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STRUCTURE OF HARVESTMEN (ARACHNIDA, OPILIONES) COMMUNITIES IN DIFFERENT, ANTHROPICALLY DISTURBED BEECH ECOSYSTEMS (WESTERN CARPATHIANS, SLOVAKIA)

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Structure of Harvestmen (Arachnida, Opiliones) Communities in Different, Anthropically Disturbed Beech Ecosystems (Western Carpathians, Slovakia). Mihál, I., Černecká, Ľ. — The authors evaluate the impact of different types of forestry management, and other anthropic disturbances, on harvestmen (Opiliones) communities in sub-mountain beech stands in the Western Carpathians. Harvestmen were studied in three main localities, consisting of nine partial plots (Žiar nad Hronom — (1) control closed canopy stand; Jalná — (2) control stand, (3) thinning stand, (4) 11-year old forest clearing, and (5) 2-year old forest clearing; Kováčová — (6) control stand, (7) coppice, (8) 10-year old forest clearing, and (9) 3-year old forest clearing). In total, 16 harvestmen species were found, representing 45.7 % of the 35 harvestmen species range known in Slovakia to date. The most abundant species, i. e., those with the highest dominance values (D), were *Lophopilio palpinalis* (D = 22.8%), *Trogulus nepaeformis* (D = 17.9%), *Lacinius ephippiatus* (D = 12.2%), *Trogulus tricarinatus* (D = 11.3%), *Oligolophus tridens* (D = 10.5%), and *Nemastoma lugubre* (D = 6.7%). At the partial plot of the 3-year old forest clearing, we found eight harvestmen species and noticed a high number of specimens (5.49) caught in one individual trap, and this was also the highest number among all the nine sites.
Key words: *Fagus sylvatica* L, harvestmen, Opiliones, managed forests, Western Carpathians, Slovakia.

Introduction

Harvestmen, of the order Opiliones, belong to the taxonomic class of Arachnida, which is dominated by the species-rich group of spiders (order Araneae). To date, there are relatively very few papers in the literature that have studied the ecology of harvestmen communities in relation to their environment, or the reactions of these invertebrates to changes in the environment. As with spiders, the vast majority of papers on harvestmen are devoted only to faunistic research, i. e., the documentation of the range of harvestmen species occurring in given biotopes, in a given location (Astaloš and Jarab, 2005; Franc and Mlejnek, 1999; Mašán, 1998; Mihál et al., 2010; Stašiov and Maršalek, 2015).

In Slovakia, there are several papers dealing with the ecological research of harvestmen. For example, a structure of the harvestmen community in the Veľká Fatra Mountains, in central Slovakia, at three different mountain biotopes, namely forest, ecotone, and meadow has been described (Jarab and Kubovčík, 2002). The harvestmen species range and dominance at the forest clear-cut, and in the adjacent fir-beech forest stand has been researched (Mihál, 1997). Similarly, the issue of forest thinning stands, and its effects on harvestmen, has been studied (Mihál and Černecká, 2014). Harvestmen were the subject of a study on the conditions of mature oak-hornbeam forests and their ecotopes, along with adjacent clear-cut areas (Mihál and Gajdoš, 2010). Harvestmen are referred to as an appropriate group of bio-indicators of topsoil condition in the sub mountain fir-beech forests (Stašiov, 2001). Similarly, the impact of different managements of agricultural crops on harvestmen occurrence has also been studied (Stašiov et al., 2011). After a major wind and snow calamity in the mountain forests of High Tatras in 2004, spider and harvestman communities became suitable indicators for the study of ecological succession of invertebrates in disturbed stands (Urbaničová et al., 2014).

It should be noted that similar ecological studies of harvestmen communities have been carried out in other European countries. For example, the harvestmen communities in the mountain forests, and open biotopes in the biosphere reserve in Spain, have been studied (Izaskun and Araceli, 2015). In Austria, the occurrence of xerophilic species of harvestmen in the ecotones of fields and agrocoenoses, into which harvestmen spread from nearby forest ecosystems (e. g. hedges, orchards, groves), has been observed (Kromp and Steinberger, 1992). In Ukraine, harvestmen (previously older) faunistic studies are known from Ukrainian Carpathians (Bartoš, 1939; Chevrizov, 1979) and new faunistical paper from Crimea is given by Snegovaya and Staręga

(2009). In Bulgaria, harvestmen communities of various forest ecosystems and open biotopes in the Vitosha Reserve have been compared (Mitov, 2007). The impact of forestry harvesting interventions on the harvestmen communities in spruce stands in the state of Maine, USA has also been assessed (Jennings et al., 1984).

The aim of our research is to evaluate the impact of different types of forestry management, and other anthropic disturbances on harvestmen communities in conditions of sub-mountain beech forest stands in the Western Carpathians, Slovakia.

Material

Characteristics of the research area

We carried out opiliofauna research of sub mountain beech forest ecosystems at three main research plots, situated in central Slovakia. See table 1 for detailed characteristics.

Research monitoring plot (RMP) Žiar nad Hronom is situated in the Štiavnické vrchy Mountains. The plot is located 1.5 km from the aluminium plant in Žiar nad Hronom, and has been formerly under the direct impact of the pollutants (emissions of acidic fluorine type) (Cicák et al., 2011; Štefančík and Mihál, 1991). Because of the emission pollution of this RMP, we included this plot in our research, as a comparison area to the other two, geographically distant, beech stands PRP Jalná and EES Kováčová. This allowed us to assess the impact of the emission source (aluminium plant) on the harvestmen communities.

