Epigeic spider and ground beetles (Carabid) communities of semi-natural and natural habitats in agricultural landscape in Slovakia

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Abstract

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We studied the spatial structure of spiders and beetles in 4 types of habitats in the Poloniny National Park. Between the years 2020 and 2021, we recorded 1,597 beetle specimens and 3,765 spider specimens using the pitfall trap method. The most represented beetles were *Poecilus versicolor* (53.4%), *Nebria brevicollis* (10.3%), *Staphylinus caesareus* (4.4%) and *Amara familiaris* (4.1%). Among the spiders, there were species *Pardosa pullata* (21.81%), *Pachygnatha degeeri* (14.21%), *Xerolycosa nemoralis* (10.28%), *Pardosa palustris* (7.86%), *Trochosa ruricola* (6.24%) and *Alopecosa pulverulenta* (4.38%). We confirmed the occurrence of two European important species of beetles (*Carabus zawadzkii, Carabus variolosus*) and 3 species of spiders belonging to the vulnerable species according to the IUCN threat status (*Gongylidiellum vivum, Palliduphantes milleri* and *Xysticus lineatus*). We also found the spider Micaria micans, which is new to the Slovak fauna and information about its distribution and habitat preferences in Slovakia is presented. Using multivariate analyzes (CCA, RDA) and classification species into bioindicative groups, we found a greater connection of adaptable and eurytopic species of ground beetles to the mesophilic meadow and of spiders to the habitat *Nardetum* pasture. Based on bioindicative groups of species (adaptable, eurytopic and relict), we found only a small difference in percentile points between spiders and beetles.

Keywords

anthropogenic intervention, beetles, bioindication, ecological significance, Slovakia, spiders

Introduction

The actual biocultural landscape with a less unfavorable basis for biodiversity has been created under the influence of a variability of cultures, economic systems, geomorphological and climatic changes. The interest in keeping the original biodiversity, interactions between them and biosystems, tracking and analyzing geographical overlaps and the impact on the economy and also the environment has become the center of attention for the scientific field (Solymosi, 2011; Baiamonte et al., 2015). Ecological models were created for monitoring the stability of the ecosystem

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and mechanisms in it, as well as the coexistence of species (Ellner et al., 2019). On the basis of this knowledge, it can be concluded that the ecological stability and coexistence of species also depend on processes mitigating population cycles, which allow the species to have an adequate rate of population growth (Coyte, 2015).

Landscape heterogeneity is influenced by habitat fragmentation, however excessive fragmentation leads to a decline in landscape connectivity, causing changes in species richness (Jeanneret et al., 2003; Lázaro and Alomar, 2019). We can assess the current status of protected species of arthropods in the habitats of the studied ecosystems on the basis of abundance and species diversity (Pakhomov et al., 2019; Pokhylenko et al., 2020).

Biomonitoring detects the actual state of environment and local habitat, and for the assessment of the ecological stability of biotopes the bioindicators are used. Biomonitoring also uses multi-species evaluation to assess the environmental status of the habitat. The capture and subsequent analysis of several bioindicators increases the detection of environmental/ecological signals indicating a change in the quality of the environment. Estimation of variables influencing several groups of bioindicators requires the application of multivariate modeling (Grossmann et al., 2016). Araneae and Coleoptera (Carabidae) are frequently used environmental bioindicators (e.g. Černecká et al., 2020; Langraf et al., 2020; Krumpálová et al., 2021; Porhajašová and Babošová, 2022).

The Coleoptera and especially the ground beetles (Carabidae) are used in various bioindicator studies focused on the reactions of species to a changing environment (e.g. fragmentation of habitats, management practices, in urban ecology, the impact of insecticides). The species of family Carabidae are influenced by management practices in pastures, mowing of meadows and fertilization. It is known that increasing management practices in pastures and meadows decreases the numbers of Carabidae species and individuals. The suitability of a bioindicator is determined by a good knowledge of species and their ecological requirements on habitats. Bioindicators are more sensitive to environmental disturbances, changes in pH, moisture and react sensitively to toxic substances (Alberti et al., 2017; Batáry et al., 2018).

Spiders are an important component of terrestrial ecosystems and are used as bioindicator groups for environmental quality assessment of ground layers of the habitats (Maelfait and Hendrickx, 1998; Vasconcellos et al., 2013; Stojanowska et al., 2020) and for evaluation of biota changes in relation to the land management (Benhadi-Marín et al., 2020).

Joint works on spiders and beetles were carried out by Noordijk et al. (2008), found more stenotopic species in the semi-natural area (Roadside verges), but compared to natural biotopes, there were fewer species of stenotopic beetles and there were fewer stenotopic spiders on the edges. From knowledge of the biology and ecology of the beetles and spiders captured, it seems likely that this is attributable to differences in "habitat quality". In Knapp and Řezáč (2015), they studied spiders and beetles in conditions of non-crop habitat islands situated inside arable land and field with crops. From the research results, they confirmed that recorded species richness of spiders increased with non-crop habitat area, whereas recorded species richness of carabid beetles exhibited an opposite trend. Varet et al. (2012) compared the invertebrate assemblages associated with two distinct urban forms (compact vs. conventional), focusing on two spiders and carabid beetles. The species richness of both groups was independent from the neighborhood design. Large carabid beetles were more abundant and small spiders less abundant in the new neighborhood design compared to the conventional one. For both carabid beetles and spiders, no difference in assemblage composition was found between neighborhood designs. Urban consolidation, by permitting a higher human density with similar arthropod assemblages, could contribute to reduce biodiversity loss in cities.

The aim of the article is to contribute new information on the assessment of the habitat type in agricultural landscape based on the Araneae and Coleoptera (Carabidae) groups.

Materials and methods

Araneae and Coleoptera research took place from May 2020 to May 2021 in five study areas and four types of biotopes (mesophilic meadows, *Nardetum* pasture, intensive meadow and fen). We used five pitfall traps for each locality, which were placed in a line at distances of 10 m apart. Altogether, there were 25 pitfall traps in five localities. A formaldehyde solution (4%) for the material fixation was used. Pitfall traps were emptied every month. We identified the collected material of Coleoptera according to Dieckmann (1983), Hurka (1996), Háva (2011), Novák (2014), Nedveď (2020). Spiders were determined according to Miller (1971) and Nentwig et al. (2023). The nomenclature and systematics of spiders follow the last version of the World Spider Catalogue (WSC, 2023) and beetles according to Check-list of beetles (Coleoptera) of the Czech Republic and Slovakia (Zahradník, 2017).

