DE GRUYTER
Biologia **72**/6: 642—651, 2017
Section Zoology
DOI: 10.1515/biolog-2017-0075

The effect of grassland management on diversity and composition of ground-dwelling spider assemblages in the Mátra Landscape Protection Area of Hungary

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Abstract: The main objective of this paper is to report the effect of shrub removal and mowing on the diversity and composition of ground-dwelling spider assemblages in Natura 2000 habitats of Mátra Mountains. We found significant effects of shrub removal and mowing on spider communities. Diversity decreased in the year following shrub removal but increased in the following years. Spider diversity in the final year decreased due to the lack of additional treatments. During our study the hay meadows were the most diverse habitats compared to control shrubs and treated shrubs. Treatments caused changes in community structure: the highest number of generalist species was observed in the treated shrubs, and the highest density of rare and protected species in the hay meadows. The high species turnover observed between hay meadows and control shrubs reflects the importance of grassland management. We conclude that shrub removal an effective grassland management action to increase spiders diversity in Natura 2000 habitats. Finally, treated shrubs require additional treatments such as mowing to ensure the spider communities inhabiting them are as diverse as those inhabiting meadows.

Key words: Araneae; grasslands; shrubs; Europe; Natura 2000 habitats

Introduction

Hay meadows and pastures are one of the most species rich habitats of Central Europe (Steffan-Dewenter & Leschke 2002; Ilmarinen & Mikola 2009) and are considered of high natural value because they can support rare plant and animal species (Pearce et al. 2005; Bock et al. 2013). Recent attention has focussed on research into the ecology of meadows (e.g., Albrecht et al. 2010; Homburger & Hofer 2012; Costley 2015). Active habitat management of grasslands can significantly improve mountain meadows increasing their recovery following anthropogenic disturbance. These grasslands are treated to prevent vegetation succession because shrub invasion can influence the distribution of moisture and nutrients (Schlesinger et al. 1990).

Our study area was located in the Mátra Landscape Protection Area in northeastern Hungary. The whole mountain is a Natura 2000 area. The aim of the Natura 2000 network is the protection of biodiversity and conservation of natural habitats and rare and vulnerable species (Magos et al. 2010). The three Natura 2000 indicator species of Mátra Mts are *Thlaspi jankea*, *Echium russicum* and the *Pulsatilla grandis*. The grasslands of Mátra Mts were developed due to anthropological influences reserving by grasslad management. The methods of grassland management are supported by the KEOP (Environment and Energy Operative Program in Hungary) application of Bükk National Park Directorate. The aims of the application are to reconstruct the mountain meadows and prevent shrub this traditional landscape.

Spiders are considered to be ecological indicator organisms (Blandin 1986): the composition of spider assemblages reflects the quality of the habitats change (Maelfait et al. 2002). The most important factors that influence the assemblage of spider communities are shading and the humidity of the soil (Entling et al. 2007). Various treatments have an effect on community composition (Pozzi et al. 1998): for instance, there is a positive relationship between vertical structure of the vegetation and the diversity and abundance of spider communities (Hatley & MacMahon 1980; Dennis et al. 2001; Harris et al. 2003). The structure of vegetation determines the attributes of spider assemblages (Hatley & MacMahon 1980).

The objectives of this study were to describe the effect of shrub removal and mowing on spider communities. We assessed diversity by analyzing different facets of alpha diversity such as species richness, diversity and evenness, and the contribution of species differentiation (beta diversity) among habitat types. Firstly, we studied the annual changes of assemblages in relation to shrub removal. Our hypothesis was that the man-

