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

Tünde SZMATONA-TÚRI<sup>1</sup>, Diána VONA-TÚRI<sup>2</sup>, Gábor MAGOS<sup>3</sup> & László URBÁN<sup>3</sup>

<sup>1</sup>FM ASzK – Forestry, Agricultural and Game Management Training School and Student Hostel of Mátra, 11 Erdész street, Mátrafüred 3232, Hungary; e-mail: turitunde79@gmail.com

<sup>2</sup> Eötvös József Reformated Education Centre, 29 Dobó Street, Heves 3360, Hungary

<sup>3</sup>Bükk National Park Directorate, Mátra Region, 6 Sánc road, Eger 3304, Hungary

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 Control shrub	51	Campanulo-Stipetum tirsae Pruno spinosae-Crataegetum with forest steppe items e.g. Acer tataricum
			Treated shrub	1	$Campanulo-Stipetum\ tirsae$
	Sár Hill	350	Hay meadow Control shrub Treated shrub	3 1 1	Campanulo-Stipetum tirsae Pruno spinosae-Crataegetum Pulsatillo montanae-Festucetum rupicolae
Parádi-Recski Basin	Parád	430	Hay meadow	2	Pastinaco-Arrhenatheretum and Fes-
			Control shrub	2	Pruno spinosae-Crataegetum with wild fruits e g Purus puraster
			Treated shrub	1	Sambucetum racemosae
High Mátra	Fallóskút	700	Hay meadow Control shrub	$\frac{1}{2}$	Anthyllido-Festucetum rubrae Pruno spinosae-Crataegetum with Quercus ceris, Carpinus betulus
			Treated shrub	1	Pastina co-Arrhena the return

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 an	nd control habitats including species abbreviations.
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Abbr.	Species	Treated shrubs	Control shrubs	Hay meadows
	Atypidae			
Aaf	Atypus affinis Eichwald, 1830	х	x	x
Np	Nemesia pannonica (Herman, 1879)	x	x	x
Nemj	Nemesia spp. juvenilis	x	A	x
Ŭ	Segestriidae			
$\mathbf{Ss}$	Segestria senoculata (L., 1758)	х	х	
Dres	Dysderidae			
Dye Dvi	Dysuera spp. juvenilis	x	x	x
Har	Harpactea rubicunda (C.L. Koch, 1838)	x	x	x
Haj	Harpactea spp. juvenilis	х	x	
	Eresidae			
Ek	Eresus kollari Rossi, 1846	х	х	х
Aph	Asagena phalerata (Panzer 1801)	v		v
Ef	Euryopis flavomaculata (C.L. Koch, 1836)	A		x
	Linyphiidae			
Sl	Stemonyphantes lineatus (L., 1758)			х
	Tetragnathidae			
Pd	Pachygnatha degeeri Sundevall, 1830		х	х
Δfa	Alonecosa farinosa (Herman 1870)	v		v
Ac	Alopecosa cuneata (Clerck, 1757)	x	х	x
Ap	Alopecosa pulverulenta (Clerck, 1757)			x
As	Alopecosa sulzeri (Pavesi, 1873)	х	х	х
At	Alopecosa trabalis (Clerck, 1757)	х	х	х
Alj	Alopecosa spp. juvenilis	х	х	х
	Arctosa lutetiana (Simon, 1876)		v	х
Ai	Arctosa spp. juvenilis	x	л	x
Aalb	Aulonia albimana (Walckenaer, 1805)	x	х	x
$\mathbf{G}\mathbf{v}$	Geolycosa vultuosa C.L. Koch, 1838	х		
Hor	Hogna radiata (Latreille, 1819)	х	х	х
Hoj Dh	Hogna ssp. juvenilis	x		x
PD Ph	Pardosa hortensis (Thorell 1872)	x	v	x
Pl	Pardosa lugubris (Valckenaer, 1802)	x	x	x
Рp	Pardosa paludicola (Clerck, 1757)	х	x	
$\mathbf{Ppal}$	Pardosa palustris (L., 1758)			х
Ppr	Pardosa prativaga (L. Koch, 1870)	х		
Ppul Pr	Pardosa pullata (Clerck, 1757) Pardosa ringgia (CL Koch 1833)	¥.	x	X
Pi	Pardosa spp. juvenilis	x	x	x
Pla	Pirata latitans (Blackwall, 1841)		x	
Tr	Trochosa robusta (Simon, 1876)	x		х
Tt	Trochosa terricola Thorell, 1856	х	х	х
Тj V	Trochosa spp. juvenilis	х	х	х
Xvn	Xerolycosa miniala (C.L. Koch, 1854) Xerolycosa nemoralis (Westring, 1861)	x		
24.911	Pisauridae	А		
$\mathbf{Pm}$	Pisaura mirabilis (Clerck, 1757)	x	х	x
Pij	Pisaura spp. juvenilis	х	х	х
a	Agelenidae			
Coa	Coelotes atropos (Walckenaer, 1830)	x	x	x
ьа Ht	Histopona tornida (C.L. Koch 1834)	x	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	х	
Ul	Urocoras longispinus Kulczynski, 1897	х	х	х
Ca	Dictynidae $(E = 1702)$			
UC	Titanoecidae	х	х	
Tsh	Titanoeca shineri (L. Koch. 1872)	x		x
-	Miturgidae	-		
Zon	Zora nemoralis (Blackwall, 1861)	x	х	
Zos	Zora spinimana (Sundevall, 1833)	х	х	
Zoj	Zora spp. juvenilis	x		x

