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Hedgerows support rich communities of harvestmen (Opiliones) in upland agricultural landscape

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Abstract

Hedgerows play important roles in agricultural landscapes and they increase biodiversity by providing habitat refugia for species sensitive to agricultural disturbance. We have studied the characteristics of the communities of harvestmen (Opiliones) inhabiting hedgerows. Harvestmen are terrestrial arachnids associated with soil surface and subsurface and sensitive to land-use and disturbance. We were specifically interested in quantifying how hedgerow characteristics (e.g., elevation, length, width, connectivity, and plant diversity) affect harvestman diversity and community composition. We expected harvestman diversity and community composition to be positively related to both hedgerow size (area, length, width) and biological attributes of hedgerows (e.g., connectivity, plant community diversity). We surveyed hedgerow characteristics and harvestman communities of 20 hedgerows in an upland agricultural landscape in the Western Carpathians. Hedgerow characteristics were measured in the field or derived from GIS layers and we used correlation and ordination methods to relate them to harvestman community metrics. We found surprisingly high taxonomic richness of harvestmen within the studied hedgerows (15 species). Importantly, the Shannon index of harvestman communities was positively related to hedgerow length and hedgerow tree layer species richness and diversity. Harvestman community composition varied with hedgerow area and width. Despite their small total area, hedgerows represented an important habitat for diverse harvestman communities and hedgerow attributes such as size and tree diversity significantly affected the composition and the Shannon index of harvestman communities. Thus, greater lengths and widths of hedgerows can provide habitats for a higher Shannon index of harvestman communities, within surrounding agricultural landscapes.

Keywords: Biodiversity; Conservation corridors; Environmental management; Landscape connectivity; Slovakia

Introduction

Hedgerows and other linear formations of unmanaged non-forest woody vegetation are conspicuous landscape

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elements and important habitats for native plants and animals in open agricultural landscapes (Critchley, Wilson, Mole, Norton & Smart, 2013; Dover, Sparks, Clarke, Gobbett & Glossop, 2000; Hannon & Sisk, 2009; Wiezik, Gallay, Wieziková, Čiliak & Dovciak, 2017) where they act as habitat refugia and conduits or barriers for species movement (e.g., Baudry, Bunce & Burel, 2000; Dmowski & Koziakiewicz, 1990). Hedgerows play substantial roles in soil protection, biodiversity conservation, and landscape ecological stability, and they are an important component of landscape planning and biodiversity conservation on local, regional and national levels (Baudry et al., 2000; Diviaková, 2010).

One of the most important functions of hedgerows in intensive agricultural landscapes is that they can provide habitat conditions that otherwise would be rare or lacking (Staley et al., 2015), specifically shaded conditions under woody canopies that decrease solar radiation and moderate microclimate and ground-level vegetation (e.g., Dovčiak & Brown, 2014). Thus, hedgerows provide additional species niche space and they may substantially contribute to local and regional biodiversity in otherwise open agricultural areas (Thomas, Parkinson, Griffiths, Garcia & Marshall, 2001). The effects of hedgerows on individual taxonomic groups and overall biodiversity depend on the hedgerow characteristics such as hedgerow length and connectivity (Ernoult & Alard, 2011) as well as on the overall landscape-scale configuration of the agricultural land-use mosaic (Baudry et al., 2000). Assessing the conservation values of different hedgerow types requires a good understanding of how hedgerow physical and biological attributes shape environmental conditions and biological communities within them. However, while the effects of hedgerow characteristics have been relatively well studied for some taxa (e.g., butterflies − Dover & Sparks, 2000; plants − Deckers, Hermy & Muys, 2004; carabid and staphylinid beetles − Griffiths, Winder, Holland, Thomas & Williams, 2007), taxon-specific information on desirable hedgerow attributes is scarce for many taxonomic groups, thus impeding the development of a better understanding of the overall effects of hedgerow parameters on biodiversity.