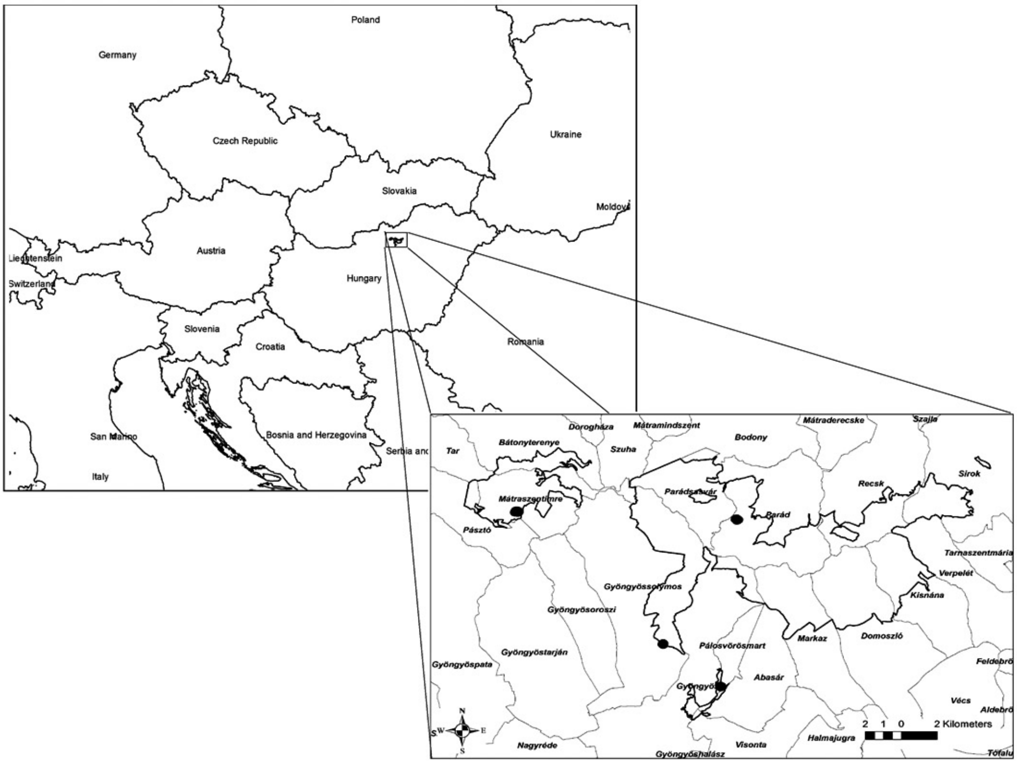

Fig. 1. Map of sampling sites in Hungary.

Table 1. Characteristics of the sampling sites.

Little region of Mátra	Sites	Altitude (m)	Habitats	Size (ha)	Vegetation
Southern Mátra	Gyöngyös-solymos	300	Hay meadow	5	*Campanulo-Stipetum tirsae*
			Control shrub	1	*Pruno spinosae-Crataegetum* with forest steppe items e.g. *Acer tataricum*
			Treated shrub	1	*Campanulo-Stipetum tirsae*
	Sár Hill	350	Hay meadow	3	*Campanulo-Stipetum tirsae*
			Control shrub	1	*Pruno spinosae-Crataegetum*
			Treated shrub	1	*Pulsatillo montanae-Festucetum rupicolae*
Parádi-Recski Basin	Parád	430	Hay meadow	2	*Pastinaco-Arrhenatheretum and Festuco ovinae-Nardetum*
			Control shrub	2	*Pruno spinosae-Crataegetum* with wild fruits e.g. *Pyrus pyraster*
			Treated shrub	1	*Sambucetum racemosae*
High Mátra	Fallóskút	700	Hay meadow	1	*Anthyllido-Festucetum rubrae*
			Control shrub	2	*Pruno spinosae-Crataegetum* with *Quercus ceris, Carpinus betulus*
			Treated shrub	1	*Pastinaco-Arrhenatheretum*

agement processes result in grasslands that have high spider diversity. Shrub removal was achieved one plant at a time, and was not followed by additional treatment, such as mowing. Also, we examined differences between habitats representing treated shrubs, control shrubs and hay meadows, at a regional scale, to analyse the effect of mowing on the assemblages of hay meadows and treated shrubs. Our hypothesis was that the most diverse habitats are the hay meadows, and that mowing of treated shrubs would produce more diverse habitats.

Material and methods

Sampling areas and methods

Our work was part of the soil zoology monitoring of KEOP project (Restoration and treatment of lawns, meadows and woody pastures) of Bükk National Park Directorate which

Table 2. Distribution of the spider species in the treated and control habitats including species abbreviations.