To evaluate the dominance of our captured beetle and spider material, we followed Stöcker and Bergmann (1977) using the dominance classes: 31.7–100% – eudominant; 10.1–31.6% – dominant; 3.2–10% – subdominant; 1.1–3.1% – recedent; less than 1% – subrecedent.

To evaluate the sozological aspect, we used threatened and potentially threatened spider species, and their degree of vulnerability was determined on the basis of the IUCN criteria (IUCN, 2012) listed in the National Red List (Gajdoš and Svatoň, 2001). For beetles, the Red list of plants and animals of Slovakia was used (Holecová and Franc, 2001).

Study area

The cadastre of Runina village lies in the northern part of the Bukovské vrchy Mts. and is a part of the Poloniny National Park and Biosphere Reserve. There are unique

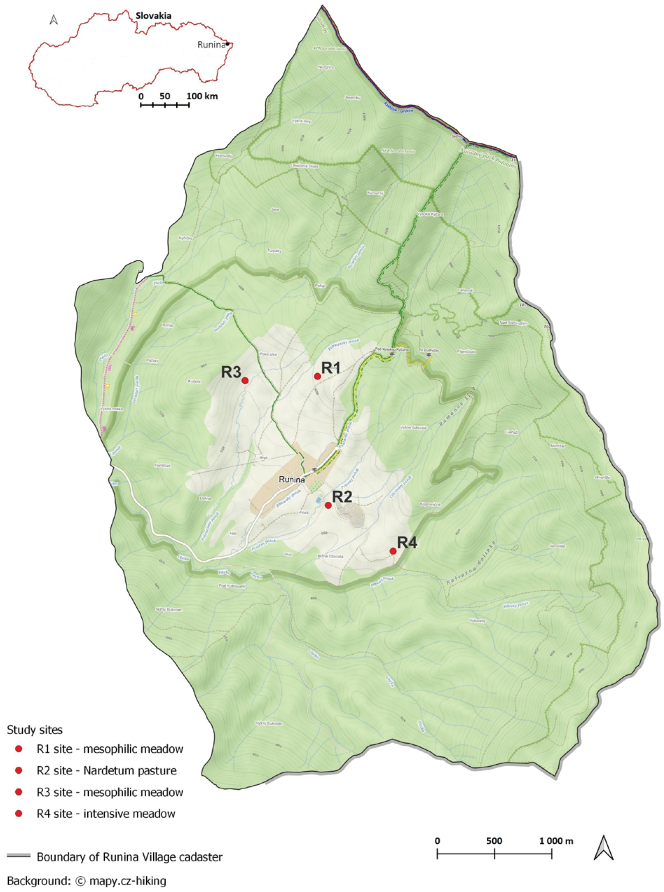

Fig. 1. Localization of study sites in the cadastre of Runina village.

habitats, including the Carpathian beech forests with many rare species of the fauna and flora. The territory is characterized by non-forest landscape elements, permanent grasslands, specially mowed meadows and also extensively used pastures, which are located in the central part of the cadastre around the village. Five study sites were established in the agriculturally exploited area of Runina village (Fig. 1):

R1 site – mesophilic meadow (49.0806 N, 22.4055 E, 566 m above sea level (m asl) represents extensively used meadow located in the northern part of the village near forest complexes.

R2 site – *Nardetum* pasture (49.0801 N, 22.3968 E, 556 m asl) represents extensively used pasture for cattle with *Nardetum* association located near central part of the village above the fens (site R5).

R3 site – mesophilic meadow (49.0705 N, 22.4072 E, 556 m asl) represents extensively used meadow located in the southeastern part of village near the buildings of the agricultural cooperative.

R4 site – intensive meadow (49.0671 N, 22.4152 E, 566 m asl) represents intensive used meadow (harrowed, sowed by grass seeds, intensively fertilized and mowed twice) located in the southeastern part of the village under the complex of agricultural cooperative.

Bioindicative classification

According to Farkač et al. (2006), ground beetles are divided into the following bioindicative groups: Group R – species with narrow ecological valence, relict and rare species of natural ecosystems. Group A – species occurring in semi-natural and well-regenerating habitats (adaptable species). Group E – species that do not have specific habitat requirements, occuring in habitats with strong anthropogenic intervention (eurytopic species).

The captured ground-dwelling spiders according to the range of their association with the originality of habitats (Buchar and Růžička, 2002) are listed in three biodindicative groups: Group R1 (climax) – species strictly living only in climax habitat minimally influenced by man´s activity (original natural habitats). Group R1–R2 (climax and seminatural) – species occurring in secondary (seminatural) habitats inhabited by species with broader ecological valency (they live also in climax habitats). Group Er (disturbed) – species which are also able to occupy habitats with a high, permanent degree of disturbance.

Data analyses

We used redundancy analysis (RDA, the length of the gradient on 1 axis is 2.8) for Araneae and also Coleoptera to determine the relationship between biotopes and species. We tested the statistical significance of habitats (mesophilic meadow, *Nardetum* pasture, intensive meadow) using the Monte Carlo permutation test in the Canoco5 program (Ter Braak and Šmilauer, 2012). Analysis in the statistical program *R version 3.6.3* (2020), R Foundation for Statistical Computing, Vienna, Austria, was focused on Rarefaction curves.

Results

Over the course of research, we recorded 1,597 beetle specimens belonging to 75 species and 12 families (Table 1). Spiders were represented by 3,765 specimens belonging to 105 species and 20 families (Table 2).

Ground beetle species *Poecilus versicolor* (Sturm, 1824) and *Nebria brevicollis* (Fabricius, 1792) were the most abundant (54.4% and 10.3%). As subdominant species there were *Amara familiaris* (Duftschmid, 1812) and *Staphylinus caesareus* (Gravenhorst, 1802) (Staphylinidae). Other species had recendent to subrecendent representation (Table 1). We found two species of European importance: *Carabus zawadzkii* Kraatz, 1854 (East-Carpathian endemic species) and *Carabus variolosus* Linnaeus, 1758, both listed in the Annex II and IV of the Habitats Directive. Their whole European conservation is implemented through the NATURA 2000 and EMERALD networks.