Harvestmen (Opiliones) are terrestrial arachnids associated in their natural habitat mainly with soil surface and occasionally deeper soil layers (Pinto-da-Rocha, Machado & Giribet, 2007) where they fulfil several essential functions that may be particularly important in agricultural landscapes. Although harvestmen are polyphagous, they prefer to prey on various invertebrates (Šilhavý, 1956) and they contribute considerably to limiting the abundance of insect pests in agricultural landscapes. For example, Todd (1949) calculated that harvestmen within a one-hectare area can consume up to 65 kg of prey per year. In addition, harvestmen are consumed by various other invertebrates and vertebrates, including various bird species (Krištín, 1988a, 1988b; Krištín & Baumann, 1996), thus supporting higher order consumers that also prey on agricultural pests and contribute to limiting insect pest densities. Moreover, harvestmen play important roles in decomposition food webs as they consume dead invertebrates and other organic remains and contribute to material cycles and energy flows within ecosystems (Šilhavý, 1956). Harvestmen have been shown to have strong interactions with other taxa (cf. their prey or predators) and thus an important role in ecological networks in terrestrial ecosystems (Pinto-da-Rocha et al., 2007).

Harvestman community structure responds to a variety of environmental drivers, with microclimate and soil surface characteristics among the most important (Branquart, Kime, Dufréne & Tavernier, 1995; Meyer, Plankensteiner, Grabher & Lutz, 1999; Todd, 1949; Almeida-Neto, Machado, Pinto-da-Rocha & Giaretta, 2006; Pinto-da-Rocha et al., 2007). Soil surface, microclimate, and invertebrate communities tend to be closely related to vegetation structure (Merino-Sáinz & Anadón, 2015; Proud, Tibbetts, Moore & Townsend, 2011; Stašiov et al., 2019). Yet, only a few studies investigated harvestman communities in hedgerows or other woody vegetation fragments (e.g., Bragagnolo, Nogueira, Pinto-da-Rocha & Pardini, 2007; Halaj & Cady, 2000; Stašiov, Michalková, Lukáčik & Čiliak, 2017), and most focused on comparing harvestman communities in hedgerows and adjacent habitats. We are not aware of any study linking individual hedgerow attributes to the structure of harvestman communities (although some studies did so for other taxa such as centipede and millipede communities; Stašiov, Diviaková, Svitok & Novikmec, 2017). To close this gap, we studied harvestman communities in hedgerows of a typical Central European upland agricultural landscape. Our objectives were to (*i*) identify hedgerow attributes that structure harvestman communities and (*ii*) provide information that can be used in assessing hedgerows for their potential in enhancing biodiversity in agricultural landscapes.

We hypothesised that hedgerow spatial characteristics (area, length, and width) as well as diversity of hedgerow plants will be positively correlated with harvestman diversity. These spatial and biological attributes were also expected to alter harvestman abundance and community composition.

Materials and methods

Study area and design

The study was conducted in the Western Carpathians in Central Europe, near the village of Žibritov in Štiavnické vrchy Mts., Slovakia (48°23′27.00″ N, 18°59′01.17″ E), elevation between 477 and 550 m above sea level (Fig. 1). The surroundings of the Žibritov village represent a typical upland landscape of the Western Carpathians characterised by a mosaic of various forms of land use: mowed meadows, pastures and arable land with the abundance of hedgerows at the property boundaries or separating different land uses. The topography of the area is hilly, soils are dominated by

