Terrestrial Ecology and Behaviour
Research Article

ACTA ZOOLOGICA BULGARICA
Acta zool. bulg., 70 (2), 2018: 195-202

Effect of Grazing Intensity on Diversity of Ground-dwelling Spiders of Grassy and Shrubby Habitats

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Abstract: The main objective of this paper is to report the effect of grazing intensity on the diversity of ground-dwelling spiders. The study was conducted in grassy and shrubby habitats of the Somhegy-Bükk pasture of the Mátra Mountains in Hungary, where grazing is considered as an experimental management. We found significant effects of grazing on spider communities. Meadow diversity increased during moderate grazing compared to the pre-treatment diversity. Species diversity decreased during intensive grazing. Spider diversity of shrub decreased during both moderate and intensive grazing. We compared grazing in shrub and meadow habitats with control habitats in case of intensive grazing. Our result showed that the control habitats had higher diversity than the grazing habitats. Spider species had narrow tolerance for habitat naturalness in the moderately grazed habitats. We could conclude that grazing is an effective grassland management action to increase spider diversity in the Somhegy-Bükk pasture. Lowering the grazing intensity is necessary in order to save and maintain the high spider diversity. Finally, there is no optimal grazing intensity for all habitats because spiders of shrubs and meadows responded differently to grazing.

Keywords: Araneae, Mátra Mountain, Hungary, grazing, pasture, shrubs

Introduction

Grazing is a wide-spread grassland management tool. The grazing mammals cause changes in abundance, population structure and diversity of plants (Bullock et al. 2001, Landsberg et al. 2003). The effect of grazing outlasts that of other management types. The treading by animals has an effect on soil texture, while the mosaic pattern of habitats results from the selective grazing by animals. Additionally, herbivorous animals contribute to increasing biodiversity as their manure provides food for several arthropod species (Kelemen 1997). The selection of grazing species is important due to differences of grazing strategies of mammals. Sheep prefers short vegetation, while cattle consumes tall vegetation, as well (Kelemen 1997).

The grasslands of the Mátra Mountains, i.e. the Somhegy-Bükk pasture, have developed under anthropological influences like grazing and mowing. The traditional meadow and pasture agriculture has disappeared completely nowadays and, along with it, the number of rare and protected species has decreased. In the meadows, shrubs and weeds grow and eventually these habitats become forests. These habitats were kept alive by mowing and grazing and replacement of these methods is necessary. Grazing was used by the Bükk National Park Directorate in this area in 2014, in order to restore the mountain meadows.

Spiders are considered indicator organisms (Blick 1988), sensitive to change of habitats structure (Duffey 1968). Their assemblages are affected by management, like mowing (Pozzi et al. 1998, Cattin et al. 2003) and grazing intensity (Dennis et al. 2001, Warui et al. 2005). Spider species do not depend on plant composition, but they are influenced by the vegetation structure (Zschokke 1996) as it controls the climate and influences the food supply for them (Samu 2007). The vegetation diversity and species richness contribute to the formation of diverse habitats and could increase spider diversity (Jeanneret et al. 2003b).

In this study, our objectives were to describe the effect of grazing intensity by sheep and cattle on spider diversity. We assessed the diversity through analysing 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 grazing intensity in meadow and shrub over a period of three years. Our hypothesis was that growing grazing intensity would decrease spider diversity, while during moderate grazing it would increase. Additionally, we examined the grazed and control habitats during intensive grazing at a regional scale, in order to analyse the differences between habitats. Our hypothesis was that, due to intensive grazing the vegetation would reduce, resulting in lower spider diversity as compared to the control habitats.

Materials and Methods

Study area and sampling

Our work started in 2014 and was supported by the Bükk National Park Directorate. Data collection was done in the north part of the Somhegy-Bükk pasture, at 430 m a.s.l. in the Parád-Recsk Basin, which has special cooler microclimate. The mechanical mowing is not possible in this area, therefore the reconstruction of habitats is done by grazing by 40 Hungarian racka sheeps and 20 Hungarian cattels. This is a 9 ha Special Protection Areas of Natura 2000 network, which has been fragmented due to succession resulting into formation of smaller habitats. Four sampling sites were selected by the Bükk National Park Directorate based on the mountain habitat attributes: grazing meadow, control meadow, grazing shrub and control cleared shrub (Fig. 1, Table 1). The grazing and control sampling sites were situated about 2-2.5 km from each other. Double-glass pitfall traps, filled with ethylene glycol, were established on the sampling sites at about 10 m distance from the edge. The annual changes of communities were examined in 2014 and 2016 and the regional differences between control and grazing habitats in 2016 (during intensive grazing). Five traps were settled along a transect, at 4-5 m from each other. The traps were deployed twice (May-July, September-November) over a six-week period each year. The cutting of meadows occurred with a mowing machine in both years, in summer or autumn depending on weather conditions. The shrub removal was done earlier in the control shrub habitats through stem cutting. The grazing occurred all days and was measured using vegetation height.