We recorded the smallest number of individuals in study area R1 (290 individuals) and the most in R3 (568 individuals). We confirmed the smallest number of species in study area R2 (32 species) and the most in R4 (40 species). We confirmed the most adaptable species in study areas R1, R3, R4 (8 species). Eurytopic species were most represented on R4, and we confirmed relict species only on R1, R2 (2 species).

For the bioindicative evaluation, we chose the family Carabidae, which was the most represented (80.1%) from the order Coleoptera. Over the research period, we recorded 1,279 carabid individuals belonging to 30 species. We observed relationships between carabid species and biotopes (mesophilic meadow, *Nardetum* pasture, intensive meadow *Menyanthes trifoliata*). We analyzed the connection of ground beetle species to habitats using the canonical correspondence analysis (RDA, SD = 1.8 on the first ordination axis). The values of the variability of taxonomic data were 41% on the first axis and 69% on the second cumulative axis. The cumulative variability of the species set explained by biotopes was 60.88% on the first axis and 83.12% on the second axis, which points to higher data heterogeneity due to environmental variables. We confirmed significant effect of the intensive meadow ($p = 0.025$; df = 2), mesophilic meadow ($p = 0.041$; df = 2) on the spatial structure of ground beetles species. The biotope of *Nardetum* pasture ($p = 0.49$; df = 2) did not have a statistically significant effect on the spatial structure of ground beetles. The environmental variables (habitats) were not mutually correlated (inflation factor = 1.245 is max. value).

The graph of the analysis of ground beetles has the species ordered into three clusters (Fig. 2). The first cluster consisted of adaptable (A) and eurytopic (E) with a connection to the mesophilic meadows habitat. The second cluster (*Nardetum* pasture) was mainly represented by adaptable (A) and eurytopic (E) species, but there were also two species belonging to group R (relict), which in-

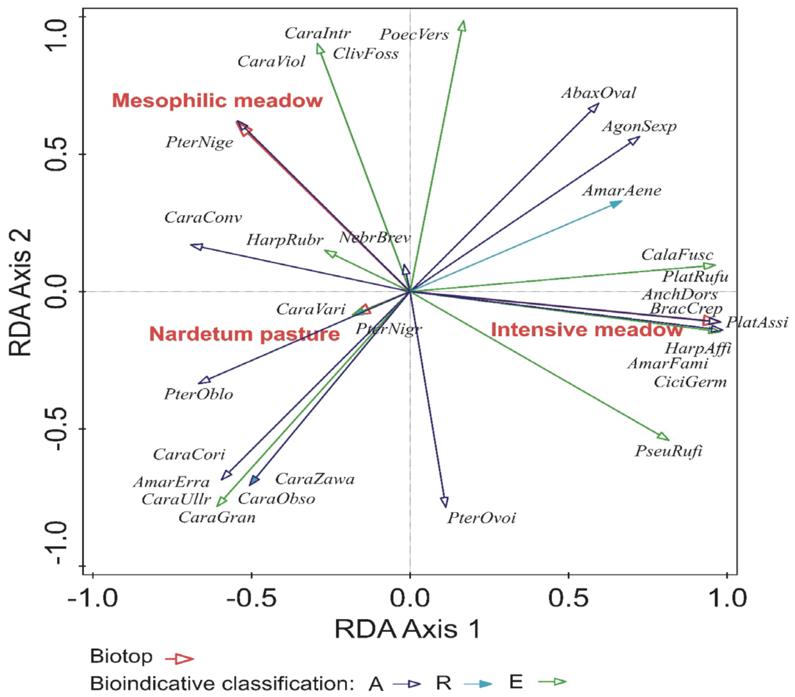

Fig. 2. RDA analysis of the dispersion of ground beetles in studied habitats.

dicates a more stable environment. The third cluster consisted of also adaptable (A), eurytopic (E) and one species belonging to group R (relict), with a link to intensive meadow. Species in the bioindicative category A (50%) were represented the most, while the bioindicative category E (40%) was 10% percentile points less. The bioindicative category R was the least represented (10%).

Considering all study sites together, wolf spiders *Pardosa pullata* (Clerck, 1757) (21.81%), *Pachygnatha degeeri* Sundevall, 1830 (14.21%) and *Xerolycosa nemoralis* (Westring, 1861) (10.28%) were dominant. Other wolf spiders *Pardosa palustris* (Linnaeus, 1758) (7.86%), *Trochosa ruricola* (De Geer, 1778) (6.24%), *Alopecosa pulverulenta* (Clerck, 1757) (4.38%) and *Trochosa terricola* Thorell, 1856 (4,06%) had subdominant presence (Table 2).

The epigeic spider communities of pasture sites R1, R2 and R3 were represented by a larger number of individuals (from 636 to 1,136 specimens). At these sites, in the epigeal layer of extensively used pastures, the wolf spider *Pardosa pullata* was edominant or dominant (from 23.5 to 37.4%). Also, *Pachygnatha degeeri* was abundant, mainly at the R1 and R2 sites. The R2 site has more xerothermic character compared to the other pastures studied, which had an impact on higher diversity, species richness, and sozological significance. For beetles, we recorded the largest number of species in study area 4 (R4), which was on the border with the forest biotope. A larger number of species can also be affected by the ecotone rule. Of the Slovak red listed species, eight ones were recorded, namely *Tapinocyba pallens* (O. Pickard-Cambridge, 1873) (R2), *Walckenaeria alticeps* (Denis, 1952) (R2), *Walckenaeria kochi* (R1), *Robertus neglectus* (O. P.-Cambridge, 1871) (R3), *Phaeocedus braccatus* (L. Koch, 1866) (R2), *Xysticus luctuosus* (Blackwall, 1836) (R2), *Gongylidiellum vivum* (O. P.-Cambridge, 1875) (R2, R3) and *Xysticus lineatus* (R1, R2, R3). The finding of *Micaria micans* (R1), which is first published record for Slovakia, is interesting from a faunistic point of view. *Micaria micans* is closely related species to M. pulicaria. Based on morphology and natural history, these two species were, in subsequent taxonomic studies synonymized. Muster and Michalik (2020) based on integrating information from molecular, morphological, ecological and distribution data re-circumscribed *M. pulicaria* group and revalidate the long forgotten *M. micans*. Until this work is published, all findings of *M. pulicaria* group from Slovakia are listed as *M. pulicaria*, and therefore revision of older material of this taxa should be necessary. The presented finding of *Micaria micans* in Runina from mesophilic meadows in Runina (10.6.2020, 1♂) was one of the first records from the territory of Slovakia. Gradually, the species was found at other locations in the 2020–2023 and also from two sites in the collections from 2017, when the spider material was determined later. In the national database, presently 23 records of *M. micans* from 20 localities are documented from Slovakia. The first the oldest 3 records are from 2017 from two localities, manely from Zoological garden Bratislava – open grassy areas (24.4.2017, 1♂, 18.7.2017, 1♀, leg. Goffová, Holecová) and from Chľaba – gravel bank of Ipel River (17.6.2017, 1♀, leg. Šestáková) (Fig. 3). Later records (2020–2023) are from different type of habitats, whether natural (e.g. alpine meadows, different type of wetlands) or man-made habitats (e.g. old orchards and waste dumps).

