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Management of semi-natural grasslands benefiting both plant and insect diversity: The importance of heterogeneity and tradition

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ABSTRACT

Biodiversity of semi-natural grasslands depends on the management practices used. However, management systems suitable for one taxon, such as plants, can be detrimental to other taxa, such as insects, and vice versa. This study attempts to support conservation management planning by clarifying the effects of different grassland management practices on species richness and species composition of vascular plants, butterflies, moths, orthopterans and ground beetles, also taking into account the effects of climate and the landscape context. The study was performed in the White Carpathians Protected Landcape Area and UNESCO Biosphere Reserve (Czech Republic), which is famous for its grasslands with the globally highest fine-scale plant species richness. Different management practices (mowing, grazing, abandonment and mixed management; the latter including the previous three) were applied for at least five consecutive years at 34 sites, where plants and different insect groups were subsequently sampled. Effects of management on species richness of different taxonomic groups were assessed using generalised linear models, whereas the effects on species composition were assessed using redundancy analysis. Management influenced plant, butterfly and moth species richness, but the effects of particular management practices on all species and species of regional conservation importance differed between these taxonomic groups. Plant and moth species richness increased with mowing, but moth species richness decreased with grazing. Mixed management favoured plant and butterfly richness. Plant species composition was infuenced by mowing, grazing and mixed management while that of moths by mowing and grazing. Orthopterans and ground beetles did not respond significantly to management. Our results indicate that conservation management should comprise the traditional practices that have historically contributed to the formation of the biological diversity of the semi-natural grasslands in the study area. In particular, grazing may not be optimal for traditional hay-meadows and mowing should be carried out similarly as in pre-intensive farmland, creating spatio-temporal heterogeneity rather than uniformly cutting large grassland areas during a short period. In general, the optimal management should be heterogeneous, applying different practices in a mosaic or at different times during the season.

1. Introduction

Temperate semi-natural grasslands are among the most biodiverse ecosystems in the world (Wilson et al., 2012; Dengler et al., 2014; Chytrý et al., 2015). They have developed under centuries-long agricultural management including either mowing for hay or grazing by livestock, or a mix of these management practices. In central Europe, semi-natural grasslands have been a traditional component of landscapes since pre-historic times (Hájková et al., 2011) and they continue to be dependent on the traditional management by mowing or grazing. However, because of changes in farming intensity and land use, thousands of hectares of these grasslands have been destroyed or their

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biodiversity deteriorated in recent decades (Wesche et al., 2012). Management intensification or abandonment are the main causes of the decline of semi-natural grasslands. Their remnants have become endangered habitats (Janssen et al., 2016), demanding costly and well-considered management, since inappropriate management practices may threaten biodiversity (Konvicka et al., 2008; Halada et al., 2011). For example, introduction of grazing as a conservation management in grasslands that were traditionally mown, or vice versa, can have detrimental effects on biodiversity.

A particular subject of disputes among biologists and practitioners is the choice of conservation management that would be suitable for different organisms, especially plants and various groups of insects. Several cases of certain management practices supporting some taxonomic groups but having adverse effects on others have been presented (Pärt and Söderström, 1999; Kruess and Tscharntke, 2002a,b; Oertli et al., 2005), whereas evidence of similar responses to management across taxa is relatively rare (Öckinger et al., 2006; Köhler et al., 2016). In European nature conservation, plant requirements for grassland management have often been more stressed than the needs of animals, but conservation management must look beyond plant communities and integrate both floral and faunal components (WallisDeVries et al., 2002; Diacon-Bolli et al., 2012).

Despite an increasing focus of research on the management effects on grassland biodiversity (reviewed e.g. by Morris, 2000; van Klink et al., 2015; Török et al., 2016), only a few studies have evaluated the diversity of more than one group of organisms in semi-natural grasslands in eastern central Europe (e.g. Cremene et al., 2005; Báldi et al., 2013; Dvořáková et al., 2014; Sutcliffe et al., 2015), although some of these grasslands are global hotspots of fine-scale plant species richness (Wilson et al., 2012; Chytrý et al., 2015). The lack of knowledge about responses of different taxa to management calls for a proper conservation planning of management in these grasslands.

In this study we assess the effect of different management practices on plant and insect diversity using an extensive dataset sampled in the White Carpathian (*Bílé Karpaty*) Mountains, Czech Republic, central Europe. This region is unique for harbouring large areas of well-preserved semi-natural grasslands, which are remarkable for their extremely high plant species richness as well as valuable invertebrate fauna (Malenovský et al., 2012; Chytrý et al., 2015). Local nature conservation authorities focus on biodiversity preservation when practising grassland management (Jongepierová, 2008). However, there are persistent conflicts especially between botanists and entomologists as to the appropriateness of different management practices for the maintenance of the diversity of different taxa. Therefore, we will test how different grassland management practices influence diversity and species composition of plants and several groups of insects, including butterflies, moths, orthopterans and ground beetles, taking into account the effects of climate and the landscape context. Our specific questions are:

(1) Which management practices support diversity of plants and different taxonomic groups of insects?
(2) Are effects of management on diversity consistent among these groups?
(3) Which is the optimal management strategy that would benefit all of these groups, or at least reconcile their contrasting requirements?