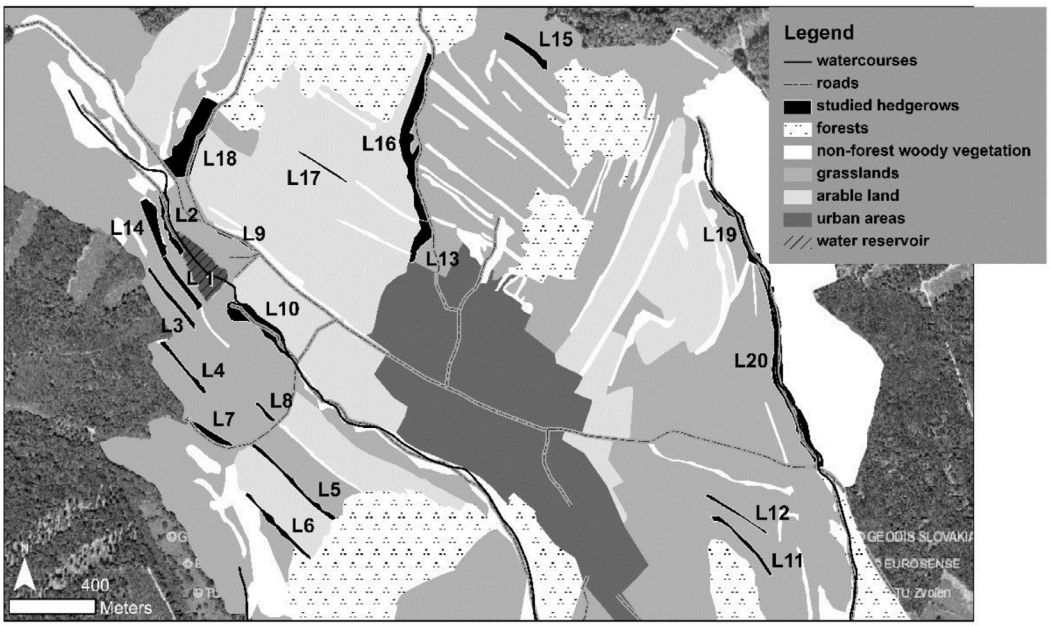

Fig. 1. Aerial photo (© EUROSENSE, Ltd. and GEODIS SLOVAKIA, Ltd.) showing the study area, distribution of studied hedgerows (L1−20) and main land use types in the surroundings of the Žibritov village (Štiavnické vrchy Mts., Slovakia).

cambisols, and climate is characterized as moderately warm and moderately humid (Konečný et al., 1998; Mazúr & Lukniš, 2002), with the average annual air temperature 7.83 °C (Šťastný, Nieplová & Melo, 2002) and average annual precipitation totals 713.6 mm (Faško & Šťastný, 2002). The natural potential (pre-disturbance) vegetation of the area is characterised as oak forests composed of sessile and Turkey oak (*Quercetum petraeae-cerris*) (Maglocký, 2002).

We randomly selected 20 hedgerows of heterogeneous origin, length, width, and vegetative composition that included hygrophilous riparian hedgerows dominated by alder (*Alnus glutinosa*) (hedgerows L2, L10, L19−20), semi-natural fragments of forest dominated by oak (*Quercus cerris*) and hornbeam (*Carpinus betulus*) (hedgerows L3−4, L8, L13−14, L16, L18), shrubby hedgerows dominated by hazel (*Corylus avellana*) and blackthorn (*Prunus spinosa*) (hedgerow L15), and mixed hedgerows composed of a heterogeneous assortment of diverse assemblages of various woody species on the meadows and along the roads (hedgerows L1, L5−7, L9, L11−12, L17) (Table 2).

Measuring hedgerow habitat characteristics

For each selected hedgerow, we described their plant species composition, morphometric, structural, and spatial characteristics using 17 variables measured in the field or extracted from various regional geological, geomorphological and soil databases (Malík et al., 2011) (see Table 1). Elevation was identified from digital terrain model (resolution of 20 × 20 m) generated from catastral maps (scale 1:10 000) (Banská Štiavnica M 36−33−19, M 36−33−20, M 36−33−24) by digitizing contour lines, known point elevations, and stream network in the ArcGIS Geographic Information Systems (ESRI). TauDEM (Terrain Analysis Using Digital Elevation Models) was used to analyze the topography of the area (Tarboton, 2004). Soil depth was obtained from the map of soil-ecological units available at the National Agriculture and Food Centre (https://portal.vupop.sk/portal/apps/webappviewer/index.html, accessed: March 1, 2019). Soil depth was characterized using broader categories: very shallow (< 15 cm), shallow (15−30 cm), intermediate (30−60 cm), deep (60−100 cm), and very deep (100−200 cm) so instead of the average depth the most common soil depth category is given (Malík et al., 2011). Spatial parameters of hedgerows (length, minimum width, area) were measured from orthophotographs in ArcGis (ZBGIS© 2018) and subsequently verified in the field. For each hedgerow, a 20-m buffer strip was delineated using GIS tools (ArcGis). The percentage cover of four main land use types (forest, grassland, arable land, non-forest woody vegetation) for each 20-m buffer strip was determined by intersecting buffer strips with the land cover database of the Institute of Landscape Ecology, Bratislava, Slovakia derived from the ZBGIS© (Primary Base for Geographic Information System). Hedgerow plant species composition was characterized according to the Zurich−Montpellier school using the extended Braun-Blanquet scale (Braun-Blanquet, 1964) on 2 plots (4 × 20 m large) placed randomly in each hedgerow. Since plant diversity may positively affect ecological stability and diversity of other taxa (e.g., Dovciak & Halpern, 2010; Stašiov et al., 2019), the diversity of individual vegetation layers (tree layer−E3, shrub layer−E2, and

Table 1. Variables measured for hedgerows in the Žibritov area of Štiavnické vrchy Mts.