Permanent research plot (PRP) Jalná is located in the Štiavnické vrchy Mountains, in the cadastre of the village Jalná–Močiar. The PRP Jalná consists of four partial research plots (PPs), where various silvicultural interventions are carried out, which subsequently determine the specific character of the biotope. Control plot (PRP-Co) is located in the mature stem stand with natural development, and without any silvicultural interventions.

For one of the three managed PPs within PRP Jalná, we selected a mature stem stand, situated about 50 m from PRP-Co, along the contour line of the same slope. At this plot, marked as PRP-Th, a free-level thinning was carried out. The last thinning intervention at the PRP-Th was carried out at the beginning of August 2012 (table 2).

Table 1. Basic characteristics of the research control plots

Orographic unit	Štiavnické vrchy Mts	Štiavnické vrchy Mts	Kremnické vrchy Mts
Characteristics	RMP Žiar nad Hronom	PRP Jalná	EES Kováčová
Localisation	48°35′15″ N 18°51′05″ E	48°33′98″ N 18°56′93″ E	48°38′10″ N 19°04′08″ E
Area, ha^{-1}	0.15	0.25	0.15
Exposition	NW	W	SW
Altitude, m a. s. l.	470	610–620	475–490
Slope (°)	5	15	15–20
Geological substrate	ryolites, ryodacites, tuff agglomerates	andesite tuff agglomerates	andesite tuff aggomerates
Soil	cambisol fluvisol, acid pseudogleys	modal cambisol, slightly acidic	modal cambisol, saturated
pH (H_2O)*	5.0	5.8	6.3
Annual rainfall, mm	636	850	653
Annual temperature, °C	9.2	6.2	8.3
Group of forest type	*Fagetum pauper superiora*	*Querceto-Fagetum*	*Fagetum pauper inferiora*
Plant association	*Dentario bulbiferae-Fagetum*	*Dentario bulbiferae-Fagetum*	*Dentario bulbiferae-Fagetum, Carici pilosae-Fagetum*
Age of stand, years	80–100	90–100	110
Woody composition of stand, %	beech 98, oak 2	beech 98, oak 1, hornbeam 1	beech 95, fir 2, hornbeam 2, oak 1
Stocking of stand	0.7	1.0	1.0
Crown cover, %	95	97	97
Source of emissions, km	1.5	7	18
Wet deposition**, kg. ha^1			
SO_4^{2-}	26.3	not measured	18.1
F^-	2.5	not measured	0.4

RMP — research monitoring plot, PRP — permanent research plot, EES — ecological and experimental stationary.

* Mean values of pH were measured at the soil depth of 1–6 cm in 2013; ** results of wet deposition are taken from an earlier publication by Dubová and Bublinec (1994).

Table 2. Basic characteristics of research partial plots (thinning, coppice)

Orographic unit	Štiavnické vrchy Mts	Kremnické vrchy Mts
Characteristics	PRP Jalná	EES Kováčová
Growth phase	thinning*	coppice**
Localisation	48°33′08″ N 18°56′51″ E	48°38′13″ N 19°04′06″ E
Area, ha^{-1}	0.25	0.41
Exposition	W	SW
Altitude, m a. s. l.	610–620	475–490
Slope (°)	15	15–20
Geological substrate	andesite tuff agglomerates	andesite tuff agglomerates
Soil	modal cambisol slightly acidic	modal cambisol saturated
pH (H_2O)***	6.3	5.9
Annual rainfall, mm	850	653
Annual temperature, °C	6.2	8.3
Group of forest type	*Querceto-Fagetum*	*Fagetum pauper inferiora*
Plant association	*Dentario bulbiferae-Fagetum*	*Dentario bulbiferae-Fagetum,*
Age of stand	90–100	26
Woody composition of stand, %	beech 100	beech 50, hornbeam 30, oak 10, aspen 5, other 5
Stocking of stand	0.7	1.0
Crown cover, %	95	97
Source of emissions, km	7	18
Wet deposition****, $kg.ha^{-1}$		
SO_4^{2-}	not measured	18.1
F^-	not measured	0.4

* Thinning (PRP-Th), free crown thinning (by Štefančík, 1974), last thinning in August 2012; ** coppice (EES-cp), forest harvesting in 1989, clearing in 2004, thinning in 2009; *** mean values of pH were measured at the soil depth of 1–6 cm in 2013; **** results of wet deposition are taken from an earlier publication by Dubová and Bublinec (1994).

Table 3. Selected characteristics of partial plots (PPs) at the clearings (PRP-cA, PRP-cB) in PRP Jalná

Characteristics	PRP-cA	PRP-cB
Localisation	48°33′10″ N 18°56′46″ E	48°30′53″ N 18°55′36″ E
Original group of forest type	*Fagetum pauper superiora*	*Fagetum pauper superiora*
Plant association	*Dentario bulbiferae-Fagetum*	*Dentario bulbiferae-Fagetum*
Forest harvesting operation*	February 2003	March 2012
Area, ha^{-1}	0.25	0.25
Age of clearing spot, years	11	2
pH (H_2O)**	6.1	5.9
Presence of free-standing tree	yes (hornbeam)	no
Implementation of plantations	no	yes (spruce, fir, beech)
Growth phase***	thicket	self-seeding
Vegetation cover (woody and plants composition)	*Fagus sylvatica, Quercus* sp., *Carpinus betulus, Betula pendula, Atropa bella-donna, Carex pilosa, Cirsium* sp., *Fragaria vesca, Galium odoratum, Paris quadrifolia, Rubus fruticosus, Rubus idaeus, Urtica dioica*	*Acer pseudoplatanus, Coryllus avellana, Fagus sylvatica, Sorbus aucuparia, Tilia* sp., *Ajuga reptans, Cirsium* sp., *Dactylis glomerata, Dryopteris filix-mas, Fragaria vesca, Galium odoratum, Melissa* sp., *Mentha piperita, Robus fruticosus, Trifolium* sp. *Urtica dioica*

* At both PPs, a small-scale clear-cut was carried out; ** mean values of pH were measured at the soil depth of 1–6 cm in 2013; *** growth phases are defined by Greguš (1968) and Korpeľ et al. (1991).