2. Materials and methods

2.1. Study area

The study area comprises the Bílé Karpaty (White Carpathians) Protected Landscape Area and UNESCO Biosphere Reserve situated in the south-east of the Czech Republic along the border with Slovakia (48°49′–49°10′N; 17°15′–18°13′E; Fig. 1). Climate varies with altitude, which ranges from 256 to 899 m (mean 469 m) at our study sites. The annual mean temperature at the study sites is 6.6–8.7 °C (mean 7.6 °C) and the annual precipitation is 533–1005 mm (mean 793 mm), peaking in June–July (Tolasz, 2007). Generally, precipitation increases and temperature decreases from the foothills situated along the north-western margins of the area towards the state border (Fig. 1; Otýpková et al., 2011). The bedrock is flysch, a sequence of alternating sandstone and claystone layers of Lower Tertiary age, which supports the development of deep and heavy cambisols. They are generally base-rich, with pH between 5.5 and 8.0, although they tend to be increasingly oligotrophic and acidic towards central and north-eastern parts of the area. Although woodlands cover more than 50% of the White Carpathians, especially at higher elevations, semi-dry meadows are the most conspicuous vegetation feature of this area (Jongepierová, 2008; Michalcová et al., 2014), hosting the highest species richness of vascular plants in the world at fine scales between 0.1 and 49 m^2 (Wilson et al., 2012; Chytrý et al., 2015). The prevailing grassland vegetation is *Brachypodio pinnati-Molinietum arundinaceae*, a transitional phytosociological association between the *Bromion erecti* and *Cirsio-Brachypodion pinnati* alliances (Chytrý, 2007). These meadows are semi-natural, spontaneously developing towards woodlands if regular management is abandoned. The meadows are probably thousands of years old (Hájková et al., 2011) and used to be mown for hay once a year in summer with occasional aftermath grazing in the late summer and autumn before the mid-20th century, in the era of pre-intensive agriculture. Currently, these meadows are subject to conservation management, which includes subsidised mowing (Jongepierová, 2008).

2.2. Field sampling and data

To analyze the effects of management on vascular plants and four insect taxa (butterflies, moths, orthopterans, and ground beetles), we sampled 34 grassland sites (min.-mean-max. area 1.5–8.8–70.7 ha, respectively; 34 sites for vascular plants, 33 for orthopterans and 31 for butterflies, moths and ground beetles) subject to different management practices, between 2006 and 2010. Sites were selected across the White Carpathians to represent the whole range of regional semi-natural grassland types (Fig. 1; see Appendix A, Tables S1 and S2 for site characteristics and Supplementary text S1 for description of vegetation types). At each site, all vascular plants were recorded in a 1-ha plot in June to early July by means of one visit at each site. In addition, four groups of insects were sampled at each site (see Appendix A for the number of visits per group): butterflies (besides true butterflies (Rhopalocera), also burnet moths (Zygaenidae), and picture-wing leaf moths (Thyrididae), i.e. unrelated but ecologically similar taxa), orthopterans (grasshoppers, bushcrickets, and crickets), moths (nocturnal macrolepidoptera) and ground beetles (Carabidae). Orthopterans and ground beetles were sampled on several dates in one growing season, butterflies and moths in two growing seasons. Butterflies and orthopterans were sampled by means of timed surveys, moths with light trapping and ground beetles by using pitfall trapping. Species abundances were classified on an ordinal scale. Lists of surveyed taxa, details of sampling methods and data processing, and nomenclature references are provided for each group in Appendix A, Supplementary text S2. To estimate the conservation value of the sites, regionally important species for the study area (including rare species and important bioindicators of natural habitats) were selected, based on national red lists (Grulich, 2012; Farkač et al., 2005) and local expert knowledge.

The following three sets of explanatory variables were recorded in the field or calculated using GIS for each site (Appendix A, Tables S3 and S4).

(1) Management was assessed as (i) 'mowing' (manually or by tractor-pulled mowers once a year); (ii) 'grazing' (by sheep, cattle, both or, at one site located within a game preserve, by fallow deer, *Dama dama*); (iii) 'abandonment' (areas where previous mowing or grazing has been terminated); (iv) 'mixed' (in most cases annual