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 the Shannon-Wiener diversity, the Simpson's diversity and the 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 (Nagendra 2002, Hill et al. 2003, Magurran 2003). Species with the highest abundance have the greatest influence on the Simpson's index (Nagendra 2002, Hill et al. 2003, Magurran 2003). The Margalef's richness index was used as a simple measure of species richness (Margalef 1958). The Pielou's evenness index expresses the evenness of the distribution of the species and is sensitive to the change of rare species. (Hill et al. 2003, Magurran 2003). The value of species turnover between habitat types was evaluated with the Wilson & Shmida's Beta diversity index (ßT). The level of complementarity of habitats within the study area was characterised with the Whittaker's β-diversity index (ßW) (Magurran 2003). It depicts the relationship between the alpha diversity and total number of species. The F-test was used to compare the ecological indices using XLSTAT 2016.07.39066 version software (https://www.xlstat.com). We classified the species into two groups representing stenotopic (prefer natural and semi-natural habitats) and disturbance-tolerant species based on their naturalness status using the Catalogue of Buchar & Růžička (2002). We applied the Jaccard similarity index for pair-wise 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).

Results

A total of 548 individuals of 41 species of 23 genera were collected at the four sampling sites (Table 2). The highest number of collected individuals occurred in the control (cleared) shrub and the fewest occurred in the grazing (cleared) shrub and in the meadow before grazing (Tables 3, 4). The assemblages had variable habitat preference. Sixteen of the registered 41 species were observed in only one of the examined habitats; 14 species were present only in the graz-

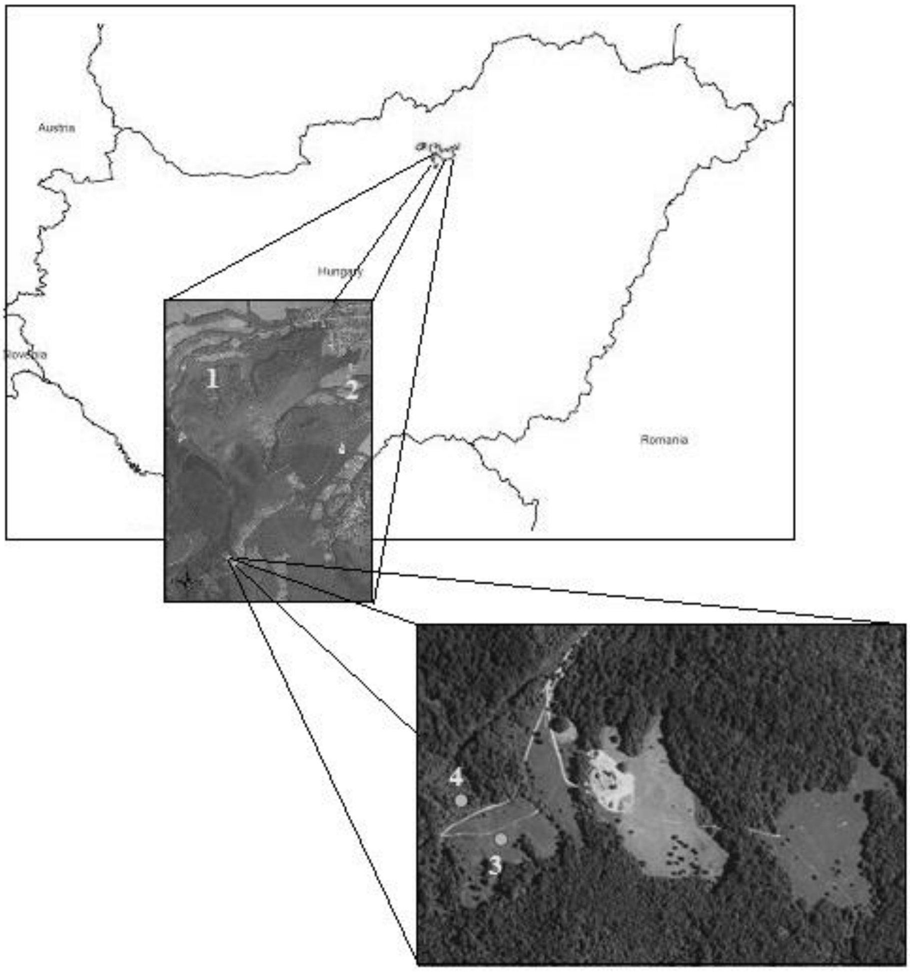

Fig. 1. Map of the sampling sites: 1-Control hay meadow, 2-Control cleared shrub, 3-Grazing hay meadow, 4-Grazing shrub.