The highest number of red listed species was documented from the aforementioned *Nardetum* pasture (site R2). Out of a total of 1,125 spider specimens caught in the epigeal layer of the intensive meadow (R4), the eudominant species *Xerolycosa nemoralis* (35%), the dominant species *Pardosa palustris* (22.4%) and together with the subdominant species *Trochosa ruricola* (9%) represented two thirds of all captured spider specimens (Table 1). Three species from the Slovak Red List were confirmed here, namely *Palliduphantes milleri* (EN), *Walckenaeria kochi* (NT) and *Erigone jaegeri* (DD). The finding of *Palliduphantes milleri* (Starega, 1972) is very important (it is an endemic of the Eastern Carpathians) from a faunistic and sozological aspect of view.

The rarefaction analysis showed that the highest species richness of Coleoptera and Araneae was in the mesophilic meadows, and low species richness in the *Nardetum* pasture was driven primarily by differences in the local abundance and species richness. The decline in species

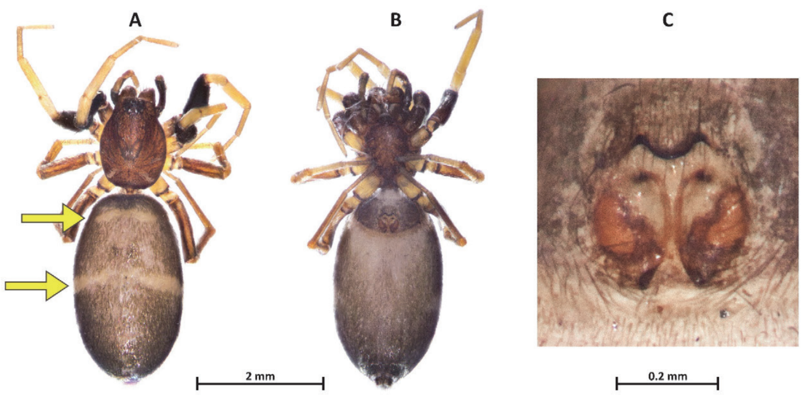

Fig. 3. Female habitus of *Micaria micans* from Slovakia (Photo A. Šestáková). A – dorsal view; B – ventral view; C – epigyna. Arrows show the abdominal white bands.

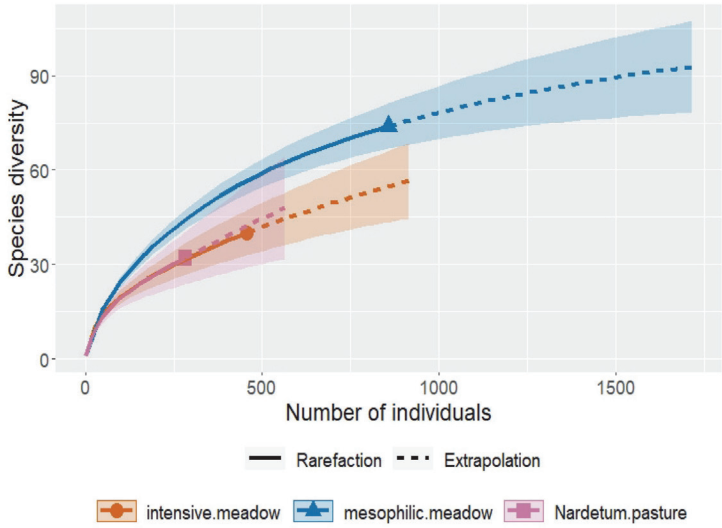

Fig. 4. Individual-based rarefaction (peripheral lines) and extrapolation curve (medium lines) of total species richness of Coleoptera.

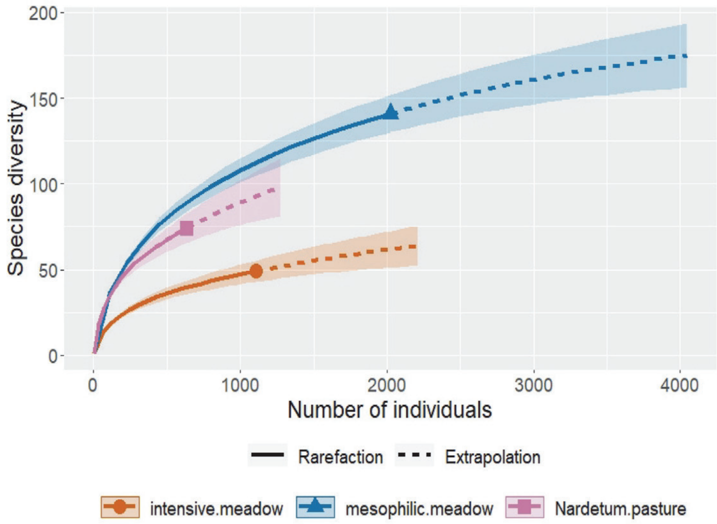

Fig. 5. Individual-based rarefaction (peripheral lines) and extrapolation curve (medium lines) of total species richness of Araneae.

richness in epigeic beetle communities is as follows in the direction of biotopes: mesophilic meadows, intensive meadow and *Nardetum* pasture. The diversity in habitats does not change with the same number of individuals. The direction of habitats is as follows: mesophilic meadow, *Nardetum* pasture and intensive meadow (Fig. 4).

The decline in species richness of spiders is as follows in the direction of biotopes: mesophilic meadow, *Nardetum* pasture and intensive meadow. The diversity in habitats not changes with the same number of individuals. Thus, the change in species richness in habitats is influenced by the number of spider specimens (Fig. 5).

