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Effects of silvicultural treatments on forest biodiversity indicators in the Mediterranean

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Abstract

Biodiversity maintenance is a key management objective and a requisite for sustainable forestry. Research efforts on the effects of forest management on biological diversity are therefore increasingly needed, particularly in regions such as the Mediterranean that have been comparatively less studied in this respect. We analysed the effects of different regeneration and stand improvement treatments on six forest biodiversity indicators (snags, mature trees, shrub abundance, shrub species richness, tree species richness and tree species diversity) in the Mediterranean region of Catalonia (NE Spain) by analysing a set of 9808 plots from the Third Spanish National Forest Inventory comprising both managed and unmanaged stands.

Managed stands had significantly fewer large-diameter trees (with the exception of *Quercus suber* forests) and snags than unmanaged ones. While clearcutting decreased tree species richness, stands with selection cutting had higher shrub and tree species richness and tree species diversity, which is consistent with the intermediate disturbance hypothesis, which states that diversity is highest at intermediate disturbance levels. Stand improvement treatments increased the number of large-diameter trees, tree species richness and diversity (cleaning and thinning), and shrub species richness (pruning), while no significant negative effect was found for any of the other indicators.

Our results suggest that preventing silvicultural disturbances may not be the best solution for conserving and enhancing biodiversity in the Mediterranean forests of Catalonia, where many stands have high tree density that impedes the establishment of a variety of plant species and the transition to more developed stages. Selection cutting may be an appropriate and sustainable regeneration treatment for Mediterranean forests in this respect, but their practical implementation should avoid the systematic harvesting of the highest quality and largest trees, which is still common in many private forests in Catalonia.

Keywords: Forest biodiversity; Biodiversity indicators; Sustainable forest management; Mediterranean forests; Silvicultural treatments; Stand improvement

1. Introduction

Biodiversity maintenance is a key management objective and a requisite for sustainable forestry and it is necessary to understand the dynamics and heterogeneity of natural forests to provide guidelines for management (Spies and Turner, 1999; Lindenmayer et al., 2000). It is also important for recognising the role of disturbances as integrated features of ecosystems (White, 1979). In this context, forest management treatments can be understood as disturbances that may have a large influence on the composition, structure and biodiversity of the forest (Niemelä, 1999; Bengtsson et al., 2000). Different species are more or less benefited by the changes in environmental conditions provided by the disturbances and different silvicultural treatments therefore lead to differences in species composition and distribution. For example, several early successional tree species which were not found in undisturbed forest were present in the harvest gaps analysed by Schumann et al. (2003) through a gap dynamics approach. In recent years, research about biodiversity in managed landscapes has been motivated by species declines and habitat loss (Halpern and Spies, 1995) and the use of management practices to emulate natural disturbances and dynamics has been explored in several studies (Hansen et al., 1991; Roberts and Gilliam, 1995; Niemelä, 1999; Bengtsson et al., 2000; Atlegrim and Sjöberg, 2004). Various fundamental differences between forestry operations and natural disturbances were reported by Niemelä (1999) for boreal forests, particularly the periodicity

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and spatial configuration of timber harvesting, residual organic matter, the frequency of fire and the use of exotic species in regeneration practices. At the same time, new harvesting practices based on natural forest dynamics have also been developed (Hansen et al., 1991). Consequently, the compatibility of timber production and biodiversity conservation is a critical challenge (Eriksson and Hammer, 2006), not only because of societal demands but also because human-managed ecosystems are critical for maintaining biodiversity (Pimentel et al., 1992). Recent studies have analysed the influence of harvesting strategies on biodiversity, suggesting alternatives to maintain biodiversity in managed forests. Deal (2007) suggests the use of light partial cutting as an alternative to increase both stand structural diversity and enhance biodiversity in old growth forests in Alaska. The cumulative landscape-scale effects of the management strategies of different land owners could also favour biodiversity as analysed by Gustafson et al. (2007).

The intermediate-disturbance hypothesis is a nonequilibrium model of diversity postulating that maximum diversity is provided by intermediate disturbance size, frequency and intensity (Roberts and Gilliam, 1995). Species diversity should increase with increasing levels of disturbance up to a point, after which diversity declines. Based on this hypothesis, several authors (Battles et al., 2001; Schumann et al., 2003) evaluated the effect of management practices with different intensities on species in various regions, concluding that intermediate disturbances favour species diversity. However, the response of biodiversity to silvicultural treatments is not well-studied in the Mediterranean region, which is considered a biodiversity hotspot and has been subjected to human impacts for centuries.