Another two managed PPs in this area were selected after the application of a small-scale clear-cut. The plot at clearing A (11-year glade plot), marked as PRP-cA, is located about 40 m away from the plot PRP-Th. A partial plot at the clearing B (2-year glade plot), marked as PRP-cB, is located in the cadastre of Podhorie village, about 5 km away from PRP Jalná. More specific characteristics of PRP-cA, PRP-cB, as well as some selected botanical and silvicultural data about both clearings are presented in table 3.

Ecological and experimental stationary (EES) Kováčová is located in the southern part of the Kremnické vrchy Mountains. Kováčová stationary EES was created as a series of five PPs, at which the stem stock of the stand was modified through harvesting interventions (Barna, 2000, 2008). Various silvicultural interventions are taking place at four of the PPs, subsequently determining a specific character of the biotope. The control plot (EES-Co) is located in the mature stem stand, with natural development, and without any silvicultural management interventions.

A coppice stand was selected as one of the three PPs at the EES Kováčová; the stand is about 200 m away from the control EES-Co, along the contour line of the same slope. This PP, marked as EES-cp, was fully harvested in 1989, and left to natural regeneration (table 2).

The other two managed PPs in this area were selected after the application of various differentiated harvesting measures. The clearing A plot, marked as EES-cA, is located about 40 m from the control plot, EES-Co. This PP consists of a naturally rejuvenated stand, where a harvesting intervention was carried out to achieve restocking 0.5. Later, in 2009 the stand was fully harvested. Regenerated beech seedlings were left at the plot, some of which are now 9–12 years old. The clearing plot B, marked as EES-cB, is located about 100 m away from the plot EES-cp, along the contour line of the same slope. More specific characteristic of EES-cA, EES-cB, and some selected botanical and silvicultural data about both clearings, are presented in table 4.

Methods

Harvestmen of the differently managed beech forests in five localities of the Štiavnické vrchy Mts., and four of the Kremnické vrchy Mts. (Central Slovakia), were collected once a month, from April 2012 to December 2012, and from April 2013 to September 2013. The material for the study (1,834 individuals of harvestmen) was gathered by pitfall trapping. For the pitfall trap, we used a plastic 0.7-litre jar (diameter 9 cm), containing 4 % formaldehyde solution. There were 72 traps (eight traps per site). In each stand, eight traps were placed in an 80 m long line (at 10 m intervals). These traps containing a non-freezing solution were also used during the winter, and were emptied in April 2013.

The dominance index (D) was calculated for the species at each locality (Losos et al., 1984). Dominance classes were arranged according to the classification previously described by Tischler (1976): (D > 10 — eu-

Table 4. Selected characteristics of partial plots (PPs) at the clearings (EES-cA, EES-cB) in EES Kováčová

Characteristics	EES-cA	EES-cB
Localisation	48°38′02″ N 19°04′11″ E	48°36′16″ N 19°04′05″ E
Original group of forest type	*Fagetum pauper inferiora*	*Fagetum pauper inferiora*
Plant association	*Dentario bulbiferae-Fagetum* *Carici pilosae-Fagetum*	*Dentario bulbiferae-Fagetum*
Forest harvesting operation*	1989, 2004, 2009	2010
Area, ha^{-1}	0.35	0.35
Age of clearing spot, years	10	3
pH (H_2O)**	5.8	5.9
Presence of free-standing tree	no after 2009	yes (beech)
Implementation of plantations	no	yes (fir, beech)
Growth phase***	thicket	advance growth
Vegetation cover (woody and plants composition)	*Betula pendula, Carpinus betulus, Fagus sylvatica, Quercus* sp., *Azarum europaeum, Carex pilosa, Cirsium vulgare, Fragaria vesca, Galium odoratum, Pulmonaria officinalis, Urtica dioica*	*Betula pendula, Carpinus betulus, Fagus sylvatica, Populus tremula, Tilia* sp., *Carex pilosa, Dentaria bulbifera, Fragaria vesca, Galium odoratum, Mentha piperita, Rubus idaeus, Rubus hirtus, Urtica dioica*

* At EES-cA, a small-scale clear-cut was carried out. First harvesting intervention was carried out in 1989 (target stocking 0.7), second intervention was carried out in 2004 (stocking 0.5) and the last, third intervention in 2009 (final clear-felling, stocking 0.0) Since the second intervention in 2004 and particularly after 2009, natural regeneration of the original undergrowth started to appear significantly at EES-cA. The average height of the undergrowth was as follows: year 1990: 15 cm, 1996: 39 cm, 2002: 80 cm, 2004: 100 cm (Barna et al., 2009); ** mean values of pH were measured at the soil depth of 1–6 cm in 2013; *** growth phases are defined by Greguš (1968) and Korpeľ et al. (1991).

dominant, 5 < D < 10 — dominant, 2 < D < 5 — subdominant, 1 < D < 2 — recedent, and 1 < D — subrecedent). Harvestmen were identified according to morphological keys (Martens, 1978; Šilhavý, 1956, 1971). Scientific nomenclature and taxonomy of species were taken from Blick and Komposch (2004).