Abbr.	Species	Treated shrubs	Control shrubs	Hay meadows
	Atypidae			
Aaf	*Atypus affinis* Eichwald, 1830	x	x	x
	Nemesiidae			
Np	*Nemesia pannonica* (Herman, 1879)	x	x	x
Nemj	*Nemesia* spp. juvenilis	x		x
	Segestriidae			
Ss	*Segestria senoculata* (L., 1758)	x	x	
	Dysderidae			
Dye	*Dysdera erythrina* (Walckenaer, 1802)	x	x	x
Dyj	*Dysdera* spp. juvenilis	x	x	x
Har	*Harpactea rubicunda* (C.L. Koch, 1838)	x	x	x
Haj	*Harpactea* spp. juvenilis	x	x	
	Eresidae			
Ek	*Eresus kollari* Rossi, 1846	x	x	x
	Theridiidae			
Aph	*Asagena phalerata* (Panzer, 1801)	x		x
Ef	*Euryopis flavomaculata* (C.L. Koch, 1836)			x
	Linyphiidae			
Sl	*Stemonyphantes lineatus* (L., 1758)			x
	Tetragnathidae			
Pd	*Pachygnatha degeeri* Sundevall, 1830		x	x
	Lycosidae			
Afa	*Alopecosa farinosa* (Herman, 1879)	x		x
Ac	*Alopecosa cuneata* (Clerck, 1757)	x	x	x
Ap	*Alopecosa pulverulenta* (Clerck, 1757)			x
As	*Alopecosa sulzeri* (Pavesi, 1873)	x	x	x
At	*Alopecosa trabalis* (Clerck, 1757)	x	x	x
Alj	*Alopecosa* spp. juvenilis	x	x	x
Afi	*Arctosa figurata* (Simon, 1876)			x
Al	*Arctosa lutetiana* (Simon, 1876)		x	
Aj	*Arctosa* spp. juvenilis	x		x
Aalb	*Aulonia albimana* (Walckenaer, 1805)	x	x	x
Gv	*Geolycosa vultuosa* C.L. Koch, 1838	x		
Hor	*Hogna radiata* (Latreille, 1819)	x	x	x
Hoj	*Hogna* ssp. juvenilis	x		x
Pb	*Pardosa bifasciata* (C.L. Koch, 1834)	x		x
Ph	*Pardosa hortensis* (Thorell, 1872)	x	x	x
Pl	*Pardosa lugubris* (Walckenaer, 1802)	x	x	x
Pp	*Pardosa paludicola* (Clerck, 1757)	x	x	
Ppal	*Pardosa palustris* (L., 1758)			x
Ppr	*Pardosa prativaga* (L. Koch, 1870)	x		
Ppul	*Pardosa pullata* (Clerck, 1757)		x	x
Pr	*Pardosa riparia* (C.L. Koch, 1833)	x	x	x
Pj	*Pardosa* spp. juvenilis	x	x	x
Pla	*Pirata latitans* (Blackwall, 1841)		x	
Tr	*Trochosa robusta* (Simon, 1876)	x		x
Tt	*Trochosa terricola* Thorell, 1856	x	x	x
Tj	*Trochosa* spp. juvenilis	x	x	x
Xym	*Xerolycosa miniata* (C.L. Koch, 1834)	x		
Xyn	*Xerolycosa nemoralis* (Westring, 1861)	x		
	Pisauridae			
Pm	*Pisaura mirabilis* (Clerck, 1757)	x	x	x
Pij	*Pisaura* spp. juvenilis	x	x	x
	Agelenidae			
Coa	*Coelotes atropos* (Walckenaer, 1830)	x	x	x
Ea	*Eratigena agrestis* (Walckenaer, 1802)	x	x	x
Ht	*Histopona torpida* (C.L. Koch, 1834)	x	x	
Ii	*Intermocoelotes inermis* (L. Koch, 1855)	x	x	x
Tc	*Tegenaria campestris* C.L. Koch, 1834	x	x	
Ts	*Tegenaria sylvestris* L. Koch, 1872	x	x	
Ul	*Urocoras longispinus* Kulczynski, 1897	x	x	x
	Dictynidae			
Cc	*Cicurina cicur* (F., 1793)	x	x	
	Titanoecidae			
Tsh	*Titanoeca shineri* (L. Koch, 1872)	x		x
	Miturgidae			
Zon	*Zora nemoralis* (Blackwall, 1861)	x	x	
Zos	*Zora spinimana* (Sundevall, 1833)	x	x	
Zoj	*Zora* spp. juvenilis	x		x

Table 2. (continued)