## Effect of grassland management on spiders

LiocranidaeLiocranidaeAgbAgroco bruenna (Elackvall, 1833)xxxMage, 1873xxxZoduZodurino germanicum (C.L. Koch, 1837)xxxZodiZodurino germanicum (C.L. Koch, 1837)xxxCasCalilepis schuszteri (Herman, 1879)xxxxDDrassodse schuszteri (Herman, 1879)xxxxDDrassodse schuszteri (Herman, 1879)xxxxDDrassodse schuszteri (Herman, 1879)xxxxDDrassodse sphosecena (Thorell, 1876)xxxxDrpDrassodse sphosecena (Thorell, 1875)xxxxDrpDrassodis publicas (C.L. Koch, 1830)xxxxDrpDrassodis publicas (C.L. Koch, 1830)xxxxG1Graphons app. juvenilisxxxxHaplodrasses signefer (C.L. Koch, 1830)xxxxHigh Informaceus signefer (C.L. Koch, 1830)xxxxTo Trabulyzelberts (Blackvall, 1833)xxxxHaplodrasses sprivernilisxxxxIdiaplodrasses sprivernilisxxxxIdiaplodrasses sprivernilisxxxxIdiaplodrasses sprivernilisxxxxIdiaplodrasses sprivernilisxxxx <th>Abbr.</th> <th>Species</th> <th>Treated shrubs</th> <th>Control shrubs</th> <th>Hay meadows</th>	Abbr.	Species	Treated shrubs	Control shrubs	Hay meadows
AgbAgroces branna (Blackwall, 1833)xxxxCodarion germanicum (C.L. Koch, 1837)xxxZodarion spp. juvenilsxxxCanphosidexxxCaseCalilepis schuszteri (Ilerman, 1879)xxxDeDrassods liphäces (Walckmare, 1802)xxxDiDrassods liphäces (Walckmare, 1802)xxxDiDrassods liphäces (Valckmare, 1802)xxxDiDrassods spicescas: (Threell, 1836)xxxDiDrassods spicescas: (Threell, 1836)xxxDiDrassods spicescas: (Threell, 1836)xxxDiDrassods spicescas: (Threell, 1836)xxxCamphos larging in strikes (L. Koch, 1836)xxxDiDrassods spicescas: (Threell, 1837)xxxCamphos larging in strikes (L. Koch, 1830)xxxxCalific draphosa larging (C. L. Koch, 1837)xxxxCiGraphosa spice with (Blackvall, 1833)xxxxGiGraphosa spice with (Blackvall, 1837)xxxxGiGraphosa spice with (Blackvall, 1837)xxxxCiGraphosa spice with (Blackvall, 1833)xxxxCiGraphosa spice with (Blackvall, 1837)xxxxMinduranes spice with (Blackvall, 1837)<		Liocranidae			
Age:     Agroece cupres Menge, 1873     x     x     x     x       Zodqi     Zodarina sp.; juvenilis     x     x     x       Cas     Calilepris schuszteri (Herman, 1879)     x     x     x       D     Drassedes eugreus (Blackwall, 1834)     x     x     x       DI     Drassedes publicas (Walckman, 1879)     x     x     x       DI     Drassedes publicas (Walckman, 1802)     x     x     x       Di     Drassedes publicas (Unic, Koch, 1680)     x     x     x       Drp     Drassedus publicas (Unic, Koch, 1680)     x     x     x       Drp     Drassedus applicas (Li, Koch, 1633)     x     x     x       Gi     Gnaphosa aberjage (Walckener, 1802)     x     x     x       Gi     Gnaphosa sepigerier (Li, Koch, 1830)     x     x     x       Has     Hapdorbassa signefier (Li, Koch, 1830)     x     x     x       Hi     Hapdorbassa signefier (Li, Koch, 1830)     x     x     x       Hi     Hapdorbassa signefier (Li, Koch, 1830)     x     x     x       Hi     Hapdorbassa signefier (Li, Koch, 1830)     x     x     x       Hi     Hapdorbassa signefier (Li, Koch, 1830)     x     x     x       Hi <td>Agb</td> <td>Agroeca bruenna (Blackwall, 1833)</td> <td>х</td> <td>х</td> <td>x</td>	Agb	Agroeca bruenna (Blackwall, 1833)	х	х	x
