despite continued debate about the relative importance of habitat fragmentation and habitat loss (Fahrig, 2003; Hanski and Gaggiotti, 2004), it is generally accepted that the size and spatial distribution of habitat remnants alters the patterns of species distribution and abundance within a landscape (Ewers and Didham, 2006).

The processes of reduction, spatial separation and increased isolation of habitats caused by fragmentation are associated with a reduction in the abundance, distribution and viability of species closely linked to these habitats (Bender et al., 2005; Fahrig and Merriam, 1994; Kleyer et al., 1996; Kupfer et al., 2006). However, not all plant species show the same response to habitat fragmentation. For instance, a number of studies have shown that the nature of the species-area relationship describing species loss from habitat fragments is confounded by differences in species traits (Cagnolo et al., 2006; Ewers and Didham, 2006; Godefroid and Koedam, 2003; Kolb and Diekmann, 2005). Some studies have shown that habitat fragmentation affected plants with specific dispersal modes (Kolb and Diekmann, 2005; Tabarelli et al., 1999), low frequency of occurrence and high habitat specificity (Hill and Curran, 2001; Iida and Nakashizuka, 1995). Plant species with different growth-forms (woody *vs*. herbaceous; short-lived *vs*. long-lived) can present different responses to fragmentation. Woody plants grow more slowly and devote the greater part of their photosynthesis to the production of structural materials for long-term survival (Chapin, 1991). Meanwhile, herbaceous plants

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0301-4797/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jenvman.2011.06.024

grow and die more rapidly and devote the greater part of their photosynthesis to reproduction and rapid turn over. These characteristics can make species respond differently to fragmentation and, if they are affected, have different response times (Ewers and Didham, 2006). In fact, it has been postulated that short-lived species like herbs should be more sensitive to edge effects which would favor colonization by ruderal species (Cagnolo et al., 2006). Influence from surrounding vegetation may actually increase the total species richness of fragmented woodlands, but reduce the fraction of habitat specialists (Harrison, 1999). Thus, an assessment of the effect of fragmentation on plant communities should be based not only on species richness but also on species type, which can be defined in terms of conservation value or ecological traits (Honnay et al., 1999a; Hill and Curran, 2001).

In the north of the Iberian Peninsula the 'the native vegetation type mixed-oak forests, dominated by *Quercus robur* L. with *Fraxinus excelsior* L. and *Castanea sativa* Miller (Onaindia et al., 2004). However, since the beginning of the 20th century much of the area has been planted with fast growing exotic species, namely *Pinus radiata* and *Eucalyptus globulus*. This change has mainly affected forest specialist species (Amezaga and Onaindia, 1997). The aim of this research was to test whether the spatial configuration of those forests, namely size, form and degree of isolation of the patches, affects all of the plant species in the same way or whether the effect varies for different growth-forms (herbaceous, ferns, climbers, shrubs and trees) and forest specialist species (Aseginolaza et al., 1988).

2. Methods

2.1. Study area

This study was carried out in the Urdaibai Biosphere Reserve (UBR) (area 220 km^2) located in the north of the Iberian Peninsula (43°19′N, 02°40′W) (Fig. 1). The UBR is one of the most important natural areas of the Basque Country (Northern Spain) due to, among other features, its unique and diverse landscape which includes a craggy countryside occupied by meadow land, oak groves, deciduous woods and, especially, pine plantations.

The native vegetation for about 80% of the UBR is mixed-oak forests, dominated by *Q. robur* L. with *F. excelsior* L. and *C. sativa* Miller (Onaindia et al., 2004). Throughout the 20th century, these

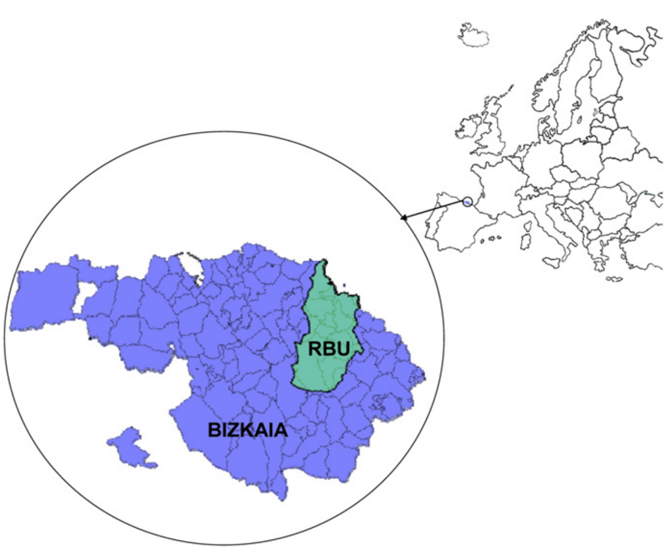

Fig. 1. Location of the study area.