Abbr.	Species	Treated shrubs	Control shrubs	Hay meadows
	Liocranidae			
Agb	*Agroeca bruenna* (Blackwall, 1833)	x	x	x
Agc	*Agroeca cuprea* Menge, 1873	x	x	x
	Zodariidae			
Zodg	*Zodarion germanicum* (C.L. Koch, 1837)	x	x	x
Zodj	*Zodarion* spp. juvenilis	x	x	x
	Gnaphosidae			
Cas	*Callilepis schuszteri* (Herman, 1879)	x	x	x
Dc	*Drassodes cupreus* (Blackwall, 1834)	x		x
Dl	*Drassodes lapidosus* (Walckenaer, 1802)	x	x	x
Dp	*Drassodes pubescens* (Thorell, 1856)	x	x	x
Dj	*Drassodes* spp. juvenilis	x	x	x
Drpr	*Drassyllus praeficus* (L. Koch, 1866)	x	x	x
Drp	*Drassyllus pusillus* (C.L. Koch, 1833)	x	x	x
Drv	*Drassyllus villicus* (Thorell, 1875)	x	x	x
Drj	*Drassyllus* spp. juvenilis	x	x	x
Ga	*Gnaphosa alpica* Simon, 1878	x	x	
Gl	*Gnaphosa lucifuga* (Walckenaer, 1802)	x		x
Gj	*Gnaphosa* spp. juvenilis	x		x
Hs	*Haplodrassus signifer* (C.L. Koch, 1839)	x	x	x
Hsy	*Haplodrassus sylvestris* (Blackwall, 1833)	x	x	
Hu	*Haplodrassus umbratilis* (L. Koch, 1866)	x	x	x
Hj	*Haplodrassus* spp. juvenilis	x		x
Mf	*Micaria fulgens* (Walckenaer, 1802)	x		
Tp	*Trachyzelotes pedestris* (C.L. Koch, 1837)	x	x	x
Zap	*Zelotes apricorum* (L. Koch, 1876)	x	x	x
Zau	*Zeloetes aurantiacus* Miller, 1967		x	
Zel	*Zelotes electus* (C.L. Koch, 1839)	x	x	x
Zer	*Zelotes erebeus* (Thorell, 1870)	x	x	x
Zh	*Zelotes hermani* (Chyzer, 1878)			x
Zla	*Zelotes latreillei* (Simon, 1878)	x	x	x
Zlo	*Zelotes longipes* (L. Koch, 1866)	x		x
Ep	*Zelotes petrensis* (C.L. Koch, 1839)	x	x	x
Zj	*Zelotes* spp. juvenilis	x	x	x
	Philodromidae			
Tha	*Thanatus arenarius* Thorell, 1872	x		x
Thf	*Thanatus formicinus* (Clerck, 1757)	x		x
Thj	*Thanatus* spp. juvenilis	x		X
	Thomisidae			
Oa	*Ozyptila atomaria* (Panzer, 1801)		x	X
Oc	*Ozyptila claveata* (Walckenaer, 1837)			X
Op	*Ozyptila praticola* (C.L. Koch, 1837)	x	x	
Os	*Ozyptila simplex* (O.P.-Cambridge, 1862)			x
Ot	*Ozyptila trux* (Blackwall, 1846)			x
Oj	*Ozyptila* spp. juvenilis		x	x
Xa	*Xysticus acerbus* Thorell, 1872	x	x	x
Xb	*Xysticus bifasciatus* C.L. Koch, 1837			x
Xc	*Xysticus cristatus* (Clerck, 1857)	x		x
Xe	*Xysticus erraticus* (Blackwall, 1834)			x
Xk	*Xysticus kochi* Thorell, 1872	x	x	x
Xla	*Xysticus lanio* C.L. Koch, 1835	x		
Xlu	*Xysticus luctator* L. Koch, 1870	x	x	x
Xm	*Xysticus minnii* Thorell, 1872	x	x	x
Xs	*Xysticus striatipes* L. Koch, 1870			x
Xj	*Xysticus* spp. juvenilis	x	x	x
	Salticidae			
Efr	*Euophrys frontalis* (Walckenaer, 1802)			x
Pet	*Pellenes tripunctatus* (Walckenaer, 1802)	x		
Pej	*Pellenes* spp. juvenilis			x

started in 2012. Data collection was done in four localities (Sár Hill Nature Reserve, Gyöngyössolymos, Fallóskút, Parád) in the Mátra Mts (Fig. 1). All sites are Natura 2000 areas, the Sár Hill is Special Area of Conservation, Gyöngyössolymos, Fallóskút and Parád are Special Protection Areas. Three sampling sites were selected in all localities representing (H) hay meadows (mowed once a year) (C) control shrubs (no treated) and (T) treated shrubs (cut once) (Table 1). Double-glass pitfall traps filled with ethylene glycol were established on the sampling sites between 2012 and 2015. Five traps were set at a distance of 4–5 m along a transect. The traps were deployed twice (May – July, September – November) over a six week period each year. Grassland management was undertaken in those habitats

Table 3. The differences between ecological parameters in relation to treatment between years (2012–2015) and different habitats (control shrubs, treated shrubs, hay meadows) by Friedman-test.

	Between years	Between different habitats
Q (Observed value)	2.040	2.800
Q (Critical value)	7.815	5.991
DF	3	2
P-value (Two-tailed)	0.564	0.247
Alpha	0.050	0.050

Table 4. Number of spider species (S), number of individuals (N), Shannon-Wiener diversity (H), Simpson's diversity (1-D), Margalef's richness index (D_{Mg}) and the evenness (E) in the different habitats.

Indices	Control shrubs	Treated shrubs	Hay meadows
S	57	69	67
N	1769	1587	1275
H	2.362	2.717	3.492
1-D	0.744	0.802	0.944
D_{Mg}	8.157	10.99	10.91
E	0.171	0.184	0.415

with advanced succession. Shrub removal done manually was the first phase of the treatment process, and occurred at the end of 2012, following sampling. Additional treatments during the next year (2013–2015) did not occur, but possibly following stem-mashing and finally mowing would be necessary. The hay meadows were mowed with a mowing machine in all years, in summer or autumn depending on weather conditions. The treatments were arranged in a rotational manner, reserving a small portion of intact (unmowed) habitat each year.