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Lodi     Zodarion spp. juvenilis     x     x     x       Case     Callieps schuzteri (Herman, 1879)     x     x     x       De     Drassodes lapidous (Walckenzer, 1802)     x     x     x       Di     Drassodes lapidous (Walckenzer, 1802)     x     x     x       Di     Drassodes pupcense     (Backwall, 1834)     x     x     x       Di     Drassodes pupcense     (Backwall, 1836)     x     x     x       Di     Drassodes pupcense     (Backwall, 1836)     x     x     x       Di     Drassodes pupcense     (Backwall, 1833)     x     x     x       Dir     Drassodes pupcense     (Backwall, 1833)     x     x     x       Dir     Drassodes pupcense     (Backwall, 1833)     x     x     x       Ca     Graphose inclugae (Walckenner, 1802)     x     x     x     x       Hay     Haplodrassus signifer (CL. Koch, 1833)     x     x     x     x       Hit     Haplodrassus signifer (CL. Koch, 1830)     x     x     x       Ideplodrassus signifer (CL. Koch, 1830)     x     x     x       Tuchyzelose polscients (CL. Koch, 1870)     x     x     x       Zal     Zelotes apricorum (L. Koch, 1870)     x	Zodg	Zodarion germanicum (C.L. Koch, 1837)	х	х	x
GraphosidaexxxDeDrassodes cupreus (Blackwall, 1834)xxxDIDrassodes gubescens (Thorell, 1856)xxxDipDrassodes pubsecens (Thorell, 1856)xxxDrpDrassodes pubsecens (Thorell, 1856)xxxDrpDrassodes pubsecens (Thorell, 1875)xxxDrpDrassyllas projecus (L. Koch, 1833)xxxDryDrassyllas projecus (L. Koch, 1835)xxxGaGnaphosa lacica Simol, 1875xxxGiGnaphosa lacica Simpler (C. L. Koch, 1833)xxxHsHaplodrassus signifer (C. L. Koch, 1830)xxxHuHaplodrassus signifer (C. L. Koch, 1830)xxxThe charastella sumbritik (L. Koch, 1850)xxxThe close sarcorantic. (S. Koch, 1857)xxxZapZelotes aprica (Walckanaer, 1802)xxxZapZelotes auraticaus Miller, 1967xxxZapZelotes auraticaus Miller, 1967xxxZapZelotes auraticaus Miller, 1967xxxZapZelotes auraticaus Miller, 1967xxxZapZelotes auraticaus (T. Koch, 1839)xxxZapZelotes auraticaus (T. Koch, 1830)xxxZapZelotes auraticaus (T. Koch, 1839)xxxZap<	Zodj	Zodarion spp. juvenilis	х	х	x
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$\begin{array}{c c c c c c c } \hline Drassyllis pracificus (L. Koch, 1866) & x & x & x & x & x & x & x & x & x & $	Di	Drassodes spn_iuvenilis	x	x	x
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Dry         Drassyllus spl. juvenilis         x         x         x         x           Drj         Drassyllus sp. juvenilis         x         x         x           Ga         Graphosa alpica Simon, 1878         x         x         x           GI         Graphosa alpica Simon, 1878         x         x         x           GI         Graphosa alpica Simon, 1878         x         x         x           Ha         Haplodrassus signifyer (C.L. Koch, 1830)         x         x         x           Hy         Haplodrassus symptivenilis         x         x         x           The Alpolodrassus symptivenilis         x         x         x         x           The Alpolodrassus sp. juvenilis         x         x         x         x           Zapot Zelotes apricorum (L. Koch, 1870)         x         x         x         x           Zal Zelotes cebus (C.L. Koch, 1839)         x         x         x         x           Zh         Zelotes latrelite (Simon, 1878)         x         x         x           Zh         Zelotes latrelite (Simon, 1878)         x         x         x           Zh         Zelotes latrelite (Simon, 1878)         x         x         x <t< td=""><td>Drp</td><td>Drassullus pusillus (C.L. Koch, 1833)</td><td>x</td><td>x</td><td>x</td></t<>	Drp	Drassullus pusillus (C.L. Koch, 1833)	x	x	x