The first author's personal collection was also used for comparisons. Majority of the material was preserved in 70 % ethanol, and deposited at the Institute of Forest Ecology, SAS Zvolen.

Results

During the research period, across all three localities, we found 16 different harvestmen species, belonging to four families, representing 45.7 % of the 35 harvestmen species range known in Slovakia to date. Table 5 shows that, only six harvestmen species were found at the RMP Žiar nad Hronom, whilst at the PRP Jalná and EES Kováčová, 15 and 13 species were found, respectively (also due to more PPs at these two localities). Among the most abundant species (i. e., species with the highest dominance values) were harvestmen *Lophopilio palpinalis* (D value = 22.8 %), *Trogulus nepaeformis* (17.9 %), *Lacinius ephippiatus* (12.2 %), *Trogulus tricarinatus* (11.3 %), *Oligolophus tridens* (10.5 %), and *Nemastoma lugubre* (6.7 %), all of which are widespread throughout the submountain beech stands.

The harvestmen species range, and their abundance and dominance values at the RMP Žiar nad Hronom are presented in table 6, showing that 69 specimens, comprising of only six harvestmen species were found in this locality. The most dominant species here were *Platybunus bucephalus* (D = 78.3 %) and *P. pallidus* (14.5 %). A much more favourable situation was found in the PRP Jalná locality, where we recorded as many as 15 harvestmen species at the four partial plots (control, thinning, older clearing, and younger clearing) (table 7). At the control plot PRP-Co, we recorded 13 species, the most dominant being *Trogulus nepaeformis* (D = 29.3 %), *T. tricarinatus* (16.8 %), and *Dicranolasma scabrum* (15.0 %). In the thinning stand PRP-Th, we recorded only nine species, with the most dominant being *T. nepaeformis* (39.5 %), *T. tricarinatus* (25.0 %), and *D. scabrum* (16.1%). At the older clearing PRP-cA, we found nine harvestmen species, the most dominant being *T. nepaeformis* (35.6 %), *T. tricarinatus* (22.9 %), and *N. lugubre* (13.6 %). At the younger clearing PRP-cB, we found 13 species, with the most dominant being *O. tridens* (39.2 %),

Table 5. A systematic review of harvestmen, overall number of individuals (Σ) and overall dominance (D, %) at the research plots during the research period

Species	RMP	PRP	EES	Σ	D	Do
Nemastomatidae Simon, 1872						
Nemastoma lugubre (Müller,1776)		*	*	122	6.7	++++
Mitostoma chrysomelas (Hermann, 1804)		*	*	4	0.2	+
Dicranolasmatidae Simon, 1879						
Dicranolasma scabrum (Herbst, 1799)	*	*	*	100	5.5	++++
Trogulidae Sundevall, 1833						
Trogulus tricarinatus (Linnaeus, 1767)		*	*	208	11.3	+++++
Trogulus nepaeformis (Scopoli, 1763)		*	*	329	17.9	+++++
Phalangiidae Latreille, 1802						
Egaenus convexus (C. L. Koch, 1835)		*	*	84	4.6	+++
Lacinius ephippiatus (C. L. Koch, 1835)	*	*	*	224	12.2	+++++
Lophopilio palpinalis (Herbst, 1799)		*	*	419	22.8	+++++
Mitopus morio (Fabricius, 1799)		*		16	0.9	+
Oligolophus tridens (C. L. Koch, 1836)	*	*	*	193	10.5	+++++
Phalangium opilio Linnaeus, 1761		*		4	0.2	+
Platybunus bucephalus (C. L. Koch, 1835)	*	*	*	90	4.9	+++
Platybunus pallidus Šilhavý, 1938	*	*	*	30	1.6	++
Zacheus crista (Brullé, 1832)		*		2	0.2	+
Sclerosomatidae Simon, 1879						
Leiobunum rupestre (Herbst, 1799)	*	*	*	8	0.4	+
Nelima semproni Szalay, 1951			*	1	0.1	+
Total	6	15	13	1,834	100	

Do — schematic marking of dominance: +++++ eudominant; ++++ dominant; +++ subdominant; ++ recedent; + subrecedent; * species recorded on research plots.

Table 6. A systematic review of harvestmen found at RMP Žiar nad Hronom throughout the research period including the overall dominance

Species	Σ	D	Do
Dicranolasma scabrum	2	2.9	+++
Lacinius ephippiatus	1	1.5	++
Leiobunum rupestre	1	1.5	++
Oligolophus tridens	1	1.5	++
Platybunus bucephalus	54	78.3	+++++
Platybunus pallidus	10	14.5	+++++
Σ of individuals	69		
Σ of species	6		

L. ephippiatus (18.6 %), and *L. palpinalis* (19.1 %). Overall, at PRP Jalná the most dominant species were *O. tridens* (20.0 %), *L. ephippiatus* (18.6 %), *T. nepaeformis* (17.4 %), *T. tricarinatus* (11.8 %), and *L. palpinalis* (9.9 %).