Table 1. Characteristics of the sampling sites.

Sampling sites	Size (~ha)	Coordinates	General treatments	Present treatments
Meadow	1.6	47°53’58.95”N 20°00’07.65”E	Mowing	Grazing
Meadow	2.4	47°55’12.68”N 20°00’00.25”E	Mowing	-
Shrub	0.5	47°54’00.97”N 20°00’05.13”E	-	Grazing and shrub control in 2015
Cleared shrub	0.7	47°55’09.45”N 20°01’10.20”E	Stem cutting	-

ing habitats. The most abundant spider species were *Pardosa palustris* (Linnaeus, 1758) and *Trochosa terricola* Thorell, 1856, both tolerant to disturbance. The abundance of these species was quite high in the grazing habitats for the control habitats. The distribution of species based on their naturalness status revealed differences between the assemblages of the different habitats. We found a positive relationship between the number of disturbance-tolerant species and grazing intensity. The number of stenotopic species was highest during moderate grazing (2015) and then decreased during intensive grazing (2016; Table 5). Species which prefer the climax habitats occurred only in the control habitats.

No significant differences were found between the ecological parameters of communities in relation to grazing (Table 6). In meadows, only the presence of cattle and sheep had a positive effect on spider diversity. It was higher during moderate grazing (2015) as compared to the pre-treatment species diversity (2014). We found a negative relationship between the species diversity and grazing intensity. Spider diver-

Table 2. Distribution of the species in the grazing and control habitats (* Stenotopic species).

	Mowed		Shrub	
Species	**Grazed**	**Control**	**Grazed and cleared**	**Control**
Dysderidae				
Dysdera erythrina (Walckenaer, 1802)	x	x	x	
**Harpactea rubicunda* (C.L. Koch, 1838)	x			
Theridiidae				
**Asagena phalerata* (Panzer, 1801)	x			
Tetragnathidae				
Pachygnatha degeeri Sundevall, 1830	x		x	
Lycosidae				
Alopecosa cuneata (Clerck, 1757)				x
Alopecosa pulverulenta (Clerck, 1757)	x		x	x
**Alopecosa trabalis* (Clerck, 1757)	x	x	x	x
**Aulonia albimana* (Walckenaer, 1805)		x	x	x
Hogna radiata (Latreille, 1819)				x
Pardosa agrestis (Westring, 1861)	x		x	
**Pardosa bifasciata* (C.L. Koch, 1834)				x
Pardosa hortensis (Thorell, 1872)				x
Pardosa lugubris (Walckenaer, 1802)	x	x	x	x
Pardosa paludicola (Clerck, 1757)			x	x
Pardosa palustris (Linnaeus, 1758)	x	x	x	x
Pardosa pullata (Clerck, 1757)	x	x	x	
**Pardosa riparia* (C.L. Koch, 1833)	x	x	x	x
**Trochosa robusta* (Simon, 1876)				x
Trochosa terricola Thorell, 1856	x	x	x	x
Agelenidae				
Eratigena agrestis (Walckenaer, 1802)	x			
**Intermocoelotes inermis* (L. Koch, 1855)	x		x	
Dictynidae				
Cicurina cicur (Fabricius, 1793)	x		x	
Liocranidae				
**Agroeca brunnea* (Blackwall, 1833)			x	
**Apoesteunus fuscus* Westring, 1851		x		x
Phrurolithidae				
**Phrurolithus festivus* (C.L. Koch, 1835)				x
Gnaphosidae				
**Drassyllus praeficus* (L. Koch, 1866)	x		x	x
Drassyllus pusillus (C.L. Koch, 1833)	x		x	x
**Gnaphosa lucifuga* (Walckenaer, 1802)				x
Haplodrassus signifer (C.L. Koch, 1839)		x		x
**Trachyzelotes pedestris* (C.L. Koch, 1837)	x		x	
Zelotes latreillei (Simon, 1878)	x			
Philodromidae				
**Thanatus arenarius* Thorell, 1872		x		x
**Thanatus formicinus* (Clerck, 1757)				x
Thomisidae				
**Ozyptila atomaria* (Panzer, 1801)	x			
**Ozyptila simplex* (O.P.-Cambridge, 1862)	x			x
Ozyptila trux (Blackwall, 1846)	x			
Xysticus bifasciatus C.L. Koch, 1837	x	x		x
Xysticus cristatus (Clerck, 1857)	x	x		x
**Xysticus erraticus* (Blackwall, 1834)				x
Xysticus kochi Thorell, 1872	x	x		x
**Xysticus luctator* L. Koch, 1870		x		