We observed relationships between spider species and habitats using the redundancy analysis (RDA, SD = 1.80 on the first ordination axis). The values of the variability taxonomic data were 39% on the first axis and 65% on the second cumulative axis. The cumulative variability of the set of species explained by habitats was 60,2% on the first axis and 84.38% on the second axis. We confirmed significant effect of *Nardetum* pasture (p = 0.0054; df = 2) and intensive meadow (p = 0.0252; df = 2) on the spatial structure of spider species. The biotope of the mesophilic meadow (p = 0.672; df = 2) did not have a statistically significant effect on the spatial structure of spiders. The environmetal variables (biotopes) were not mutually correlated (inflation factor = 4.1276 is max. value).

The graph had species of spiders arranged in three clusters, the first cluster consisting of species preferring the conditions of the mesophilic meadow habitat. The second cluster consisted of species correlated with the conditions of *Nardetum* pasture. The third cluster consisted of species preferring intensive meadow. Species in the R1–R2 (57.63%) bioindicative category were represented the most, while the Er bioindicative category (22.03%). The R1 bioindicative category was the least represented (8.47%) and the category of unclassified species was represented by 11.86 % (Fig. 6).

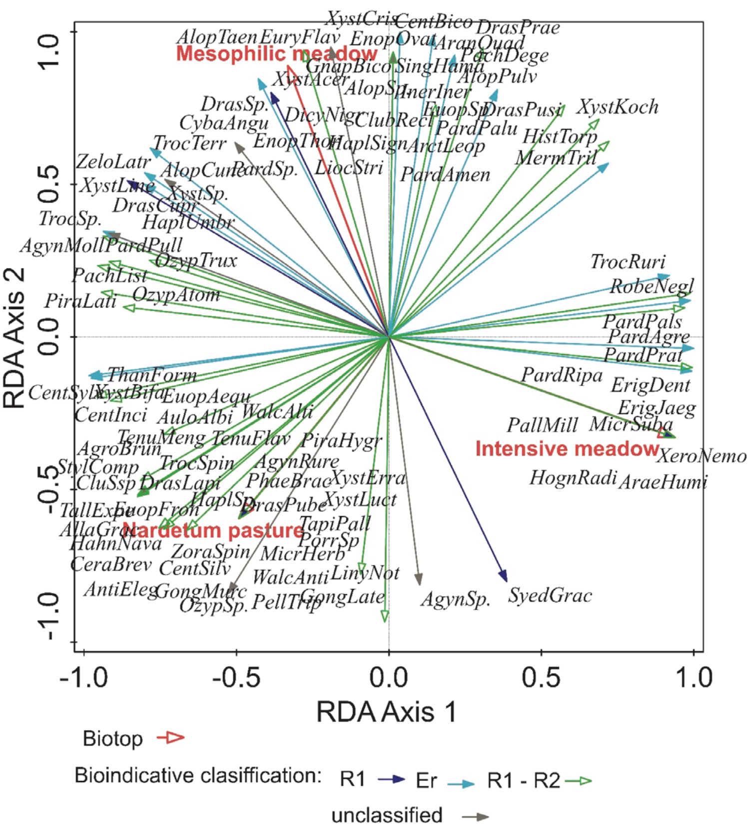

Fig. 6. RDA analysis of the dispersion of spiders in studied habitats.

Discussion

In many parts of the world, the landscape is changing at an unprecedented rate with negative consequences for the environment. As a result, there is a social demand to better understand the causes, trends and regularities of these changes in order to establish mechanisms for their regulation and speed of spread (Theodor et al., 2022). In our study, we examine the species composition of two groups of bioindicators, Araneae and Coleoptera (Carabidae), on four study areas. Many beetle and spider species living in ecosystems exposed to disturbance and anthropogenic interference have a bigger ecological tolerance than species strictly associated with natural habitats. They have high local density which associated with agriculture, forestry or urbanization (Pearce and Venier, 2006, Kotze et al., 2011; Porhajašová et al., 2018; Radkova et al., 2019). In our study we recorded the eudominant representation of the bioindicative family Carabidae (79.9%, 1,293 individuals) from the order Coleoptera. Similarly, spiders are considered one of the most abundant groups of predators in different agriculatural ecosystems (Wise, 1993; Foelix, 2010; Benamú et al., 2017). They present a rich in species group of invertebrates, which inhabit all terestrial ecosystems and their microhabitats. Also, habitat requirements for many spider species are well known (Keer van et al., 2009), and spiders are used for conservation assessment (Samu et al., 2008). The above-mentioned facts relate to the use of family Carabidae and spiders as very good bioindicators, which was also confirmed by many scientific studies. They react quickly to changes in the environment due to environmental and anthropogenic changes. Based on the species composition and division into bioindicative groups, we can determine the quality of the habitat. We can also use them as predictors of the environment and determine the quality of the biotope for the future (e.g. Maelfait et al., 1989; Maelfait, 1996; Maelfait and Hendrickx, 1998; Willet, 2001; Maelfait et al., 2004; Keer van et al., 2009; Brygadyrenko, 2015; Yang et al., 2016; Galle et al., 2018; Schwerdt et al., 2018; Putchkov et al., 2020; De et al., 2021).

Spiders and also species of the family Carabidae are an important components of the fauna of ecosystems, where their importance is influenced by diverse bionomics and abundance (Wise 1993; Barton et al., 2011; Nyffeler and Birkhofer, 2017). In our study, the species diversity of the studied habitats decreased similarly for both studied taxa, but spiders, with the same number of individuals, showed a change in species richness. This means that slight changes in management of biotops may cause important changes in the spider assemblage composition, which was already presented by Weibull et al. (2003), Maelfait et al. (2004), Schmidt et al. (2005), Isaia et al. (2006), Dobrovodská et al. (2019), Kolb et al. (2020).

The agricultural landscape of the Runina, similarly as in all Poloniny region, has undergone changes in the land use. In the Poloniny National Park, but in its other part (Ruské), Oszlányi et al., 2014 reviewed driving forces of land use change, related subsequent changes in the management practices and their consequences for spider diversity. It was found that despite unprecedented changes of the socio-economic systems and the land management during the studied period (last 2 decades), the region still hosted a high biodiversity. The study of spider communities in 1999 and 2011 indicated increased abundance, taxonomic diversity, and occurrence of threatened spider species. In Runina, we have only presented data from 2020 but similarly also here we can constant that study area hosts still a high biodiversity. Species richness in mesophilous meadow in Starina in 2011 was 51 species and in the same habitat in Runina from 59 to 65 species on 3 study sites, species richness in fens 40 species in Ruské vs. 37 species in Runina. Considerably similar composition of ground-living spider communities, diversity and species richness were found also in mesophilic meadows and fens in Ulička dolina Valley (Poloniny) in 2011–13 (Žila and Gajdoš, 2015).