In the locality EES Kováčová (table 8) at 4 partial plots (control, coppice, older clearing and younger clearing), we recorded 13 harvestmen species. At the control stand EES-Co, we directly recorded 8 species (*T. nepaeformis* 35.3 %, *L. palpinalis* 20.2 % and *T. tricarinatus* 16.8 %). In the nearby beech coppice stand EES-cp, we recorded 11 species (*T. tricarinatus* 27.6 %, *L. ephippiatus* 26.0 % and *T. nepaeformis* 25.2 %). At the older clearing EES-cA, we found 10 species (*L. palpinalis* 36.0 %, *T. nepaeformis* 29.2 %, and *N. lugubre* 18.5 %). At the younger clearing EES-cB, we found 8 species (*Egaenus convexus* 13.7 %, *T. nepaeformis* 11.2 % and *T. tricarinatus* 8.6 %). Overall at the EES Kováčová, the most dominant species were *L. palpinalis* (35.7%), *T. nepaeformis* (19.7%), *T. tricarinatus* (11.8 %), *N. lugubre* (9.3 %) and *E. convexus* (7.8 %).

An interesting comparison between individual PPs is presented in table 9 that includes data on the number of species and the number of specimens collected per 1 pitfall trap at a given PP. When we compare the control plots (RMP, PRP-Co, and EES-Co), we find that the least harvestmen species (6) were found at the RMP, whereas more species (8) were found at EES-Co and the most (13) at PRP-Co. Low harvestmen occurrence at RMP is also confirmed by the number of specimens per 1 trap (0.84); when this value is much higher in the other two localities (1.25 at EES-Co and up to 1.83 at PRP-Co), there were not only more harvestmen species than at RMP but also more specimens per trap. Comparing PRP-Th and EES-cp, we can see a higher number of species at EES-cp (12) but a lower number of specimens per 1 trap (1.41). On the other hand at PRP-Th, despite the lower number of recorded species (9), the number of specimens per 1 trap (1.49) was a bit higher. The comparison of two similarly aged (older) clearings PRP-cA and EES-cA is also of interest; we found the

Table 7. A systematic review of harvestmen found at PRP Jalná throughout the research period including the overall dominance and the dominance at individual PPs

Species	Co	Th	cA	cB	Σ	D	Do
Dicranolasma scabrum	15.0	16.1	11.9	0.2	60	7.3	++++
Egenus convexus	1.2			2.0	10	1.2	++
Lacinius ephippiatus	4.2	4.0	10.2	31.4	152	18.6	+++++
Leiobunum rupestre	1.2	1.6		0.5	6	0.7	+
Lophopilio palpinalis			2.5	19.1	81	9.9	++++
Mitopus morio	4.2	2.4	0.8	1.2	16	2.0	++
Mitostoma chrysomelas	1.2		0.8		3	0.4	+
Nemastoma lugubre	4.8	1.6	13.6	2.0	34	4.2	+++
Oligolophus tridens	1.2		0.8	39.2	163	20.0	+++++
Phalangium opilio				1.0	4	0.5	+
Platybunus bucephalus	13.2	6.5		0.2	31	3.8	+++
Platybunus pallidus	7.2	3.2		0.2	17	2.1	+++
Trogulus nepaeformis	29.3	39.5	35.6	0.5	142	17.4	+++++
Trogulus tricarinatus	16.8	25.0	22.9	2.5	96	11.8	+++++
Zacheus crista	0.6		0.8		2	0.2	+
Σ of individuals	167	124	118	408	817		
Σ of species	13	9	9	13	15		

Co — control plot; Th — thinning plot; cA — clearing spot A; cB — clearing spot B.

Table 8. A systematic review of harvestmen found at EES Kováčová throughout the research period including the overall dominance at individual PPs

Species	Co	cp	cA	cB	Σ	D	Do
Dicranolasma scabrum	12.6	3.3	5.6	1.6	38	4.0	+++
Egenus convexus		1.6	1.0	13.7	74	7.8	++++
Lacinius ephippiatus	1.7	26.0	0.5	7.0	71	7.5	++++
Leiobunum rupestre			0.5		1	0.1	+
Lophopilio palpinalis	20.2	2.4	36.0	4.2	338	35.7	+++++
Mitostoma chrysomelas			0.5		1	0.1	+
Nelima semproni		0.8			1	0.1	+
Nemastoma lugubre	11.8	2.4	18.5	6.8	88	9.3	++++
Oligolophus tridens	0.8	5.7	0.5	3.9	29	3.1	+++
Platybunus bucephalus	1.7	2.4			5	0.5	+
Platybunus pallidus		2.4			3	0.3	+
Trogulus nepaeformis	35.3	25.2	29.2	11.2	187	19.7	+++++
Trogulus tricarinatus	16.0	27.6	7.7	8.6	112	11.8	+++++
Σ of individuals	119	123	195	511	948		
Σ of species	8	11	10	8	13		

Co — control plot; cp — coppice; cA — clearing spot A; cB — clearing spot B.

Table 9. The number of harvestmen species and specimens caught per 1 pitfall trap at individual PPs

PPs	RMP	PRP Co	EES Co	PRP Th	EES cp	PRP cA	EES cA	PRP cB	EES cB	Σ all PPs
Σ species	6	13	8	9	12	10	10	13	8	16
Σ individuals	0.84	1.83	1.25	1.49	1.41	1.36	1.90	4.74	5.49	20.31

same number of species (10) on both but a higher number of specimens per 1 trap (1.90) was recorded at EES-cA, i. e. more harvestmen were caught in the traps at this PP. Different situation occurred when we compared two similarly aged (younger) clearings at PRP-cB and EES-cB, where we found a higher number of species (13) at PRP-cB. We found fewer species (8) at EES-cB; however, we recorded a high number of specimens per 1 trap (5.49) that is not only higher than the value at PRP-cB but also the highest value for all PPs.