sity decreased during the year of intensive grazing (2016) when the vegetation was reduced. In shrub habitats spider diversity was lower under moderate grazing (2015) as compared to the pre-treatment species diversity (2014). Spider diversity continued to dwindle in the following year (2016), when besides grazing it was affected by shrub control. There was a positive correlation between grazing intensity and Pielou's evenness index of shrub communities during intensive grazing (Table 3). When comparing the grazed and control habitats, we no found significant differences (Table 6). In both types of habitats (hay meadow and cleared shrub) the control habitats had higher diversity than the grazed habitats (Table 4).

There was a decrease in time in the Wilson & Shmida's Beta diversity index of the assemblages of grazing habitats (meadow: 14-15: 0.6; 15-16: 0.31; shrub: 14-15: 0.6; 15-16: 0.54). The Jaccard similarity index was the highest between communities in moderate and intensive grazing years (Table 7). There was a higher species turnover between habitats in the case of cleared shrub (0.62) as compared to hay meadows (0.45). There was a distinct difference among different habitats in relation to grazing. We observed higher similarity between control and grazed hay meadows as compared to shrubs (Table 8). There was high complementarity of the species between these habitats. The Whittaker'ß species diversity was 1.1.

Discussion

In this study, we examined the influence of grazing intensity comparing shrubby and grassy habitats. There are evidences, that grazing and trampling have an influence on spiders (De Keer et al. 1989, Maelfait & DeKeer 1990, Gibson et al. 1992 a, b). Vegetation is affected by the type of grazing animals

Table 3. Annual dynamics of the number of individuals (N), number of species (S), Margalef's index (D_{Mg}), Shannon-Wiener index (H), Simpson's diversity (1-D) and the evenness (E). 2014-before grazing, 2015-moderate grazing, 2016-intensive grazing.

Ecological parameters	Hay meadow			Shrub		
	Before grazing	Moderate grazing	Intensive grazing	Before grazing	Moderate grazing	Intensive grazing
N	32	58	99	58	53	44
S	8	19	16	7	10	8
D_{Mg}	3.751	4.926	4.135	2.955	2.771	2.378
H	2.404	2.652	2.19	2.236	1.931	1.733
1-D	0.892	0.899	0.803	0.874	0.798	0.729
E	0.79	0.671	0.447	0.719	0.574	0.567

Table 4. Number of individuals (N), number of species (S), Margalef's index (D_{Mg}), the values of Shannon-Wiener index (H), Simpson's diversity (1-D) and the evenness (E) of grazing and control habitats during intensive (2016) grazing.

Ecological parameters	Hay meadows		Cleared shrubs	
	Intensive grazing	Control	Intensive grazing	Control
N	99	48	44	156
S	16	18	8	29
D_{Mg}	4.135	4.391	2.378	5.545
H	2.19	2.683	1.733	2.799
1-D	0.803	0.919	0.729	0.911
E	0.447	0.812	0.567	0.566

Table 5. Distribution of species based on their naturalness status.

	Number of disturbance-tolerant species	Number of stenotopic species
Before grazing (2014)	13	4
Moderate grazing (2015)	11	7
Intensive grazing (2016)	6	4

Table 6. Annual (between years) and regional (between grazing and control habitats) differences between assemblages relation to grazing (Significance level alpha=0,05).

	Annual		**Regional**
	Hay meadow	**Shrub**	
Ratio	0.419	1.161	0.453
F (Observed value)	0.419	1.161	0.453
F (Critical value)	9.605	9.605	7.146
DF1	4	4	5
DF2	4	4	5
p-value (Two-tailed)	0.420	0.888	0.405

Table 7. Similarity between assemblages in the years of different grazing intensity in the case of hay meadow (A) and shrub (B).