Variable	Abbreviation	Average (min.; max.)
Local abiotic characteristics		
Elevation (m a. s. l.)	EL	518 (477; 550)
Hedgerow area (m^2)	A	3256 (509; 9838)
Hedgerow length (m)	L	183 (47; 400)
Hedgerow minimum width (m)	W_{min}	10 (4; 20)
Soil depth (cm)	SD	30−60 (<15 to >100)
Local biotic characteristics		
Number of plant species in tree layer	S (E3)	5.8 (3; 11)
Number of plant species in shrub layer	S (E2)	13.2 (7; 20)
Number of plant species in herbaceous layer	S (E1)	29.2 (13; 49)
Shannon diversity of tree layer plant species	*H* (E3)	1.62 (1.05; 2.34)
Shannon diversity of shrub layer plant species	*H* (E2)	1.59 (0.76; 2.80)
Shannon diversity of herb layer plant species	*H* (E1)	3.28 (2.47; 3.86)
Defoliation of tree layer (%)	D (E3)	7.3 (0; 50)
Defoliation of shrub layer (%)	D (E2)	8.9 (0; 25)
Land use characteristics (within in 20 m buffer)		
Forests (%)	Forests	3 (0; 15)
Grasslands (%)	Grasslands	60 (0; 100)
Arable land (%)	Fields	18 (0; 100)
Non-forest woody vegetation (%)	NFWV	15 (0; 60)
Connectivity		
Connectivity (categorical: 1−3)[a]	C	1 (30%); 2 (40%); 3 (30%)

[a]Percentage of hedgerows in each category is given.

herbaceous layer−E1) was evaluated as both the number of species (species richness) and Shannon diversity index *H* (Jost, 2006) calculated from individual plant species field measurements (using the Braun-Blanquet combined scale that integrates species abundance and coverage in each layer; Barkman, Doing & Segal, 1964). Plant nomenclature followed Marhold and Hindák (1998). Connectivity of hedgerows (to other hedgerows or woody vegetation) and the defoliation of woody vegetation layers (loss of foliage − the main symptom of hedgerow health condition) were evaluated in the field. Hedgerows were characterized in three categories as connected to (1) forest stands or (2) other hedgerows, and as (3) isolated hedgerows. The degree of defoliation was visually estimated as the percentage of missing or damaged foliage (to nearest 5%; Kunca, 2013; Pavlenda, Pajtík & Priwitzer, 2014).

Characterizing harvestman communities

Harvestman communities were sampled by pitfall trapping during the lenght of a growing season (end of May to end of August 2006). Three pitfall traps were installed in each studied hedgerow: one was placed in the centre of the hedgerow (intersect of the longitudinal and transverse axis of the hedgerow) and two traps were located close to longitudinal edges of hedgerows (at least 5 m from the edge, and in the middle of the transverse direction). We used glass jars with the volume of 0.7 l (25 cm tall and with 7.5 cm diameter at the mouth) as pitfall traps. The traps were half-filled with a 10% formaldehyde solution. To eliminate evaporation from traps, a few drops of glycerol were added into each trap. The material from the traps was collected at the end of August and samples from all three traps within the same hedgerow were pooled together to form one composite sample. The content of the pitfall traps was rinsed with water in the laboratory and hand sorted. Harvestmen were identified to the lowest possible taxonomic level (to species in almost all cases) according to Wijnhoven (2009). For the analyses, only individuals of harvestmen identified to species level were considered (99.1% of all collected individuals). Identified material was conserved in 70% ethylalcohol and stored as voucher specimens in the collection of the first author at the Technical University in Zvolen. From the field data, we calculated the Shannon diversity index of harvestmen of individual hedgerows following Pielou (1966).

Data analyses

Due to the relatively high number of potential explanatory environmental variables (17) compared to the number of hedgerows, we initially pre-screened all species-environment relationships with non-parametric correlation analyses using Spearman ρ.