Statistical analyses

We used the PAST Paleontological Statistic suite for data analysis (Hammer et al. 2001). Besides species richness and number of individuals we computed Shannon-Wiener diversity, Simpson's diversity and evenness (Pielou's index) in order to analyse the ground-dwelling spider communities. The Shannon-Wiener index is more sensitive to the frequency of rare species (Hill et al. 2003; Magurran 2003; Nagendra 2002). Species with the highest abundance have the greatest influence on the Simpson's index (Hill et al. 2003; Magurran 2003; Nagendra 2002). Margalef's richness index was used as a simple measure of species richness (Margalef 1958). The Pielou evenness index expresses the evenness of the distribution of the species and is sensitive the change of rare species (Hill et al. 2003; Magurran 2003). The value of species turnover between habitat types was evaluated with Wilson & Shmida's Beta diversity index (βT). The level of complementarity of habitats within the study area was characterized with Whittaker's β-diversity index (βW) (Magurran 2003), which depicts the relationship between the alpha diversity and total number of species. Friedman's test was used to compare the ecological indices using XLSTAT 2016.07.39066 version software (https://www.xlstat.com). Rare and vulnerable species were examined based on relative abundance (Ar) and we classed the species preference for habitats using Catalogue of Buchar & Růžička (2002). The classification of the species to categories was based on 13/2001. (V.9.) KöM decree (http://www.termeszetvedelem.hu/vedett-fajok-listaja-a-13-2001-v-9-kom-rendeletben) of Hungary. The vulnerable (VU) category is used for all protected spider species of Hungary following the nomenclature of IUCN. We applied the Jaccard similarity index for pairwise comparison of similarities of habitats based on species composition. This index calculates the similarity based on the absence and presence of the species (Schmera & Erős 2008). Community separation was represented with Detrended Correspondence Analysis using XLSTAT 2016.07.39066 version software.

Results

Gamma- and alpha-diversity

A total of 88 species were collected at 12 sampling sites (Table 2). Significant differences were found between ecological parameters of communities in relation to shrub removal, and also between habitats that were treated in different ways (Table 3). We collected a total of 5,154 individuals. Spider diversity was higher after shrub control compared to pre-treatment species diversity. Species diversity was significantly higher in the second year after shrub removal. There was a decrease in the ecological parameters monitored in the final year of the study (Fig. 2). Hay meadows had the highest diversity of habitats compared to the treated shrubs and control shrubs, but the spider assemblages of treated shrubs had the highest species richness (Table 4). A correlation was observed between species richness and the number of individuals as a result of shrub removal in the first three years, although no such trend was evident in the last year (2015). No correlation in the number of species and individuals was evident among the three different habitats (Fig. 3).

Community assemblage and abundance

The highest number of collected individuals occurred in the control shrubs and the fewest occurred in the hay meadows. According to habitat preference the assemblages of communities were variable. Twenty species of all registered 88 species were observed in only one

