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Reprint of "Biodiversity in low-intensity pastures, straw meadows, and fallows of a fen area–A multitrophic comparison"☆

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ABSTRACT

Despite the Europe-wide protection of wetlands, knowledge on the performance of management strategies for biodiversity conservation across different trophic levels is still relatively scarce. Here, we compare old straw meadows with restored low-intensity pastures and with fallows in a fen area in the northern pre-Alps. We sampled biodiversity at three trophic levels including plants, leafhoppers and spiders. Plant species richness was significantly enhanced by grazing and mowing compared with fallows. In contrast, species numbers and abundances of leafhoppers and spiders were highest in pastures and lowest in meadows. Endangered plant species were relatively rare in the restored pastures, which were still nutrient rich compared with meadows. Thus, land-use history can constrain restoration success for dispersal limited plant species in the short term. Although fallow plots were poorer in terms of species richness, their leafhopper and spider assemblages were highly differentiated and comprised a number of exclusive species, some of which were endangered. Our results suggest that maximum biodiversity can best be maintained by the diversification of management types. Enhanced abundances of leafhoppers and spiders in pastures may improve prey availability for predators such as amphibians, reptiles, and birds. Low-intensity grazing is currently rather uncommon in Central European fens, but our results encourage more widespread use of cattle for managing this type of habitat.

1. Introduction

Intense mowing and grazing can have a strong detrimental impact on grassland biodiversity at various trophic levels (Morris and Lakhani, 1979; Gibson et al., 1992; Kruess and Tscharntke, 2002), especially when combined with fertilization, drainage and reseeding (Day and Detling, 1990; Huntly, 1991; Watkinson and Ormerod, 2001). Highly productive grasslands are often characterized by low floral diversity due to the exclusion of competitively inferior plant species by dominant, fast-growing species (Hautier et al., 2009). In contrast, low-intensity grazing and mowing are generally expected to enhance plant diversity (Collins et al., 1998; Olff and Ritchie, 1998). The removal of plant biomass through grazing or mowing reduces light competition and enables the growth of less competitive plant species (Milchunas et al., 1988; Huntly, 1991; Belsky, 1992). Compared with small mammals, cattle are particularly well-suited for grassland management because they can use low-quality food (i.e., dominant plants such as reed and sedges) and increase habitat heterogeneity by creating disturbance patches (Olff and Ritchie, 1998). In addition, trampling and faecal deposition can increase regeneration sites and soil heterogeneity (Steinauer and Collins, 1995; Schrama et al., 2013).

According to earlier theoretical work, plant diversity is considered a major determinant of the diversity at higher trophic levels (Hutchinson, 1959; Root, 1973; Hunter and Price, 1992). However, this statement is not well supported by more recent

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studies (Vessby et al., 2002; Castagneyrol and Jactel, 2012; van Klink et al., 2015). The effect of mowing on arthropods might differ from effects on plants: during mowing the vegetation and most of its inhabitants are removed in one catastrophic event, thus dramatically reducing shelter, food resources and deposited eggs and also causing direct mortality among arthropods (Morris, 1981; Nickel and Achtziger, 1999, 2005). In contrast, low-intensity grazing poses a spatially and temporally heterogeneous disturbance that is expected to be less disruptive to animal populations. Traditional management types like mowing once a year in autumn or low-intensity grazing, are often associated with high biological diversity, and restoration by low-intensity management measures can improve biodiversity in formerly intensively used fields (Tscharntke and Greiler, 1995; Wettstein and Schmid, 1999).

Hence, management of wet grasslands for biodiversity conservation poses a number of dilemmas for applied ecologists: too much management may lead to land degradation and loss of biodiversity, while too little management may lead to succession from grassland to woodland and the loss of grassland habitats (Watkinson and Ormerod, 2001). In addition, management strategies optimal for plant conservation may impair the survival of arthropods, especially if uniformly applied to large areas (Cattin et al., 2003; Schmidt et al., 2008). Thus, differentiated management may be needed to meet the conservation demands of different groups of organisms. A considerable number of studies have already been published on effects of conservation managements such as grazing or mowing on plant and arthropod diversity (reviewed by Swengel, 2001; Middleton et al., 2006; van Klink et al., 2015). However, the vast majority of these studies focused on one single taxon (van Klink et al., 2015).