Subsequently, five variables with Spearman $\rho > 0.4$ (EL, L, S (E3), *H* (E3), NFWV); Table 3) were selected and related to richness and Shannon diversity using generalized linear models (GLM) with Poisson and Gaussian distributions, respectively (McCullagh & Nelder, 1989). Since richness and Shannon diversity of the tree layer (S (E3) and H (E3)) were strongly correlated ($r = 0.98$), only Shannon diversity H (E3) was used in GLMs. Thus, the full models initially contained four predictor variables and they were simplified by backward elimination procedure based on likelihood-ratio tests. Only those variables whose elimination caused significant ($\alpha = 0.05$) increase in deviance were retained in the final models. No multicollinearity problems

were encountered, as all variance inflation factors (VIFs) were less than 1.2.

To investigate the variation in harvestman community composition relative to environmental variables, we used non-metric multidimensional scaling (NMDS) based on Jaccard dissimilarity (McCune, Grace & Urban, 2002). The vectors of environmental variables were projected into the ordination in the direction of their maximal correlations with the site scores on the axes (and scaled relative to the correlations). Statistical significance of fitted environmental vectors was assessed using permutation test (10,000 permutations).

This approach allowed us to investigate all species-environment relationships (including those with correlated variables) without the risk of missing any important information. This heuristic ordination approach does not necessarily uncover cause-effect relationships, but it can generate new hypotheses to test in the future for wider populations.

All analyses were performed in R (R Core Team, 2015) using libraries Hmisc (Harrell, 2014) and vegan (Oksanen et al., 2013).

Results

In total, 913 individuals of harvestmen from 15 species (1 taxon determined to genus) were recorded (Table 2). The most abundant and most frequently occurring species were *Egaenus convexus, Lacinius ephippiatus* and *Zachaeus crista*, comprising 67.0% of all collected individuals. The overall epigeic activity of harvestmen ranged from 2 to 94 individuals and the number of species from 1 to 14 species, per hedgerow per study period. Shannon diversity also varied considerably among harvestman communities of individual hedgerows (0−2.14).

The Shannon index of harvestman communities showed significant positive relationship with hedgerow length, and marginal positive relationships with tree layer diversity and richness as well as elevation (Table 3; Fig. 2). In addition, harvestman richness was significantly positively correlated with proportion of non-forest woody vegetation in the 20-m buffer zone around the hedgereows. Also tree layer richness and hedgerow area showed positive relationships with harvestman species richness, although marginally non-significant (Table 3; Fig. 2). However, when we combined these variables using GLMs, only Shannon diversity of the tree layer was significantly positively related to both richness ($\chi^2 = 1.04$, $p = 0.044$) and the Shannon index of harvestman communities ($F_{(1,18)} = 5.52$, $p = 0.030$).

Species composition of harvestman communities significantly varied across the hedgerows within our study area and it was linked to hedgerow area ($r^2 = 0.32$, $p = 0.041$) and minimum width ($r^2 = 0.39$, $p = 0.015$) rather than to the Shannon diversity or richness of the vegetation ($p > 0.1$) (Fig. 3).

Discussion

We found a surprisingly high number of harvestman taxa in the study area (< 2 km^2); the 15 observed species represent 43% of all harvestman species that occur in Slovakia

Table 2. Overall epigeic activity of harvestman species recorded within the surveyed hedgerows (by hedgerow number, L1−20). Numbers indicate the total number of specimens recorded in each hedgerow.