native mixed-oak forests were heavily fragmented and, as a result, today they cover only about 6% of the total area of the Urdaibai Reserve (Rodríguez-Loinaz et al., in press) as has happened with other natural forests in other parts of the word (Schessl et al., 2008). Afterward, the traditional practices of timber and coal production were abandoned and the remaining forest patches started a process of regeneration (Michel, 2006).

2.2. Patch selection and vegetation sampling

A total of 33 patches of mixed-oak forest situated in the UBR were selected by means of the land use map at a 1:10 000 scale (Fig. 2). The selection was made as a function of size, since a principal objective was to establish if the diversity of vascular plant species was affected by the size of the patch. Therefore, 18 patches of a size between two and 3 ha and 15 patches of a size between ten and 30 ha were selected. There was no difference in altitude, slope, soil type or geographical location between small and large patches (small patches: mean altitude: 133 ± 18.89 m, slope: 25 ± 2.10%, pH: 4.65 ± 0.10, UTM_X: 525 762 ± 687, UTM_Y: 4.7984 10^6 ± 1534 and large: mean altitude: 174 ± 17.36 m, slope: 30 ± 2.61%, pH: 4.76 ± 0.11, UTM_X: 526 363 ± 962, UTM_Y: 4.7965 10^6 ± 1693). This selection was determined after analysis of the distribution of patch sizes given that these were the only sizes that occurred in significant numbers. The following indices were determined for each patch: area, distance to the nearest patch of mixed-oak forests (edge to edge) (NND, measure of the degree of isolation) and the fractal dimension (FD, measure of the form) (Mc Garigal et al., 2002), for which the v-LATE software was used (Lang and Tiede, 2003).

Since sampling effort and number of species recorded are usually related (Magurran, 1988; Hill et al., 1994; Lomolino, 2001), the area sampled was kept constant in all sites in order to avoid sampling artefacts on the effects of habitat fragmentation (Hill et al., 1994). In each of the patches (large and small) one plot of 25 m × 25 m was located approximately in the center of each patch in order to minimize possible edge effects. Within each plot, five sub-plots of 2 × 1 m were delineated. One was in the center and the other four separated by 12 m, making a cross with an arm running with the slope and the other perpendicular to it. The number of sub-plots was determined according to the method of the species/area curve (Kent and Coker, 1992). In these sub-plots the pattern of vegetation during June and July 2005 was studied. In each sub-plot, plant species were identified and the percentage cover for each plant species, calculated through visual estimation, was determined. In order to determine percentage cover, five different strata (levels) were considered, i.e. 0–0.20, 0.20–1, 1–3, 3–7, >7 m, following Brower and Zar (1977) and Onaindia et al. (2004). The total percentage cover for each plant species was obtained by adding up its percentage cover in each of the five different strata. In addition, the cover of trees as an indirect measure of quantity of light was measured, as light condition is one of the main factors in forest habitats (Sarlöv-Herlin and Fry, 2000) and it is known to affect vegetation (Amezaga et al., 2006; Borchsenius et al., 2004).

Summing the cover in the five sub-plots, the total cover of each species in the sampled area was obtained. Using these data the indices of richness (S) and Shannon (H′) and Simpson (1-D) diversity were calculated. These indices were obtained for the overall vegetation and for the different growth-forms present. Five grownforms were considered: herbaceous, ferns, climbers, shrubs and trees. Not woody species were separated in herbaceous and ferns, due to their botanical difference, and woody species were separated in climbers, shrubs and trees. To classify not climber woody species as shrub or tree the following criteria was used: not climber woody species that usually do not reach heights higher than 3 or

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