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No difference in plant species diversity between protected and managed ravine forests

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ABSTRACT

The influence of management practices on forest ecosystems is usually analyzed by a comparison of species composition and richness. Different types of management practices increase plant species richness, mainly due to an increase in the number of ruderal and open habitat species. So far, most of the studies have been performed in the forest types that were most common in the studied regions. In this study we focused on broadleaved ravine forests that are spatially limited to specific habitat conditions, including steep rocky slopes with skeletal soil and unstable ground. These forests are local biodiversity hotspots, and, due to limited accessibility, have been subject to only limited management practices, mainly removal of single trees.

We collected a dataset of 215 plots sampled between 1991 and 2015 in both managed forests and protected areas. We used multivariate techniques to compare the differences in the overall species composition. In addition, we compared differences in diversity, structural and habitat indices to find any possible differences. There were no differences in both the plot level and accumulative species richness and diversity indices between protected and managed forests. In addition, a comparison of habitat conditions and different ecological groups, including ruderal and open habitat species, alien species and ancient forest indicator species also revealed no differences. The only significant differences between the protected and managed forests related to the evenness and shrub cover.

We concluded that low intensity forest management in ravine forests resembles natural disturbances, which are characteristic of natural ravine forests. The species composing these communities are adapted to frequent natural disturbances and thus forest management did not influence significant habitat conditions. However, to fully understand the effect of these practices on biodiversity, a comparison of structural characteristics is needed.

1. Introduction

During the last millennia, the vast majority of forests in Europe were heavily changed by human activity (Christensen and Emborg, 1996; Kalis et al., 2003; Sabatini et al., 2018). Except for the obvious management activities, like clearing of forests for agricultural and industrial purposes, forest management also affects natural processes (Bengtsson et al., 2000). Different types of management activities influence forest ecosystems by changing the forest stand structure (Kuuluvainen et al., 1996; Commarmot et al., 2005; Wesely et al., 2018), species composition (Okland et al., 2003; Nagaike et al., 2005; Sebastià et al., 2005; Durak, 2012; Horvat et al., 2017a; Kaufmann et al., 2017), soil properties (Carlson and Groot, 1997; Thiffault et al., 2011; Gross et al., 2018; Kovács et al., 2018) or local microclimate (Chen et al., 1999; Daolan et al., 2000; Frey et al., 2016). In addition, forest management influence the availability of particular ecological niches by affecting the presence of coarse woody debris, pits and mounds after natural disturbances or giant trees (Peterson et al., 1990; Nilsson and Baranowski, 1997; Bobiec, 1998; Christensen et al., 2005; Ódor et al., 2006).

It is generally believed that unmanaged forests under strict protection in national parks and nature reserves promote biodiversity and host more species than managed forests. Many studies, however, showed that the relationships between forest management and biodiversity are very complex. The effect of forest management activities depends largely on the type and magnitude (Halpern and Spies, 1995). For example, clear-cutting has a different effect on forest biodiversity than shelterwood lodging or coppicing (Nagaike et al., 2005). In addition, the time since management was abandoned can have significant effects on species diversity in unmanaged forests, because the forest condition and structure change over time (Fenton and Bergeron, 2008; Horvat et al., 2017a; Horvat et al., 2017b). Interestingly, recent reviews have revealed that different components of the biodiversity may

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respond both positively and negatively to forest management intensity and time since abandonment (Paillet et al., 2010; Biber et al., 2015; Dieler et al., 2017). Organisms that mainly depend on deadwood, forest cover continuity and presence of large trees, including bryophytes, lichens, fungi and saproxylic beetles, were negatively affected by forest management. On the contrary, the diversity of vascular plants was usually higher in managed forests. Understanding these effects coupled with a growing awareness of the important role of natural resources has fundamentally changed management practices over the last decades. Methods emulating natural processes, like natural disturbances or saving coarse woody debris, are gaining popularity among forest managers and are replacing harmful clear-cuttings (Christensen and Emborg, 1996; Angelstam, 1998; Bengtsson et al., 2000; Firm et al., 2009; Long, 2009).

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Although previous research has gained great insights into the effect of forest management on biodiversity, more comparative studies are needed instead of purely descriptive ones (Paillet et al., 2010). In addition, these comparisons should be based on more comprehensive and insightful measures than just on species richness. For example, a vast number of studies have shown higher plant species richness in managed forests compared to unmanaged forests (Graae and Heskjær, 1997; Nagaike et al., 2005; Schmidt, 2005; Paillet et al., 2010; Horvat et al., 2017a; Kaufmann et al., 2017). However, a simple number of species recorded per plot is not always a good measure of the conservation status of forest stand. For example, Brunet et al. (1996) showed that species richness in the herb layer increased with management intensity mainly due to the establishment of ruderal species from the seed bank, while species richness of typical forest flora remained unaffected by the management. Most of the studies were performed in forest types that predominate in particular regions. In Europe, this includes mainly beech and mixed beech-fir forests, oak and oak-hornbeam forests and mountain spruce forests. The effect of forest management on biodiversity in forest types that are characteristic of more specific habitat conditions have not been well studied.