In table 10, we present selected ecological characteristics according to which we conclude the abundance of individual species at PPs, i. e. we list the selection of PPs with the most frequent occurrences of harvestmen. In terms of eudominant (E) and dominant (D) occurrence of individual species, we can conclude that EES-cB appears to be the most suitable PP for the most abundant occurrence of harvestmen. The dominant species here were *L. palpinalis*, *E. convexus*, *N. lugubre* and *L. ephippiatus*. At the same time, EES-cA that includes species *N. lugubre*, *D. scabrum* and *T. tricarinatus*, also appears 3 times in categories E and D. In terms of their ecological type, we can conclude that 5 of those species belong to the mesohyghrophilic harvestmen, whereas 3 of those species can also be found in alluvial and waterlogged forest biotopes and two species are xerothermophilic harvestmen.

The partial plot EES-cA is made up of high growth of natural regeneration that is well differentiated into herbaceous and bush layer and a layer of young trees. Here, a so-called "cover effect" of the herbaceous and bush layer is applied, which creates shaded microhabitats that are not directly exposed to sun radiation. In these microhabitats, there is relatively stable lower temperature and higher humidity compared to the open free area exposed to direct sun radiation and that is the reason for such abundant occurrence of eurytopic, mesohygrophilic harvestmen *N. lugubre*, *D. scabrum*, *T. tricarinatus*, *L. palpinalis* and *L. ephippiatus*. The same is true of the conditions at EES-cB, where the immature tree layer at this 3-year old clearing is supplemented by a herb-rich and bush layer spreading fast, particularly on the third year after the harvesting intervention. At EES-cB,

Table 10. A distribution of harvestmen at individual PPs according to their dominance

Species	E	D	R	Sr
Dicranolasma scabrum	PRP-Th	EES-cA	EES-cB	PRP-cB
Egaenus convexus	EES-cB		PRP-Co	
Lacinius ephippiatus	PRP-cB	EES-cB	RMP	EES-cA
Leiobunum rupestre			PRP-Co	EES-cA
Lophopilio palpinalis	EES-cB			
Mitopus morio			PRP-cB	PRP-cA
Mitostoma chrysomelas			PRP-Co	EES-cA
Nelima semproni				EES-cp
Nemastoma lugubre	EES-cA	EES-cB	PRP-Th	
Oligolophus tridens	PRP-cB	EES-cp	PRP-Co	EES-cA
Phalangium opilio				PRP-cB
Platybunus bucephalus	RMP		EES-Co	PRP-cB
Platybunus pallidus	RMP	PRP-Co		PRP-cB
Trogulus nepaeformis	PRP-Th			PRP-cB
Trogulus tricarinatus	EES-cp	EES-cA		
Zacheus crista				PRP-cA

E — eudominant; D — dominant; R — recedent; Sr — subrecedent.

a xerophilic species *E. convexus* also occurring in the open and warmed microhabitats in forest ecotones joins the group of the E and D species, which are also characteristic for the habitat at EES-cB.

On the other hand, from table 10 we can also conclude the results about the recedent (R) and subrecedent (Sr) representation of harvestmen at individual PPs, i.e. we can find out which PPs had the least suitable ecological conditions for the occurrence of harvestmen. For example, in table 10 in the categories R and Sr, PRP-cB was the most frequently occurring (up to 6-times) with the lowest values of the occurrence for the species *D. scabrum*, *T. nepaeformis*, *Phalangium opilio*, *P. bucephalus*, *P. pallidus* and *Leiobunum rupestre*. It should be added that the habitat PRP-cB (2-year old clearing, see table 3), was formed by a relatively weak herbaceous layer successively overgrowing the fresh clearing. This layer has not yet developed into a microhabitat suitable for the occurrence of mostly mesohygrophilic harvestmen mentioned above. At the open PRP-cB, we presume more favourable conditions for the occurrence of xero- and heliophilic harvestmen such as *P. opilio* and *L. rupestre* that do not avoid open biotopes. However, as can be seen from table 7, even these two species occurred only sporadically, as an indication of the generally inadequate conditions for a more abundant occurrence of harvestmen at younger forest clearings. PRP-Co, as can be seen in table 10, came out as the second least suitable PP for the occurrence of harvestmen, with the lowest occurrence numbers for species *Mitostoma chysomelas*, *P. bucephalus*, *E. convexus*, *O. tridens* and *L. rupestre*. Low presence of thermophilic species typical for open positions (*E. covexus* and *L. rupestre*), at the control plot is not surprising. On the other hand, we expected a higher presence of mesohygrophilic and eurytopic forest species *M. chysomelas*, *P. bucephalus* and *O. tridens* at PRP-Co.

Looking back at table 1 it can be seen that individual localities are situated at various distances from the nearest major source of industrial emissions — the aluminium plant in Žiar nad Hronom. At the same time, high values of sulphur and fluor depositions as the main pollutants from the nearby aluminium plant were also recorded in the stand RMP. In this respect, it is interesting to note that in the stand RMP Žiar nad Hronom throughout the whole research period, there were only 6 harvestmen species recorded, whilst at the comparable control localities PRP-Co Jalná and EES-Co Kováčová, 13 and 8 harvestmen species, respectively were recorded. This imbalance of species can be, apart from other reasons, hypothetically attributed to the negative impact of emissions, which all three localities are exposed to at varying degrees depending on their distance from the emission source (RMP — 1.5 km, PRP — 7 km, EES — 18 km).