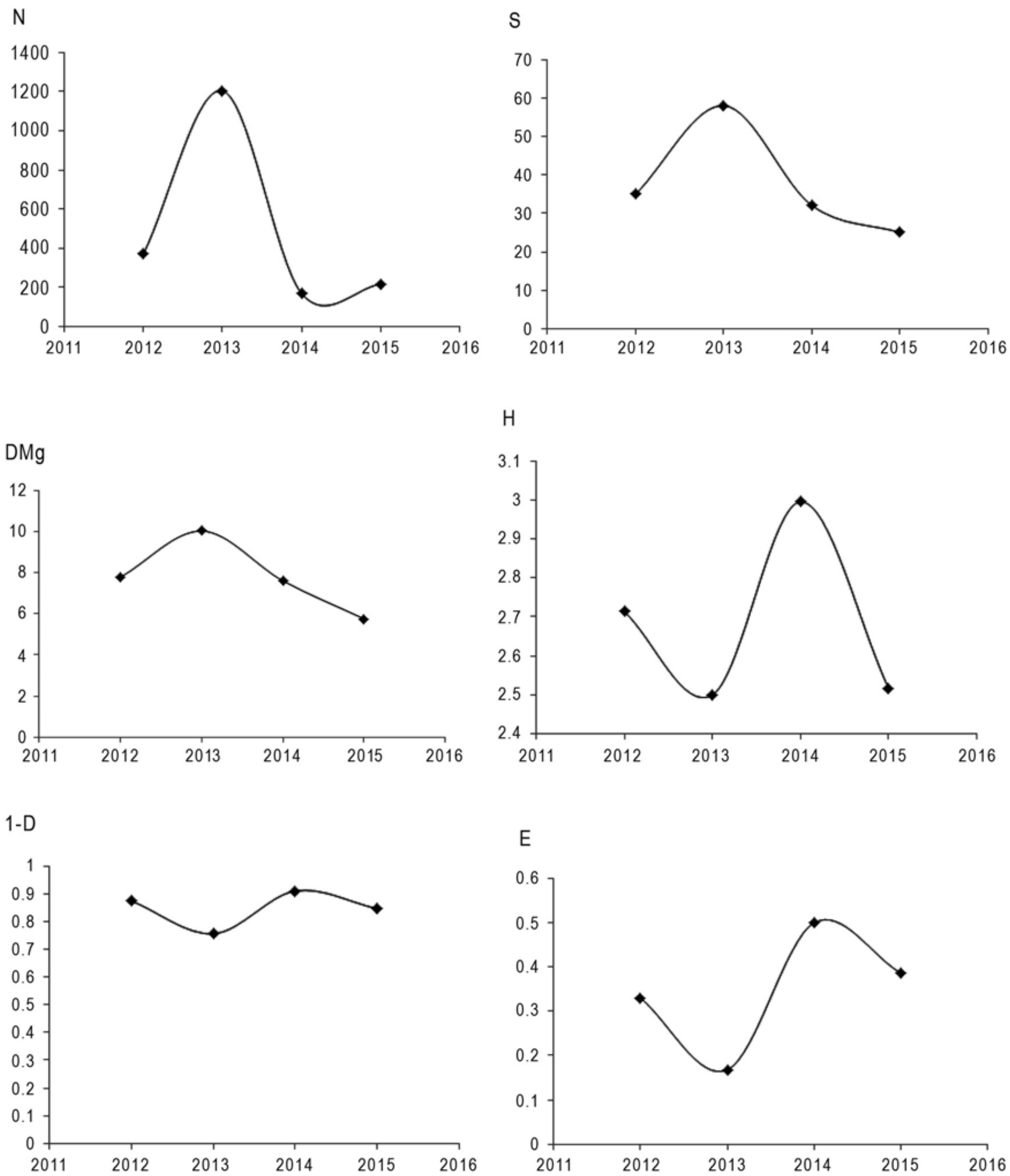

Fig. 2. Annual dynamics of the total number of spider individuals (N), number of species (S), Margalef's index (D_{Mg}), the values of Shannon-Wiener index (H), Simpon's diversity (1-D) and the evenness (E) in the treated shrubs before (2012) and after shrub removal (2013–2015).

of the examined habitats. We found 10 species which were present only in meadows. Sixty nine percent of grassland species were recorded in the treated shrubs, while 42 species were ubiquitous in their distribution. The most abundant spider species was *Pardosa lugubris* (Walckenaer, 1802) which was generally ubiquitous, although was rare in the control shrubs and treated shrubs in hay meadows. The abundance of this species was quite low in the hay meadow for the control shrubs and treated shrubs. The distribution of rare and vulnerable species revealed differences between the assemblages of communities. The abundance of rare species was higher in the meadows than in the other habitats (Table 5). The number of generalist and grassland species increased in the year following shrub removal (2013) and then decreased in 2014–2015. The number of generalist individuals was significant in the treated shrubs (32) compared to control habitats (control shrubs: 18, hay meadows: 22).

Beta-diversity and similarity

The Wilson & Shmida's Beta diversity index was highest between 2012 and 2014 in the treated shrubs (Table 6). We observed the highest species turnover between control shrubs and hay meadows, and the lowest turnover was between control shrubs and treated