Taxa (rows)/Hedgerow number (columns)	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15	L16	L17	L18	L19	L20	∑
Phalangiidae																					
Astrobunus laevipes (Canestrini, 1872)	26		2		5				11	3	6	2	1	1		3	3	1	13	2	79
Egaenus convexus (C. L. Koch, 1835)	46	27	19	19	6	3	16		52	6	21	12	32	4	5	8	5	8	7	13	309
Lacinius ephippiatus (C. L. Koch, 1835)	15	12	4		9	1				17	1		31	2		4		27	21	27	171
Leiobunum rotundum (Latreille, 1798)	3		1								2										6
Lophopilio palpinalis (Herbst, 1799)	6	1	2							1				1						2	13
Oligolophus tridens (C. L. Koch, 1836)	21	7	3		1					2			1	1	1				3	1	41
Opilio sp.	6																		1	1	8
Phalangium opilio Linnaeus, 1758	1									1											2
Platybunus bucephalus (C. L. Koch, 1835)	1	1	1									2	1	2				3			11
Rilaena triangularis (Herbst, 1799)	4	2	2	2	1				2		2	1	2			1				1	20
Zachaeus crista (Brullé, 1832)	27		40	10	6		2		2		5		13	1	7	3	3		6	1	126
Dicranolasmatidae																					
Dicranolasma scabrum (Herbst, 1799)	2		1			1	3	2	2		4		6			1		1			23
Nemastomatidae																					
Mitostoma chrysomelas (Hermann, 1804)		1	3												1						5
Nemastoma lugubre (Müller, 1776)	2		4		1									1						1	9
Trogulidae																					
Trogulus tricarinatus (Linnaeus, 1767)	12	12	6	8	1	2	1		15	9	3	4	7	1		1	1			7	90
∑ Specimens	172	63	88	39	30	7	22	2	84	39	44	21	94	14	14	21	12	40	51	56	913
∑ Species	14	8	13	4	8	4	4	1	6	7	8	5	9	9	4	7	4	5	6	10	136

Table 3. Spearman correlation coefficients (p-values in parentheses) between environmental variables and harvestman community species richness and Shannon diversity (*H*). Statistically significant (at $p < 0.05$) correlations are in bold; marginally significant (at $p < 0.1$) correlations are in italics. .

Variable	Richness	Shannon *H*
Local abiotic characteristics		
Elevation (m a. s. l.)	0.29 (0.215)	*0.41 (0.070)*
Hedgerow area (m^2)	*0.40 (0.084)*	0.37 (0.112)
Hedgerow length (m)	0.28 (0.225)	**0.49 (0.028)**
Hedgerow minimum width (m)	0.33 (0.155)	0.24 (0.310)
Soil depth (cm) [a]	−0.06 (0.812)	−0.14 (0.552)
Local biotic characteristics		
Number of plant species in tree layer	*0.41 (0.075)*	*0.42 (0.064)*
Number of plant species in shrub layer	0.22 (0.355)	0.31 (0.177)
Number of plant species in herbaceous layer	0.04 (0.868)	0.17 (0.479)
Shannon diversity of tree layer plant species	0.35 (0.129)	*0.42 (0.069)*
Shannon diversity of shrub layer plant species	−0.13 (0.598)	0.07 (0.777)
Shannon diversity of herb layer plant species	0.01 (0.975)	0.08 (0.753)
Defoliation of tree layer (%)	0.07 (0.759)	0.17 (0.468)
Land use characteristics (prop. in 20 m buffer)		
Forests (%)	−0.09 (0.707)	−0.07 (0.775)
Grasslands (%)	0.09 (0.697)	0.05 (0.825)
Arable land (%)	−0.20 (0.395)	<0.01 (0.986)
Non-forest woody vegetation (%)	**0.47 (0.038)**	0.31 (0.187)
Connectivity		
Connectivity (categorical: 1−3)	−0.18 (0.459)	−0.12 (0.605)