In this study, we focused on communities of broadleaved ravine forests that are spatially limited to specific habitat conditions, including steep rocky slopes with skeletal soil and unstable ground. Ravine forests play an important role as biodiversity hotspots and contribute to the protection of the soil and water resources. A survey conducted in France proved that sycamore ravine forests have higher ecological value than the surrounding mixed forest (Paillet et al., 2008). Due to high biodiversity and limited economic value, most stands of ravine forest were subject to extensive management or remained unmanaged (Paillet et al., 2008). Ravine forests are a subject of frequent natural disturbances due to being located on unstable ground on steep slopes, and thus constitute a very interesting study system. We hypothesized that the low intensity forest management that was commonplace until recently outside protected areas had an effect similar to natural disturbances of low to moderate magnitudes. To test this hypothesis, we selected a dataset of 215 plots sampled in both managed and protected forests and tested these two groups for significant differences in species composition. In addition, we compared numerous characteristics related to species richness, including diversity and evenness indices, species richness, cover of tree, shrub and herb layers as well as the contribution of alien species, ancient forest indicator species and species characteristic of open habitats.

2. Material and methods

2.1. Study object and vegetation database

As an object of the study, we selected broadleaved forests dominated by species of maples (*Acer pseudoplatanus, A. platanoides*) and other 'noble' forest trees with Hart's-Tongue fern (*Phyllitis scolopendrium*) occurring in the herb layer. This specific type of forest is characterized by a narrow ecological niche and it grows on steep slopes and ravines with north-west to east aspects on calcareous screes with shallow soils (Ellenberg, 2009). This forest community type has been recognized as a *Phyllitido-Aceretum pseudoplatanii* Moor 1952 association (Clot, 1990; Matuszkiewicz, 2001). At present, most of the maple forest stands are protected as a priority habitat type Natura 2000 (code 9180). Until recently, however, many of these forest stands were localized outside protected areas and could have been managed with different intensity. As an extreme case, a clear cut in a ravine forest stand was documented at the beginning of the 2000s to obtain a better landscape view and to make the rocks available for climbing (Bodziarczyk and Malik, 2006).

Almost all stands of this type of forest in Poland were sampled during a detailed study on the ecology of *Phyllitis scolopendrium* (Bodziarczyk, 2012). This resulted in detailed phytosociological descriptions of more than 500 plots sampled by one person, which were thus free from observer bias. These phytosociological relevés are stored in the Forest Database of Southern Poland (Pielech et al., 2018). As some research has clearly shown that comparing species diversity of vascular plants between protected and managed forests is trustworthy only when the site conditions are the same (Graae and Heskjær, 1997; Schmidt, 2005), we tried to ensure high homogeneity in our dataset in terms of environmental conditions. First, as mentioned above, our studied forest type has a very narrow ecological niche. Second, to eliminate possible differences within a broad geographical range, we limited the further analyses to one geographical mesoregion, which was the Carpathians.

We used the following criteria for selecting vegetation data from the database: (i) locality in the Carpathians; (ii) cover of tree or shrub layers higher than 50% and (iii) occurrence of *Phyllitis scolopendrium*. As a result, we obtained a subset of 215 forest plots, including 83 plots localized within protected areas (national parks and nature reserves) and 132 plots localized in managed forests (both private and managed by Polish State Forests) (see Fig. 1). The comparison of these two subsets revealed no significant differences in terms of slope and aspect (*t*-test: $t = 0.708$, $p = 0.479$ and $t = 0.663$, p-value = 0.508, respectively); however, we identified significant differences in elevation (*t*-test: $t = -4.152$, $p = 0.00005$). The samples from protected areas were located at higher elevations than the samples from managed forests (at 600.3 and 517.5 m a.s.l., respectively; see Table 1). This pattern reflects the history of forest management within the studied area; in general, forest stands at lower elevations could be easily accessed and were more affected by human pressure. As a result, national parks and nature reserves were established at higher elevations to protect the most preserved forests. Nevertheless, we found that the difference in the mean altitudes was lower than 100 m and so does not affect the meaningfulness of our comparison, and thus can be neglected.

All the plots were sampled within the large study area and the protected areas are very diverse in terms of their history. For that reason, for the plots located in protected areas we calculated how many years had passed since the establishment of the protection to the date of vegetation sampling. Based on these data, we estimated that – on average – these plots have been unmanaged for about five decades. This includes, however, plots unmanaged for more than eight decades as well as several plots from protected areas that were established less than two decades before the sampling occured.