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Ga       Graphosa dipica Simon, 1878       x       x       x         GI       Graphosa spp. juvenilis       x       x       x         Hs       Haplodrassus signifer (CL. Koch, 1839)       x       x       x         Hs       Haplodrassus signifer (CL. Koch, 1839)       x       x       x         Hu       Haplodrassus splustris (Blackwall, 1833)       x       x       x         Hu       Haplodrassus splustris (Blackwall, 1833)       x       x       x         Mf       Micaria fulgens (Walckenaer, 1802)       x       x       x         The Arbitedoress splustris (CL. Koch, 1837)       x       x       x       x         Zaloz zelotes auritacus Miller, 1967       x       x       x       x         Zelotes auritacus Miller, 1970       x       x       x       x         Zaloz Zelotes hermani (Chyzer, 1878)       x       x       x       x         Zia       Zelotes hermani (CL, Soch, 1860)       x       x       x       x         Zia       Zelotes spluspice (L. Koch, 1860)       x       x       x       x         Zia       Zelotes hermani (CL, Soch, 1866)       x       x       x       x         Zia       Zelotes	Drj	Drassyllus spp. juvenilis	х	х	x
Gl       Graphosa heirhaga (Walckenaer, 1802)       x       x         Gj       Graphosa spp. juvenilis       x       x         Hs       Haplodrassus signifer (C.L. Koch, 1839)       x       x         Hs       Haplodrassus signifer (C.L. Koch, 1839)       x       x         Hu       Haplodrassus subratiis (L. Koch, 1830)       x       x       x         Hu       Haplodrassus subratiis (L. Koch, 1837)       x       x       x         Tp       Thalpdarkassus subratiis (L. Koch, 1837)       x       x       x         Zap       Zelotes aurantiacus Miller, 1967       x       x       x         Zau       Zelotes aurantiacus Miller, 1967       x       x       x         Zal       Zelotes corrant (L. Koch, 1839)       x       x       x         Zh       Zelotes longipes (L. Koch, 1839)       x       x       x         Zha       Zelotes longipes (L. Koch, 1830)       x       x       x         Zho       Zelotes longipes (L. Koch, 1830)       x       x       x         Zha       Zelotes persensis (C.L. Koch, 1830)       x       x       x         Tha       Thanatus arenarius Thorell, 1872       x       x       x         Thi </td <td>Ga</td> <td>Gnaphosa alpica Simon, 1878</td> <td>x</td> <td>х</td> <td></td>	Ga	Gnaphosa alpica Simon, 1878	x	х	
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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

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

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.

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	
Ν	1769	1587	1275	
Н	2.362	2.717	3.492	
1-D	0.744	0.802	0.944	
$D_{Mg}$	8.157	10.99	10.91	
Ē	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 ( $\beta$ T). The level of complementarity of habitats within the study area was characterized with Whittaker's  $\beta$ -diversity index ( $\beta$ W) (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.

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'  $\beta$  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 man-



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

agement 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).

Constant			Ar	(%)		
Species		Т	С	Н	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 $(\beta_T)$		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 $(\beta_{\rm T})$		Treated shrubs	Control shrubs
(~1)	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 vear 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