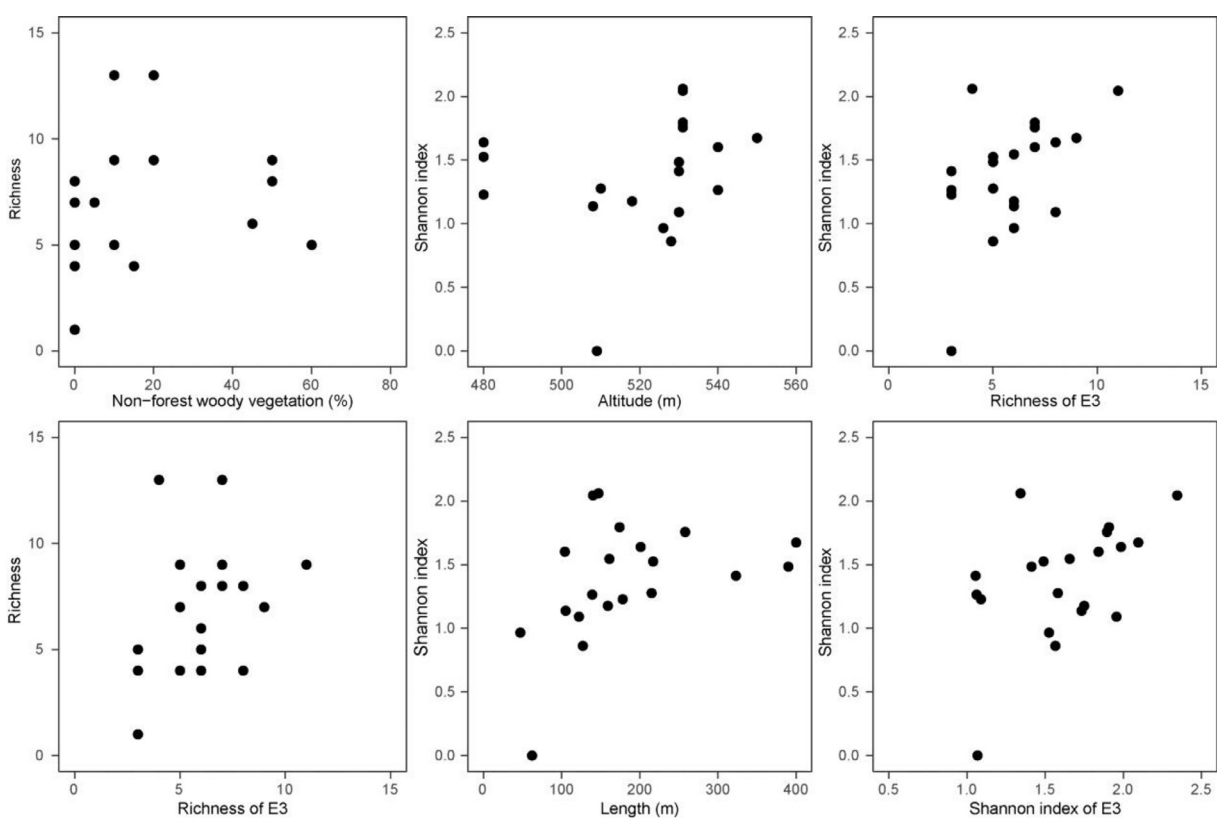

Fig. 2. Pair-wise relationships between diversity characteristics of harvestman communities (richness, Shannon index) and environmental variables. All relationships showed Spearman $\rho > 0.4$ (see Table 3). E3 = tree layer.

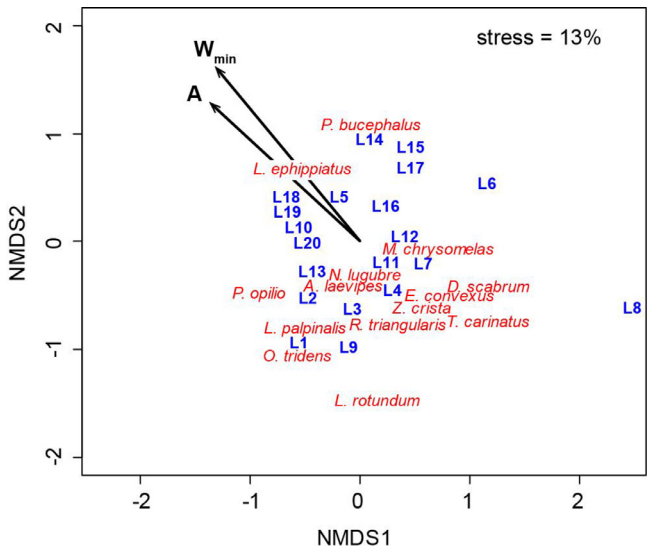

Fig. 3. Two-dimensional solution of non-metric multidimensional scaling of harvestman communities based on Jaccard dissimilarity. The vectors of significant environmental variables were fitted onto the ordination in direction of maximal correlation. Species scores were added as weighted averages of site scores. Final stress value is displayed. For abbreviations of environmental variables see Table 1.

(Stašiov, 2004). Such high local taxonomic richness may result from diverse environmental conditions found in the fine-scale mosaic landscape characterized by varied low intensity land-uses and the variation in hedgerow attributes (e.g., length, width, area, and tree diversity).

