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Dynamics of understorey herbaceous plant diversity following shrub clearing of cork oak forests: A five-year study

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Abstract

Cork oak forest management has been traditionally oriented towards optimization of cork production. Shrub clearing is a traditional silvicultural practice aimed to: (1) facilitate cork extraction (conducted every nine years); (2) increase cork yield by reducing competition from neighbouring shrubs; and (3) reduce fire risk by decreasing fuel load. These silvicultural practices, however, may interfere with current objectives of conservation and sustainable use of biodiversity. The effects of shrub clearing on different diversity components were assessed in three structurally contrasting forests sites, located in Southern Spain. A fenced experimental plot (1 ha) was established at each forest site. Half of each plot was shrub-cleared and the other half was left unmanaged (control stand). Afterwards, the presence of herbaceous species was monitored during five consecutive years in a total of 120 permanent quadrats (1 m^2). Species richness (α- and γ-diversity) increased with the clearing, mainly by expansion of open grassland species, while β-diversity declined due to the homogenizing process associated with this expansion. Thus, the herbaceous species composition was modified by these silvicultural practices, especially the second year following treatment application. Effects differed across forest stands, being more marked in the *Open Woodland*, while there was no significant effect observed in the closed *Forest*. Understorey herbaceous communities were resilient to shrub clearing and initial diversity values were approximately restored after five years. The high resprouting potential of shrubs contributed to this resilience. Based on the results of this study, we propose several low costs strategies to be incorporated in forest management plans to reconcile cork oak extraction with the maintenance of biodiversity.

Keywords: Mediterranean forest; *Quercus suber*; Silvicultural practices; Species richness; Sustainability

1. Introduction

Mediterranean plant communities exhibit a remarkable biodiversity, which is in part maintained by a certain level of anthropogenic exploitation derived from ancient land use practices (Pons and Quézel, 1985; Blondel and Aronson, 1999; Grove and Rackham, 2001). Current forest policy is concerned with the development of sustainable forest management practices that allow simultaneous exploitation of goods and services, and preservation of structural and functional attributes of forest ecosystems (Riley, 1995; Brown et al., 2001; Thomas et al., 2006). Understanding how silvicultural practices impact plant community structure (e.g., biodiversity) and function is thus a critical goal of current applied ecology (Franklin, 1993; Roberts and Gilliam, 1995; Pimentel et al., 1997; Decocq et al., 2004; Young et al., 2005).

The management of cork oak forests in the Mediterranean Basin has been mainly oriented towards maximization of annual yield in cork production. For this purpose, the forest is typically divided into various management units which are periodically managed (roughly every nine years, depending on the locality) for cork extraction. Shrub clearing is a common silvicultural practice associated with cork extraction, which consists of cutting of shrubby cover and damaged trees every nine years, with the following objectives: (1) to facilitate the extraction of oak tree bark to obtain cork; (2) to increase cork production by reducing competition from neighbouring shrubs; and (3) to reduce the risk of fires by decreasing the amount of

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fuel. Traditionally, shrub clearing was carried out manually and only around productive cork oaks, saving money and energy, and indirectly minimizing the damaged area. Today, due to both public subsidies to forestry and availability of motor powered machinery, shrub clearing is far more intensive and extensive, producing a more homogeneous and intense perturbation in managed forests. Shrub clearing could negatively impact herbaceous plant species diversity in the forest understorey.

In general, forest management has been identified as one of the main causes of plant diversity loss (Gilliam and Roberts, 1995); however, an increasing number of studies show that silvicultural practices can have a positive or neutral effect on understorey plant species richness (e.g., North et al., 1996; Gale et al., 1998; Jenkins and Parkers, 1999; Battles et al., 2001). Nevertheless, the number of plant species (species richness) is only one component of biological diversity; the understorey species composition, the spatial scale (β- and γ-diversity), as well as other components, such as number of endemic species and taxonomic singularity of the elements (Ojeda et al., 1995), must be also taken into consideration (Zavala and Oria, 1995). In addition, the effects of silvicultural practices should be evaluated over a temporal sequence. This long-term perspective is critical for the design of sustainable and conservation-oriented management practices (Scarascia-Mugnozza et al., 2000; Rees et al., 2001).