Majzlan (2015) conducted research on coleopterocenoses in the Poloniny National Park, which also includes Runina. In total, he obtained 852 species of beetles, of which 72 species from the Carabidae family were represented. The European important species covered by the NATURA 2000 decree from the Carabidae family were *Carabus zawadszkii* and *Carabus variolosus*. We also recorded the European important species *Carabus zawadszkii* in our results. This species was also addressed by Gajdoš et. al. (2022) and also confirmed its occurrence in the Poloniny National Park.

Biomonitoring is important for tracking gradual changes and detecting the impact of management on the environment. Biodiversity is lower in agricultural landscape than in natural ecosystems. In agricultural landscape, there is a prevalence of eurytopic species over relict and adaptable species due to the disturbance of natural habitats (Baranová et al., 2013; Jaďuďová et al., 2016; Lemic et al., 2017), which we also confirmed in our research with ground beetles and spiders. In our research, we divided the species of both analysed taxa into three bioindicative groups each: Carabidae (according to Farkač et al., 2006) to adaptable, relict and eurytopic, and the spiders (according to Buchar and Růžička, 2002) to climax, climax and seminatural, and disturbed. Using multivariate analysis of ground beetles and spiders, we recorded that as disturbance increased, the number of adaptive species declined and they were gradually replaced by eurytopic species. In habitats with a decreasing effect of disturbing factors, the number of eurytopic species decreased and the number of adaptable ones increased; relict species also began to appear. Species richness and abundance of stentopic species associated with natural habitats (carabids and spiders belonging to R and R1 bioindicative groups) indicated less disturbed study sites. In such habitats, we also confirmed the presence of the European important beetle species *Carabus zawadzkii* and *Carabus variolosus*, redlisted carabid species *Carabus obsoletus* and nine redlisted spiders. Many authors, such as Maelfait et al. (2004); Finch (2005); Wiezik et al. (2007); Samu et al. (2008); Igondová and Majzlan (2015), Dobrovodská et al. (2019) have also reported the same effect. The difference in proportion of abundance between individual bioindicatory groups of both taxa Carabidae (R, A, E) and Araneae (R1, R1–R2, Er) was minimal. This fact points to a similar informative character about the habitat of study sites.

Various studies dealt with the assessment of habitat based on ground beetles and spiders. These groups of animals respond sensitively to changes in environmental conditions and, by joint analysis of the species community, achieve better results in determining its quality (Noordijk et al.; 2008), Knapp and Řezáč, 2015)). In our work, we also connected the analysis of these taxa to determine the status of habitats, which can be used for example in habitat protection. The contrasting patterns of carabid and spider activity density could also be caused by the direct interactions between these two groups of predators, as intra-guild predation between carabids and spiders recorded (Varet et al. 2012; Davey et al., 2013).

The presence of the alien spider species *Mermessus trilobatus* (Linyphiidae) (originally from North America) was also documented in the epigeic assamblages of meadows (R1), *Nardetum* pasture (R3) and intensive meadow (R4), abundant mainly on R3 and R4 sites which are the most disturbed by human activities. This species was presumably imported to southwestern Germany in the 1970ies by the US Army and dispersed from there (Nentwig et al., 2023). It has probably spread across Slovakia only in recent years continuely from western to eastern part, as its first recorded appearance in the country is from alpine meadows in Salatin (Western Tatras) in 2012 at an altitude of 1,880 m (unpublished). Its first published records were reported from the Botanical garden in Košice in 2014 and 2015 (Šestáková et al., 2017). It has not even been reported during the numerous arachnological researches of the non-forest ecosystems of the Poloniny Mts. over the last two decades (Svatoň et al., 2003; 2005; Žila et al., 2012; Žila and Gajdoš 2014; 2015). We assume that during the period of intensive above-mentioned researches in Poloniny, the species has not yet spread to this easternmost part of Slovakia. This to some extent confirms the fact, the first record of this species from Ukraine (locality near Slovakian border) is only from 2017 (1♂, 10.5.2017), found in mountain massif Svydivets' located in the Ukrainian Carpathians at an altitude of 1,495 m (Hirna, 2017), similarly as the first Slovakian record in higher altitude. At present, species is not listed as invasive species in Slovakia because its abundance on the localities is not so high that is a threat to native species and biodiversity, but its invasive potential is high. It is able to occupy various types of habitats from natural to man-made from lowland until high mountains and its abundance is gradually increasing in many localities. In the national database presently 425 its records from 270 localities are listed. *Trilobatus* occurs also in a wide range of agricultural habitats in its non-native range (Schmidt et al., 2008), with preference of less disturbed meadows to intensively cultivated farmland (Narimanov et al. 2021), so the study area in Runina is suitable for this species.

Conclusions

During our research, we registered changes in the structure of the studied beetle and spider communities, on the examined areas of the agrarian used land of Slovakia. Based on the structure of the communities of spiders and beetles in the investigated biotopes, we can say that adaptable and eurytopic species of ground beetles had a greater connection to the mesophilic meadow biotope, and in the case of spiders, to the *Nardetum* pasture biotope.The proportion of bioindicative groups for both carabid beetles and spiders showed a very similar ratio, with a clear predominance of the adaptable species (over 50% for both taxa). Based on the proportion of relict species in both carabid and spider communities, we found that the least disturbed habitats are the mesophilic meadow and *Nardetum* meadow. The results of our study bring a more suitable option of assessing of the habitat type based on species composition of two different taxonomic groups, namely beetles and spiders.