Correlation analysis revealed relationships between the Shannon index of harvestman communities and hedgerow length. Hedgerows can be considered to be transitional (ecotone) habitats that tend to harbor higher species diversity than the adjacent agricultural habitats as they provide conditions to species adapted to both transitional habitats with woody vegetation cover as well as more open adjacent agricultural. Our study thus corroborates findings of other authors in other regions; for example, Padmavathy and Poyyamoli (2011) found that the arthropod species composition (including harvestmen) was highly influenced by total hedgerow length in the studied agricultural fields in India, while Klimeš and Špičáková (1984) found that harvestman communities were most diverse and most abundant in transitional ecotonal habitats between the studied wooded and open habitats in the Czech Republic.

The observed effect of minimum hedgerow width on the composition of harvestman communities is likely to be related to the sensitivity of microclimate to hedgerow width. Since microclimate shows a steep gradient between open habitats and those under closed forest canopies (e.g., Dovčiak & Brown, 2014), narrow hedgerows are likely to experience higher solar radiation and heat stress, lower humidity and greater fluctuations of microclimatic conditions than wider hedgerows would. Consistently with this idea, the most narrow hedgerows in our study (L4, L7−8, L15; Fig. 1) lacked some of the documented species of shaded mesic habitats such as *Lophopilio palpinalis, Lacinius ephippiatus*, and *Platybunus bucephalus* (Table 2) (cf. Stašiov, 2004).

In some of our studied hedgerows, the size of their area correlated positively with the number of recorded harvestman species. One possible explanation for the occurrence of more species in larger areas is the fact that they provide more varied types of microhabitats (Lack, 1969). Bragagnolo et al. (2007) corroborated that forest fragment size was positively related to harvestman species richness in Atlantic forest fragments in Brazil.

The positive influence of richness and Shannon diversity of the tree layer on richness of harvestman communities was probably related to the effect of the tree layer on microhabitats. The higher diversity in the tree layer may have a positive effect on higher and more stable moisture and it may dampen temperature fluctuations, which can create more favorable conditions for at least some harvestman species. Unlike scorpions and many spiders, harvestmen are very sensitive to dehydration, and the requirement for moist habitats is likely to be a significant ecological factor that limits the occurrence of most species (Pinto-da-Rocha et al., 2007). In addition, the higher diversity of the tree layer represents in general a higher structural complexity of habitats as different tree species vary in their morphological, biochemical, and phenological features. According to Colmenares, Baccaro and Tourinho (2016) arthropod diversity and the non-flying arthropod food web, including harvestmen, are strongly influenced by habitat components related to plant architecture and habitat structural complexity. Even Proud et al. (2011) pointed out that arthropod diversity (including harvestmen) is strongly influenced by habitat components related to plant architecture and habitat structural complexity. However, we still poorly understand the relationship between arthropod diversity and the vegetation structure at different spatial scales.

Numerous studies have shown that habitats with tree vegetation provide more suitable conditions for harvestmen than arable land as reflected by the higher Shannon index of harvestman communities in habitats dominated by woody species (Mihál, 1998, 2003; Pinto-da-Rocha et al., 2007; Spungis, 2008 etc.). This corresponds with the positive correlation of harvestman richness and proportion of non-forest woody vegetation observed in our study. Within agricultural landscapes, hedgerows enable occurrence of those harvestman taxa (as well as other invertebrate groups) that are often missing in the surrounding more open areas (Halaj & Cady, 2000; Nazzi, Paoletti & Lorenzoni, 1989; Pfiffner & Luka, 2000). Thus, in addition to other important functions, hedgerows can play an important role also as arthropod refugia within intensively-used agricultural landscapes (cf. Olechowicz, 2004).

Conclusions

The hedgerows in our study provided habitats for 43% of the harvestman species found in Slovakia just within a relatively small study area. Moreover, we showed that hedgerow attributes (particularly area, width, and diversity of the tree layer) are among the key variables that land managers should consider when designing land management or biodiversity conservation plans. By observing the positive relationships between the diversity of hedgerow vegetation and harvestman community, our work provides further evidence that diversity may beget more diversity (cf. 'rich get richer', Stohlgren, Barnett & Kartesz, 2003). Hopefully, our study may contribute in a small way as a call for a better understanding of the role of hedgerows and their wider appreciation and protection within agricultural landscapes.

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