In connection with the impact of industrial emissions on the poor species range of harvestmen at RMP Žiar nad Hronom, we must recall that in the past (April 1991) we had directly recorded a mass incidence of adult specimens of *Platybunus bucephalus* in the stand RMP that were occurring in large numbers on the bark of beech stems. Since then, however, we have not seen a similar phenomenon at RMP, not even in other harvestmen species that always only occurred sporadically at RMP. Ample presence of harvestmen at PRP Jalná and EES Kováčová can, with relatively equal ecological-climatic conditions of all three localities, to some extent reflect the negative effects of the emission load of the forest stand RMP on its opiliofauna.

Discussion

Our results from RMP Žiar nad Hronom, PRP Jalná and EES Kováčová describe the dynamics of the species range, the abundance of individuals and the dominance of harvestmen species in different anthropically disturbed submountain beech forests. The values obtained are comparable with other data from the literature that deals with the issue of the ecological research of harvestmen depending on changes of their habitat.

For example, the ecological structure of harvestmen communities Jarab and Kubovčík (2002) were studied in conditions of mixed mountain forest stands in northern Slovakia. Among the species with the highest dominance were the harvestmen most frequently occurring in the conditions of closed canopy mountain forests (for example *P. bucephalus* D = 85.7 %; *N. lugubre* and *T. nepaeformis* — both 42.9 %). *Mitopus morio* (85.7 %) and *O. tridens* (71.4 %) were the typical species for the ecotone communities. *Lacinius horridus* (28.6 %), *L. epippiatus* and *P. opilio* (both 14.3 %) were occurring in mesophilic meadows that are characteristic for these biotopes (Jarab and Kubovčík, 2002).

Rich species variety was also found by Mihál and Černecká (2014) in the differently managed stands near two forest reserves in Central Slovakia, where shade- and mesohygrophilic species *T. nepaeformis*, *T. tricarinatus* and *N. lugubre* were occurring at anthropically disturbed biotopes (thinning, clearing). The occurrence of these species in the ecotone communities and in the forests affected by logging was also recorded in the research of harvestmen in oak-hornbeam stands after forest harvesting. Mihál and Gajdoš (2010) found overall 16 harvestmen species, with the most abundant species represented in the collections by the forest and clearing community (12 species). Ten species of harvestmen were found in the ecotone on the edge of the forest. The number of specimens was the highest at the clearing (13.1 sp./collection from 1 trap), somewhat lower in the forest (1.7 sp./collection from 1 trap) and the lowest number was on the edge of the forest (10 sp./collection from 1 trap). Species *Zacheus crista* was eudominantly represented in all localities, with the most numerous occurrence on the edge of the forest. Species *Rilaena triangularis* was occurring in the forest and *L. palpinalis* at the clearing. Open areas in the forest after logging made it possible for some xerothermophilic harvestmen species and the harvestmen that like open and part shaded forest biotopes to penetrate here (Mihál and Gajdoš, 2010).

The dynamics of the harvestmen species diversity depending on environmental changes due to forest harvesting was studied in the beech-fir forest stand in Central Slovakia, where it was found that most of the species were occurring at the most shaded and most fully stocked areas, which indicates the demands of most harvestmen for sufficient soil humidity and shading of the biotope (Mihál, 1997). Equally, this states that species of the genus *Trogulus* and *N. lugubre* were, thanks to suitable microclimatic conditions (cover effect of herbaceous and bush growth), often occurring also at the clearing (*T. nepaeformis* D = 1.4 %, *N. lugubre* 9.6 %). In the closed canopy stand, species *P. bucephalus* (32.2 %) and *T. nepaeformis* (10.3 %) were the most dominant.

When studying the impact of forest harvesting interventions on the structure of opiliofauna, it was found that the most significant changes in harvestmen communities happen in the least stocked forest stands with low species diversity of harvestmen (Stašiov, 2001).

A strong wind and snow calamity in High Tatras in northern Slovakia in 2004 affected more than 120 km^2 of forests uprooted more than 2 mil. m^3 of trees and triggered a massive cascade of abiotic and biotic impacts on populations, communities and ecosystems of the affected land. Harvestmen, as one of the monitored groups of invertebrates reacted fast to the changed environmental conditions (Urbaničová et al., 2014). It was found that at the locality affected by windstorm and subsequently by forest fires during the later years of succession, harvestmen mobilized only by a small value of activity index, 0.71–1.4 (index reflecting an average recalculated activity for 100 days per 1 trap). In the locality where the trees uprooted by the calamity were removed, thus creating a forest clearing, the index value was also relatively low (1.2–3.5). In the locality where the trees uprooted by the calamity were left in the stand, the index value was higher (1.8–5.9). Finally, in the control locality with no effects of the windstorm calamity, the index value found was the highest (13.4–16.5).

The ecological research of the xerophilic harvestmen species distribution was carried out by Kromp and Steinberger (1992) in Austria: in it shows a high occurrence of harvestmen in the ecotones of fields and agrocenoses into which harvestmen spread from nearby forest ecosystems (for example hedgerows, orchards, groves etc.). Xerophilic and heliophilic harvestmen were also studied by Stašiov et al. (2011) in Slovakia on agricultural soil under different managements, where 8 species of harvestmen were found with the most occurring species *Z. crista* (303 ex.), *P. opilio* (207 ex.) and *R. triangularis* (108 ex.), i. e. the species typical for open biotopes and ecotone communities.