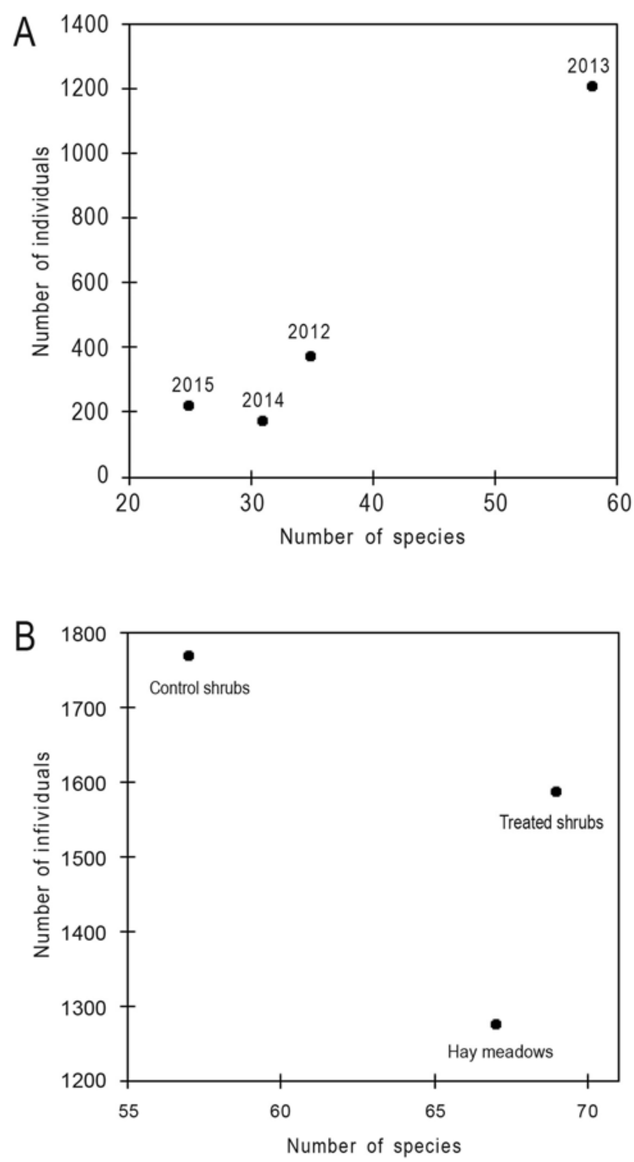

Fig. 3. Correlation between number of spider species and individuals (A) during years and (B) in the different habitats.

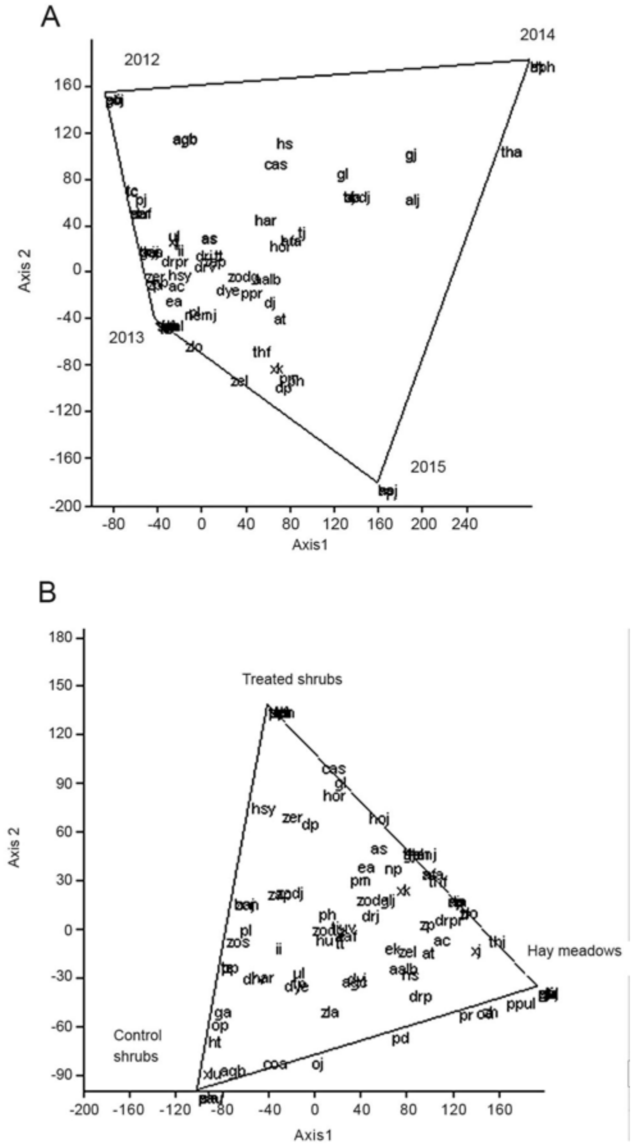

Fig. 4. The separation among the (A) years and (B) different habitats using Detrended Correspondence Analysis (see abbreviations of species in Table 2).

shrubs (Table 7). There was a decrease in the Jaccard similarity index between the assemblages of treated shrubs (between year 2012–2013: 0.54; year 2013–2014: 0.43; year 2014–2015: 0.33). There was a distinct difference among different habitats in relation to treatments. There was a similar difference in the treated shrubs from hay meadows (0.61) and control shrubs (0.6). The differentiations of assemblages are represented in the ordinations (Fig. 4). There was low complementarity of the species between these habitats. The Whittaker' β species diversity was 0.39.