Our study aims to assess the effects of different silvicultural practices on forest biodiversity indicators in the Mediterranean region of Catalonia (NE Spain), considering the intensity of the silvicultural treatments through the amount of removed basal area. We performed an analysis at the stand level using a large data set based on thousands of inventory plots of the Third Spanish National Forest Inventory (3SNFI; Ministerio de Medio Ambiente, 1997–2007), which have increasingly incorporated different measures related to biodiversity and now contains a large amount of valuable information on the state of the tree and shrub species in the region. Specifically, the aim of this study is to analyse the effects of regeneration cuts and stand improvement treatments on six biodiversity indicators (snags, large-diameter trees, shrub abundance, shrub species richness, tree species richness and tree species diversity) obtained from the 3SNFI plots in Catalonia. These indicators were selected because they could be estimated from the information available in the 3SNFI and because they are widely used in the literature (Marrugan, 1989; Noss, 1990; Alberdi et al., 2005). We conducted two major analyses: (i) comparing indicators of biodiversity between managed and unmanaged stands, and (ii) evaluating the effects of each of the silvicultural treatments with different intensity on the biodiversity indicators, testing the hypothesis that the intermediate disturbances resulting from management increase Mediterranean forest diversity. We conclude by discussing implications for maintaining and enhancing biodiversity when managing Mediterranean forests.

2. Materials and methods

2.1. Study area

The study was performed in the Mediterranean region of Catalonia (NE Spain). This region has a high topographical and microclimate variability with the coastline of the Mediterranean Sea in the East and the Pyrenees Mountains in the North (Fig. 1). Conditions in the region have favoured great vegetation diversity and a high number of endemic species. Forests in the Mediterranean basin have been strongly transformed by human activity for centuries and no virgin forests remain in Catalonia. Currently, forests occupy about 38% of the territory, with an additional 23% occupied by other wooded lands, due mainly to complex topography that made difficult the agricultural and demographic expansion towards the mountains (Terradas et al., 2004). According to the 3SNFI (Ministerio de Medio Ambiente, 1997–2007), the dominant forest tree species in Catalonia are *Pinus halepensis*, *Pinus sylvestris*, *Quercus ilex*, *Pinus nigra, Pinus uncinata* and *Quercus suber*, followed by *Quercus pubescens*, *Fagus sylvatica*, *Pinus pinea*, *Quercus faginea*, *Quercus petraea*, *Abies alba*, *Pinus pinaster* and *Castanea sativa*.

Nearly 81% of the forested area is privately owned in Catalonia (Terradas et al., 2004). Most of these private forests are unmanaged and only about 25% of them have an updated management plan developed in accordance with the official regulations of the Catalan Government to promote sustainable forestry (see http://mediambient.gencat.net/cat/cpf/). This is a consequence of low economic return that most owners expect to get from the management of Mediterranean forests (Terradas et al., 2004), mainly due to the slow growth and low timber yields that are characteristic in this region. In recent years there has been a considerable increase in the number of managed forests resulting from subsidies and other initiatives from the Catalan Government.

2.2. Data source and analysis

The Third Spanish National Forest Inventory (3SNFI; Ministerio de Medio Ambiente, 1997–2007) gathered information from 12,234 field plots in Catalonia from July 2000 to August 2001, which was the data source both for the forest biodiversity indicators and for the type of management carried out in each of the field plots. 3SNFI plots are located according to a systematic sampling design in the intersections of the 1 km × 1 km UTM grid that fall inside forests and other woodlands, with an average sampling intensity of one plot per 1 km^2 of land. Plots in the 3SNFI are circular and concentric, with a variable size that depends on the tree diameter at breast height (DBH), with a plot radius of 5 m for trees with a DBH from 75 to 125 mm, of 10 m for trees with a DBH from 125 to 225 mm, of 15 m for trees with a DBH from 225 to 425 mm, and a radius of 25 m for trees with a DBH of at least 425 mm.