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Supplementary material

Table 1. List of species of beetles from studied locations with bioindicative classes of the Carabidae family according to Farkač et al. (2006) and their listing in IUCN categories of Slovak Red List – RL (Holecová and Franc, 2001)

Familia/species	Code	RL	BG	Study sites 1	2	3	4	∑
Byrrhidae								
Byrrhus pilula (Linnaeus, 1758)			–	3	1	1	4	9
Byrrhus pustulatus (Forster, 1771)			–				2	2
Morychus aeneus (Fabricius, 1775)			–				1	1
Cantharidae								
Ancistronycha tigurina (Dietrich, 1857)			–	1				1
Cantharis rustica Fallén, 1807			–	3	1	1		5
Carabidae								
Abax ovalis (Duftschmid, 1812)	AbaxOval		A			2	2	4
Agonum sexpunctatum (Linnaeus, 1758)	AgonSexp		A			3	5	8
Amara aenea (De Geer, 1774)	AmarAene		E		6	2	6	14
Amara erratica (Duftschmid, 1812)	AmarErra		R	1	1			2
Amara familiaris (Duftschmid, 1812)	AmarFami		E	3	8	3	52	66
Anchomenus dorsalis (Pontoppidan, 1763)	AnchDors		E				3	3
Brachinus crepitans (Linnaeus, 1758)	BracCrep		E				1	1
Calathus fuscipes (Goeze, 1777)	CalaFusc		E			1	21	22
Carabus convexus (Fabricius, 1775)	CaraConv		A	3	1	3	1	8

Table 1 – Continued

Familia/species	Code	RL	BG	Study sites 1	2	3	4	∑
Carabus coriaceus Linnaeus, 1758	CaraCori		A	1	1			2
Carabus granulatus Linnaeus, 1758	CaraGran		E	21	4	1	1	27
Carabus intricatus Linnaeus, 1761	CaraIntr		A			1		1
Carabus obsoletus Sturm, 1815	CaraObso	LR (cd)	A	1				1
Carabus zawadszkii Kraatz, 1854	CaraZawa		R	1				1
Carabus ullrichi Germar, 1824	CaraUllr		A	5				5
Carabus variolosus Fabricius, 1787	CaraVari	LR (cd)	R		1			1
Carabus violaceus Linnaeus, 1758	CaraViol		A			1		1
Cicindela germanica Linnaeus, 1758	CiciGerm		A		1		14	15
Clivina fossor (Linnaeus, 1758)	ClivFoss		E			3		3
Harpalus affinis (Schrank, 1781)	HarpAffi		E				18	18
Harpalus rubripes (Duftschmid, 1812)	HarpRubr		E	1	9	2	1	13
Nebria brevicollis (Fabricius, 1792)	NebrBrev		A	53	17	52	42	164
Platyderus rufus (Duftschmid, 1812)	PlatRufu		A				1	1
Platynus assimilis Paykull, 1790	PlatAssi		A				1	1
Poecilus versicolor (Sturm, 1824)	PoecVers		E	104	177	371	201	853
Pseudoophonus rufipes (DeGeer, 1774)	PseuRufi		E	3	1		18	22
Pterostichus niger (Schaller, 1783)	PterNige		A	2		11		13
Pterostichus nigrita (Paykull, 1790)	PterNigr		E		1			1
Pterostichus oblongopunctatus (Fabricius, 1787)	PterOblo		A	4		1		5
Pterostichus ovoideus (Sturm, 1824)	PterOvoi		A	2			1	3
Coccinellidae								
Harmonia axyridis Pallas, 1773			–		1			1
Curculionidae								
Alophus triguttatus (Fabricius, 1775)			–		1	9		10
Graptus kaufmanni (Stierlin, 1884)			–		6	20		26
Larinus sturnus (Schaller, 1783)			–	1				1
Lepyrus capucinus (Schaller, 1783)			–	1		6		7
Liophloeus gibbus E.F. Germar, 1817			–				1	1
Liophloeus tessulatus (Müller, O.F., 1776)			–			1		1
Neoglanis intermedius (Boheman, 1842)			–		1	1		2
Orchestes fagi (Linnaeus, 1758)			–	1				1
Otiorhynchus ovatus (Müller, O.F., 1776)			–				1	1
Peritelus sphaeroides Germar 1824			–	3		6	1	10
Dermestidae								
Dermestes murinus Linnaeus, 1758			–			2	2	4
Elateridae								
Agrypnus murinus (Linnaeus, 1758)			–	1	3	6	2	12
Athous subfuscus (O.F. Müller, 1764)			–	3	7	12	7	29
Ctenicera pectinicornis (Linnaeus, 1758)			–	1			1	2
Myllaena intermedia W.F. Erichson, 1837			–				1	1
Selatosomus gravidus (Germar, 1843)			–				1	1
Geotrupidae								
Geotrupes stercorarius (Linnaeus, 1758)			–			2		2
Chrysomelidae								
Aphthona nonstriata (J.A.E. Goeze, 1777)			–				1	1
Colaphus sophiae (Schaller, 1783)			–				1	1
Galeruca pomonae (Scopoli, 1763)			–	2	5		10	17
Galeruca tanaceti (Linnaeus, 1758)			–				11	11
Chrysolina staphylaea (Linnaeus, 1758)			–		1		1	2
Neocrepidodera ferruginea (Scopoli, 1763)			–	3		4		7
Scarabaeidae								
Chaetopteroplia segetum (Herbst, 1783)			–		1	1		2

Table 1 – Continued

Familia/species	Code	RL	BG	Study sites 1	2	3	4	∑
Onthophagus coenobita (Herbst, 1783)			–			1		1
Onthophagus ovatus (Linnaeus, 1767)			–			2		2
Silphidae								
Silpha obscura Linnaeus, 1758			–	6	6	3	14	29
Staphylinidae								
Anthobium atrocephalum (Gyllenhal, 1827)			–	10		1		11
Hypnogyra angularis Ganglbauer, 1895			–		1			1
Mniusa incrassata (Mulsant & Rey, 1852)			–			3	1	4
Mycetoporus nigricollis Stephens, 1835			–	1	1			2
Myllaena intermedia W.F. Erichson, 1837			–	2				2
Ocypus nitens Schrank, 1781			–		2		1	3
Ontholestes tessellatus (Geoffroy in A.F. Fourcroy, 1785)				–			2	1 3
Philonthus decorus (Gravenhorst, 1802)			–	1	5	3		9
Platydracus fulvipes (Scopoli, 1763)		LR:nt	–		1			1
Staphylinus caesareus (Gravenhorst, 1802)			–	39	7	22	3	71
Staphylinus erythropterus Linnaeus, 1758			–	2	3	1		6
Stenus cicindeloides (Schaller, 1783)			–	1		1		2
∑ individuals				290	282	568	457	1,597

RL = Red List, BG = Bioindicative groups (R – relict and rare, A – adaptable, E – eurytopic), 1, 3 = mesophilic meadows; 2 = *Nardetum* pasture; 4 = intensive meadow.