Here we compare effects of low-intensity cattle crazing, late-annual mowing and fallowing on highly abundant, highly diverse and functionally important groups representing three trophic levels: plants, leafhoppers (meant here as Auchenorrhyncha including also planthoppers) and spiders. We expect substantial differences in the numbers of species between the three management types. Specifically, plants are expected to benefit mainly from mowing, while species numbers and abundances of leafhoppers and spiders should be enhanced by low-intensity grazing. Due to different habitat preferences and differences in their sensibility to disturbances among species, we expected distinct communities of the respective groups between the three management types. We further expect a negative relationship between plant species richness and nutrient availability and a positive relationship between plant species richness and the number of leafhopper species, which feed on few or only one plant species.

2. Methods

2.1. Study sites

In May 2014, 21 sites were selected in a fen area of one square kilometer along a peat bog margin north of the town of Kißlegg, Germany (47°49′06″N/9°53′07″E). Seven sites were old and traditionally managed straw meadows, which are mown annually in late summer for gaining winter straw. Another seven sites were restored low-intensity pastures on formerly intensively used meadows. These pastures have been grazed for 10–15 years with cattle (approx. one livestock unit per hectare and year, during summer). The remaining seven sites were fallows mown on an irregular basis (every 3–30 years) to prevent tree encroachment. At each site we established two crosswise transects (length: 50 m) marked with wooden pegs at the starting points and the intersection.

2.2. Field methods

We sampled all groups of organisms in late May, at the beginning of July, and mid-September 2014. Plant species, vegetation height, the cover of vascular plants, and the percentage of bare ground were recorded within a 2 m wide strip along each transect. Plant taxonomy follows Breunig and Demuth (1999). Leafhoppers and spiders were collected along transects with suction sampling (25 times 5 s per transect, suction tube opening with a diameter of 14 cm) with a modified STIHL SH 85 leaf blower. The catch was transferred into a large white plastic box, and all visible leafhoppers and spiders were taken with aspirators. Leafhopper sampling was complemented by standardized sweep netting (50 beats per transect, with a D-shaped sweep net frame 32 cm broad) to include also species living in the higher vegetation strata. Pitfall traps were used to sample ground-dwelling spiders. Four pitfall traps per site were distributed on the transects. As capture fluid, we used a 30% ethylene glycol solution (with some droplets of soap and 1 g Quinine chloride per litre as a bitter agent to prevent mammals from drinking the fluid; see Jud and Schmidt-Entling, 2008). The pitfall traps were installed during each suction sampling round and operated for 2 weeks. Leafhoppers and spiders were transferred to 90% ethanol and identified to species level in the laboratory. Juvenile leafhoppers were also identified to species level (from instar II/III onwards; see Stöckmann et al., 2013), juvenile spiders were identified to family. Leafhopper taxonomy follows Nickel and Remane (2002) and the taxonomy of spiders corresponds to the World Spider Catalog, version 16 (2015).

2.3. Statistical analysis

All data were pooled per site (seven sites per management type). The conservation status of plant species (only the categories 1–3) was retrieved from the red-list for the pre-Alps of the federal state Baden–Wuerttemberg (Breunig and Demuth, 1999). The conservation status of leafhoppers and spiders (categories 1–3) was retrieved from the national red lists (Blick et al., in press; Nickel et al., in press). Species richness, the number of endangered species, and the abundances of leafhoppers and spiders were compared among the three management types using generalized linear models with quasi-poisson error distribution followed by an ANOVA (χ^2-test for the overall effect and Tukey-test for the pairwise comparison of means). Plant, leafhopper, and spider communities were compared with non-metric multidimensional scaling (NMDS) followed by a PERMANOVA based on 1000 permutations using adonis from the R-package vegan (Oksanen et al., 2013). From the same R-package we used the betadisper function to compare the homogeneity of multivariate dispersion as an estimate of beta-diversity (Anderson et al., 2006). Differences in the mean distance to the centroid were tested with ANOVA (F-test and Tukey-test). Ellenberg indicator values for moisture and nitrogen were calculated for every site. This is a well-established and reliable method to characterize environmental variables of study sites based on plant species (Schaffers and Sýkora, 2000; Diekmann, 2003). Vegetation characteristics were compared among the three management types using ANOVA (F-test). To test for the relative importance of environmental factors in determining species richness we calculated generalized linear models following quasi-poisson error distribution. Here, the management types, moisture index, nitrogen index and plant species richness (for leafhoppers and spiders only) entered the full models as fixed effects. Model selection was based on QAICc using the dredge function from the MuMIn R-package. The final model was tested with a Type-II ANOVA (χ^2-test). All statistical analyses were conducted in R version 3.1.2 (R Development Core Team, 2014).