Discussion

Shrub removal and diversity

Shrub removal is not a focus of grassland management. There is little data available as to the effect of this management phase on spiders. Rushton (1988) investigated spider communities in different shrub clearance regimes and found that diversity was similar. Hatley & MacMahon (1980) reported that among different types of shrub perturbations the highest species richness was in the tied shrub compared to the control and clipped shrubs. In Hungary Rákóczi & Samu (2012) studied the effect of Syringa eradication which resulted in slight changes to spider assemblages, with the shrub control preventing long term effects. Similarly, our data showed that the treatment had a positive influence on spider diversity, although the treatments caused significant changes in the diversity of spider assemblages. Plant communities are influenced by periodic disturbances, such as mowing which removes plant biomass (Hulbert 1988; Maret & Wilson 2000) and shrub removal. Shrub removal is the first phase of the grassland management

Table 5. Relative abundance (Ar) of rare and vulnerable spider species in treated shrubs (T), control shrubs (C) and hay meadows (H).

Species		Ar (%)			
		T	C	H	Total
Vulnerable species	*Nemesia pannonica*	0.6	0.1	1.1	1.9
	Eresus kollari	0.01	0.01	0.03	0.07
	Atypus affinis	0.03	0.09	0.05	0.19
	Geolycosa vultuosa	0.01	0	0	0.01
Rare species	*Arctosa figurata*	0	0	0.05	0.05
	Zelotes aurantiacus	0	0.01	0	0.01
	Drassodes cupreus	0.01	0	0.01	0

Table 6. Spider species turnover between assemblages in different years in relation to shrub removal.

Wilson & Shmida's Beta diversity index (β_T)		2012	2013	2014
	2013	0.294	0	0.392
	2014	0.448	0.392	0
	2015	0.392	0.500	0.500

Table 7. Spider species turnover between different habitats in relation to the treatments.

Wilson & Shmida's Beta diversity index (β_T)		Treated shrubs	Control shrubs
	Treated shrubs	0	0.250
	Hay meadows	0.250	0
	Control shrubs	0.242	0.333

process, and can change soil humidity, lighting conditions and structure. These conditions may explain why the assemblages had a relatively low diversity in the year following shrub removal. Higher diversity was observed the next year, possibly caused by the presence of nearby refuge habitats that ensured the survival of species. Microclimate changes can influence the number of individuals of spiders (Kohyani et al. 2008) and could explain why species richness and numbers of individuals increased directly after shrub removal. As poikilothermic organisms, spiders likely prefer those habitats where more sunlight reaches the ground (Schwab et al. 2002; Dekoninck et al. 2009). The higher abundance of grassland species after shrub removal indicated changes had occurred to habitat sturcure. A reduction in species richness was observed in the last year where shrub growth encroached upon grassland habitats. Our result proves that the treated shrubs would need more years and more treatments (e.g., mowing) in order to become habitat for spider assemblages typical of original grassland.

Mowing and diversity

Hay meadows can be important spider habitats, as illustrated by the high diversity in this study. In other studies, the high spider diversity of hay meadows has also been observed (Pozzi et al. 1998; Decleer 1990; Noordijk et al. 2010). Mowing has a positive effect on floral diversity in meadows (Buttler 1992; Güsewell et al.1998): the higher plant richness supports diverse habitat structure, therefore the number of spider species increases (Zschokke 1996; Tews et al. 2004; Malumbres-Olarte et al. 2013). According to Pozzi et al. (1998), habitats need minimal mowing in order to maintain rich spider assemblages. In more open habitats the sward often includes greater numbers of herb species and fewer grasses, thereby explaining the correlations between arthropod diversity and flower diversity (Noordijk 2009a). Mowing has similar direct influences compared to shrub removal. During our study rotational management was used in order to maintain shelter and food recourses for spider species. Other studies have shown that 10% of the total habitat is applied ratio (Munguira & Thomas 1992; Humbert et al. 2009; Noordijk et al. 2009a). Our study and others prove that hay meadow can be conserved with both restoration managements actions (mowing and shrub removal) maintaining spider and floral diversity (Morris 2000). These grassland habitats that are maintained by treatments are valuable for spider species because the treatments reduce the presence of competitor species (Curry 1994), and help to maintain ecosystem processes (Ryser et al. 1995; Bartha 2007).

In our study, shrub removal and mowing can be considered as an intermediate disturbance (Connell 1978), which has a positive effect on diversity (see Máthé & Balázs 2006; Grandchamp et al. 2005). The annual treatments can be considered as a slight disturbance that produces higher diversity of the spider assemblages than in untreated habitats.

From a complementarity perspective, it is preferable to conserve more than a quarter of the biodiversity of a habitat patch with habitat restoration since almost 40% of spider species were the same in the different habitat types. Because no additional treatments were applied, these habitats are threatened with succession. Therefore it is necessary to continue the treatments if we are to maintain diverse spider communities and assist with the overall recovery of these valuable ecosystems.

Acknowledgements

This work was part of the KEOP project. We thank employees of the Bükk National Park Directorate, especially Dudás György and Kemény Attila. We also thank Andrew J. Hamer and Weiperth András for the proof-reading of the language.

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Received January 18, 2017
Accepted March 10, 2017