		2014	2015	2016
(A)	2015	0.25	1	
	2016	0.36	0.518	1
		2014	2015	2016
(B)	2015	0.172	1	
	2016	0.277	0.294	1

Table 8. Similarity between grazed and control habitats during intensive grazing.

	Grazing hay meadow	Control hay meadow	Grazing cleared shrub
Grazing hay meadow	1		
Control hay meadow	0.370	1	
Grazing cleared shrub	0.35	0.238	1
Control cleared shrub	0.297	0.468	0.233

and the grazing intensity. Warui et al. (2005) compared the influence of domesticated and wild animals on spiders in the Kenyan Savannah. Their results showed that the cattle grazing had higher negative effect on spider diversity than the wild animals grazing. Pastures can be important spider habitats, as illustrated also by our study. We found that spider diversity was higher during moderate grazing as compared to pre-grazing diversity. Our data confirm the result of previous studies that intensive grazing decreases the spider diversity (Gibson et al. 1992a, Zulka et el. 1997, Bell et al. 2001, Pétillon et al. 2007, Horváth et al. 2009, Szinetár & Samu 2012). This can be explained with the positive relationship between the vertical vegetation structure and the diversity and abundance of spider communities (Hatley & MacMahon 1980, Dennis et al. 2001, Harris et al. 2003) owing to the sensitivity of spiders to the vegetation structure (Gibson et al. 1992 a, b). The structured vegetation is more valuable for spiders due to higher prey supply which increases the species diversity (Samu 2007). Moreover, vegetation can influence the number of individuals of spiders through controlling the microclimate (Kohyani et al. 2008). The decrease in spider diversity during intensive grazing can be explained by the fact that the previous spider assemblage is completely removed (Delchev & Kajak 1974). Grazing has an effect on species abundances (Bonte et al. 2000) and community composition. Moderate grazing results in patchy mosaic grassland providing the possibility of migration between tall and short vegetation (Bonte et al. 2000). The homogenous cover of intensive grazed areas with no refuges causes high abundance of diurnal running spiders (see Pétillon et al. 2007). These explain the higher diversity and the higher number of stenotopic species in the moderately grazed habitats as compared to the intensively grazed habitats, where the disturbance-tolerant species were dominant. Horváth et al. (2009) found significant influences of grazing intensity on spiders. Other studies (Hemm & Höfer 2012, Szinetár & Samu 2012) have not observed significant differences between sparsely grazed and intensively grazed areas.

We found differences in the effect of grazing between meadow and shrub habitats during moderate grazing. Spider diversity of meadows increased, while in shrub habitats it decreased. Hemm & Höfer (2012) found that species richness of spiders was higher in the shrubby area than in the grasslands. The cause of this may be the different habitat preference of the species in the studied habitats. The grassland species are positively influenced by moderate grazing on the meadows as it lowers the vegetation height and increases the sunlight amount reaching the ground. In the case of shrubs, the intensive cattle grazing reduces the clumpiness of the vegetation and changes the pattern of shrub distribution (Steifan & Kadmon 2006), which have an effect on spider assemblages. During the study period, the shrub habitats were treated with shrub removing agents causing higher disturbances for spider communities. The shrub removal can change soil humidity, lighting conditions and structure. These conditions may explain why the diversity decreased in this year. The higher value of the Pielou's index for shrub habitats that were subject to intensive grazing and shrub removal, reflects the absence of rare species, and that the distribution of mainly disturbance-tolerant species was even. The higher species turnover between years with moderate and intensive grazing as compared to the one between moderate and pre-grazing years indicated the high effect of intensive management.

Moderate grazing might be categorised as an intermediate disturbance (Conell 1979), which causes high diversity. Our annual and regional examinations showed the highest spider diversity was registered during moderate grazing on the Somhegy-Bükk pasture in the Mátra Mountain. In addition, we found a high number of stenotopic species on the moderately grazed habitats, as well. To conclude, the moderate grazing is an optimal grassland management to maintain the meadows that provide habitats for several spider species and maintain high spider diversity. It is important to consider, beside the selection of grazing intensity, the habitat types and structure as the effect of grazing was different for shrub and meadow habitats. The application of both grazing and shrub removal is considered as disturbance on communities and is decreasing the species diversity.

Acknowledgements: We thank the employees of the Bükk National Park Directorate, especially Dudás György and Kemény Attila. We thank Fodor Dávid for proof-reading of the language.

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Received: 03.04.2017
Accepted: 12.07.2017