In this study, we investigated the effects of shrub clearing on various components of understorey herbaceous biodiversity, and their temporal trends along a period of five years. Using cross-comparisons between shrub-cleared and paired unmanaged stands, we examined whether initial biodiversity values (previous to treatment application) were restored before completion of the cork extraction cycle. The study was conducted in three stands located within one of the largest cork oak forests in Europe, ''Los Alcornocales'' Natural Park (South Spain). The selected stands varied structurally, representing a wide range of cork oak forests in this region: an open woodland with nearby grasslands, a woodland with small trees and intermediate tree density, and a closed forest.

Specifically, we sought to answer the following questions: (i) What are the effects of shrub clearing on the different diversity components (α-, β- and γ- diversity) of the herbaceous understorey?; (ii) Is there any temporal change in herbaceous composition after shrub clearing?; (iii) What is the balance between local colonization and extinction rates?; (iv) Are these changes, if any, consistent across forest stands?; and (v) How persistent are these effects over a five-year period?

2. Methods

2.1. Study area and forest sites

The study area is located in the oak forests of Aljibe Mountains, near the Strait of Gibraltar, in Southern Spain. Bedrock is dominated by Oligo-Miocenic sandstone, with a rough relief and a highest peak of 1092 m a.s.l. Climate is subhumid mediterranean-type, with cool and wet winters, alternating with warm and dry summers. Mean annual temperature ranges from 14.6 to 18.4 °C, with a mean monthly maximum of 36 °C (July) and mean monthly minimum of 2 °C (January). Mean annual rainfall varies from 701 to 1331 mm (mean of 1056 for 15 weather stations), depending on the effects of the local orographic relief. The mean number of frost days ranges from 10 to 20 days per year at the highest altitude, to one day per year in the vicinity of the coast (see climate description in Mejías et al., 2007).

Vegetation is dominated by evergreen cork oak (*Q. suber*) forests, mixed with winter deciduous oaks (*Q. canariensis*), which are more abundant near streams (Urbieta et al., in press). The shrubby understorey is diverse and rich in endemic taxa (see general vegetation description in Ojeda et al., 2000). The area is located in the Baetic-Riffian diversity hot spot, which extends across South Spain and North Morocco, and is rich in endemic plant species, but also is threatened by human intervention (Medáil and Quézel, 1997). Most of the forested area was protected in 1989 as *Los Alcornocales* (meaning ''cork oak forests'') Natural Park, covering about 1680 km^2.

The main forest enterprises are cork extraction from *Q. suber* trees (their bark is stripped off every nine years), free-range livestock (mainly cattle), and game hunting (especially of red deer and roe deer) (see a description of the Park management in CMA, 2005).

Three structurally different forest sites were selected within this protected study area (Fig. 1): a closed forest (hereafter called *Forest*) at ''Tiradero'' site (36° 9′ 46″ N, 5° 35″ 39″W), 335-360m a.s.l. on a NE slope; a wodland located at ''Buenas Noches'' (hereafter called *Woodland*, 36° 22′ 56″N 5° 34′57″W), 410–450 m a.s.l. on a NE slope; and an open woodland (hereafter called *Open Woodland*), at ''Panera'' site (36° 31′ 54″N, 5° 34′ 29″W), 530–560 m a.s.l. on a NW slope. Values of stand tree density, basal area and woody species composition of the three forest sites are shown in Table 1 (see also Quilchano et al., 2008 for description of study sites). Differences in overstorey canopy cover (leaf area index, LAI) and light availability at ground level (GSF) are also shown in Table 1. Both parameters were quantified by hemispherical photographs, a widely accepted technique for exploring forest structure and understorey light conditions (see details in Valladares and Guzmán, 2006). Photographs were taken in the centre of each of 120 sampling quadrats (see sampling design below) in spring (April-May) of 2001, at 0.5 m above ground level, using a horizontally-levelled digital camera (Coolpix 4500, Nikon, Tokio, Japan) with a fish-eye lens of 180° field of view (FCE8, Nikon). Images were analysed using Hemiview Canopy Analysis software version 2.1 (1999, Delta-T Devices Ltd, Cambridge, UK).

The forest stand (*Forest*) exhibited the highest basal area and the lowest light availability at ground level. The overstorey consisted of a well-developed mixed *Q. suber–Q. canariensis* stands and the shrub layer was dominated by *Phillyrea latifolia* and *Viburnum tinus*. The woodland stand (*Woodland*) had the highest tree density, though with a lower total basal area in comparison with the *Forest* site. Leaf area index (LAI) and light availability values (GSF) were intermediate between the other