Similar ecological studies of harvestmen communities were carried out in other European countries; for example the dynamics of harvestmen occurrence in the close canopy forest was compared to the occurrence in the open biotopes in Vitosha Reserve in Bulgaria (Mitov, 2007). Important ecological factors affecting the species abundance were altitude, soil type, vegetation and slope exposure. It was found that in the forest stands the dominant species were *L. palpinalis*, *M. morio*, *T. tricarinatus*, whereas species *P. opilio*, *Z. crista* as well as *T. tricarinatus* and *L. palpinalis* dominated on the open biotopes. In Spain, in the mountain forest ecosystems, harvestmen communities were studied by Izaskun and Araceli (2015) in the closed canopy mountain forests and on the open biotopes where the typical species for forests were *Leiobunum rotundum* and *Paraoligolophus agrestis*, for shrubbery biotopes were *P. opilio* and *Odiellus simplicipes* and for the mountain pastures were *P. opilio* and *Leiobunum blackwalli*.

Harvestmen were the subject of ecological study also in the USA state Maine, where the impact of harvesting interventions on harvestmen communities in spruce forest stands was studied by Jennings et al. (1984). The authors found that out of the total of 7 harvestmen species, *Leiobunum calcar* represented the most in the collections (D = 90 %). The most individuals and species of harvestmen were recorded in the strips of the original stands that have not been felled, between the clear-cut areas, and in the original closed canopy forest. Conversely, the least specimens and harvestmen species were found on the areas of 1 to 6 years old clearcuts.

As harvestmen are sufficiently mobile arachnids belonging to the group of food opportunists and can occur in bulk in the season, they are a permanent part of the soil zooedafone in practically all ecotone communities, with the parallel occurrence of species typical for forest as well as species of open biotopes. Based on knowledge of the bio-indication properties of harvestmen and the knowledge of their species diversity in the examined biotope, in the cases of severe structural changes of the biotope, we can observe a separation of harvestmen species diversity into guilds that will subsequently populate only that part of the habitat that suits them in terms of ecotrophic and ecotopic demands (Mihál et al., 2010).

Conclusion

During our research in all three localities (RMP Žiar nad Hronom, PRP Jalná, and EES Kováčová), we found 16 harvestmen species in total belonging to 4 families, which represents 45.7 % of the harvestmen species range known so far in Slovakia (n = 35). Only 6 harvestmen species were found in the locality RMP Žiar nad Hronom, whilst much more were found at PRP Jalná and EES Kováčová thanks to a higher number of partial plots in these two localities). Harvestmen *Lophopilio palpinalis* (dominance D = 22.8 %), *Trogulus nepaeformis* (17.9 %), *Lacinius ephippiatus* (12.2 %), *Trogulus tricarinatus* (11.3 %), *Oligolophus tridens* (10.5 %) and *Nemastoma lugubre* (6.7 %), i. e. harvestmen generally widespread in the conditions of submountain beech forest stands, were among the most numerous species.

Total 15 harvestmen species were recorded in the locality of PRP Jalná at four partial plots (PPs). The most dominant ones were: *Oligolophus tridens* (20.0 %), *Lacinius ephippiatus* (18.6 %), *Trogulus nepaeformis* (17.4 %), *T. tricarinatus* (11.8 %) and *Lophopilio palpinalis* (9.9 %). 13 species were recorded in the locality EES Kováčová at four PPs. The most dominant ones were: *Lophopilio palpinalis* (35.7 %), *Trogulus nepaeformis* (19.7 %), *T. tricarinatus* (11.8 %), *Nemastoma lugubre* (9.3 %) and *Egaenus convexus* (7.8 %).

At PP marked as EES-cB (3-year old clearing), we found 8 harvestmen species, whilst we recorded a high number of specimens caught per 1 trap (5.49), which was the highest value out of all the nine PPs in all localities. The lowest number of caught specimens per 1 trap (0.84) was recorded in the industrial emission stand RMP Žiar nad Hronom.

In terms of the highest values of the eudominant and dominant occurrence of individual species, we can conclude that the most suitable PP for the most abundant occurrence of harvestmen appears to be EES-cA (10-year old clearing) and EES-cB (3-year old clearing), where the most dominant species were *Lophopilio palpinalis*, *Egaenus convexus*, *Nemastoma lugubre, Lacinius ephippiatus, Dicranolasma scabrum* and *Trogulus tricarinatus*. These PPs are strongly affected by the so-called "cover effect" of the herbaceous and bush layer, which creates shaded microhabitats that are not directly exposed to sun radiation. In these microhabitats, there is relatively stable lower temperature and humidity compared to the free open area exposed to direct sun radiation, and therefore eurotopic, mesohygrophilic harvestmen *Nemastoma lugubre*, *Dicranolasma scabrum*, *Trogulus tricarinatus*, *Lophopilio palpinalis* and *Lacinius ephippiatus* might be occurring here.

Individual research localities are at different geographical distances from the nearest significant source of industrial emissions — the aluminium plant in Žiar nad Hronom. In this respect, it is interesting to note that in the stand RMP Žiar nad Hronom throughout the research period, only 6 harvestmen species were recorded, whilst in comparable control localities at PRP-Co Jalná and EES-Co Kováčová, 13 and 8 harvestmen species, respectively were found. This imbalance of species can be, apart from other reasons, hypothetically attributed to the negative impact of emissions that all three localities are exposed at varying degrees, due to the different geographical distance from the aluminium plant in Žiar nad Hronom (RMP — 1.5 km, PRP — 7 km, EES — 18 km).

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