Table 2. List of ground-dwelling spider species (Araneae) of study sites with codes and their bioindicative classification according to Buchar and Růžička, 2002 and their listing in IUCN categories of Slovak Red List – RL (Gajdoš and Svatoň, 2001)

Familia/species	Code	RL	BG	Study sites 1	2	3	4	∑
Agelenidae								
Agelena labyrinthica (Clerck, 1757)	AgelLaby		R1– R2	12	3	5	4	24
Allagelena gracilens (C. L. Koch, 1841)	AllaGrac		R1– R2	1	1			2
Histopona torpida (C. L. Koch, 1837)	HistTorp		R1– R2			3	2	5
Inermocoelotes inermis (L. Koch, 1855)	InerIner		R1– R2	2		2	1	5
Amaurobiidae								
Callobius claustrarius (Hahn, 1833)	CallClau		R1– R2	1				1
Araneidae								
Araneus quadratus Clerck, 1757	AranQuad		R1– R2			1		1
Singa hamata (Clerck, 1757)	SingHama		R1– R2			1		1
Clubionidae								
Clubiona neglecta O. P.-Cambridge, 1862	ClubNegl		R1– R2	3			1	4
Clubiona reclusa O. P.-Cambridge, 1863	ClubRecl		R1– R2			2		2
Clubiona sp.	CluSsp		–	2	2			4
Cybaeidae								
Cybaeus angustiarum L. Koch, 1868	CybaAngu		R1– R2	2		2		4
Dictynidae								
Argenna subnigra (O. P.-Cambridge, 1861)	ArgeSubn		R1– R2	1				1
Gnaphosidae								
Drassodes cupreus (Blackwall, 1834)	DrasCupr		R1– R2	1	1	1		3
Drassodes lapidosus (Walckenaer, 1802)	DrasLapi		R1– R2	1	1			2
Drassodes pubescens (Thorell, 1856)	DrasPube		R1– R2		1			1
Drassodes sp.	DrasSp.		–	1		1		2
Drassyllus praeficus (L. Koch, 1866)	DrasPrae		R1– R2	6	4	15	7	32

Table 2 – Continued

Familia/species	Code	RL	BG	Study sites				∑
				1	2	3	4	
Drassyllus pusillus (C. L. Koch, 1833)	DrasPusi		R1– R2	3	3	7	5	18
Gnaphosa bicolor (Hahn, 1833)	GnapBico		R1			1		1
Haplodrassus signifer (C. L. Koch, 1839)	HaplSign		Er			2		2
Haplodrassus sp.	HaplSp.		–		1			1
Haplodrassus umbratilis (L. Koch, 1866)	HaplUmbr		R1– R2	1	1	1		3
Micaria micans (Blackwall, 1858)	MicaMica	new	R1– R2	2				2
Phaeocedus braccatus (L. Koch, 1866)	PhaeBrac		R1		1			1
Zelotes latreillei (Simon, 1878)	ZeloLatr		Er	3	1	2		6
Zelotes sp.	ZeloSp.		–	1	1	1	1	4
Hahniidae								
Antistea elegans (Blackwall, 1841)	AntiEleg		R1– R2		1			1
Hahnia nava (Blackwall, 1841)	HahnNava		R1– R2	2	10			12
Cheiracanthidae								
Cheiracanthium sp.	CheiSp.		–	3				3
Linyphiidae								
Agyneta affinis (Kulczyński, 1898)	AgynAffi		R1– R2	2	12	8	5	27
Agyneta mollis (O. P.-Cambridge, 1871)	AgynMoll		R1– R2	5	6	5	1	17
Agyneta rurestris (C. L. Koch, 1836)	AgynRure		Er	1	2	1	1	5
Agyneta sp.	AgynSp.		–		2		1	3
Araeoncus humilis (Blackwall, 1841)	AraeHumi		Er				1	1
Centromerita bicolor (Blackwall, 1833)	CentBico		Er	3		36	2	41
Centromerus incilium (L. Koch, 1881)	CentInci		R1– R2	3	10	2		15
Centromerus silvicola (Kulczyński, 1887)	CentSilv		R1		1			1
Centromerus sylvaticus (Blackwall, 1841)	CentSylv		Er	10	14	6	2	32
Ceratinella brevis (Wider, 1834)	CeraBrev		R1– R2	1	10			11
Dicymbium nigrum brevisetosum Locket, 1962	DicyNigr		Er	1	1	5		7
Erigone dentipalpis (Wider, 1834)	ErigDent		Er			1	17	18
Erigone jaegeri Baehr, 1984	ErigJaeg	DD	R1				1	1
Gongylidiellum latebricola (O. P.–Cambridge, 1871)	GongLate		R1– R2	1	1		1	3
Gongylidiellum murcidum Simon, 1884	GongMurc		R1		1			1
Gongylidiellum vivum (O. P.-Cambridge, 1875)	GongVivu	VU	R1– R2		1	1		2
Linyphiidae not det.	LinyNot		–	1	2	1	1	5
Mermessus trilobatus (Emerton, 1882)	MermTril		Er	6	8	27	21	62
Micrargus herbigradus (Blackwall, 1854)	MicrHerb		R1– R2		1			1
Micrargus subaequalis (Westring, 1851)	MicrSuba		R1– R2				1	1
Oedothorax gibbosus (Blackwall, 1841)	OedoGibb		R1– R2	4				4
Oedothorax retusus (Westring, 1851)	OedoRetu		Er	9	1			10
Palliduphantes milleri (Starega, 1972)	PallMill	VU	R1				1	1
Porrhomma sp	PorrSp		–		1			1
Styloctetor compar (Westring, 1861)	StylComp	LC	R1 – R2	6	4			10
Syedra gracilis (Menge, 1869)	SyedGrac		R1		1		1	2
Tallusia experta (O. P.-Cambridge, 1871)	TallExpe		R1– R2	3	3			6
Tapinocyba pallens (O. Pickard-Cambridge, 1873)	TapiPall		R1– R2		1			1
Tenuiphantes flavipes (Blackwall, 1854)	TenuFlav		R1– R2		1			1
Tenuiphantes mengei (Kulczyński, 1887)	TenuMeng		R1– R2		2			2
Walckenaeria alticeps (Denis, 1952)	WalcAlti	DD	R1– R2		1			1
Walckenaeria antica (Wider, 1834)	WalcAnti		R1– R2		4		1	5
Walckenaeria kochi (O. P.-Cambridge, 1873)	WalcKoch		R1– R2	1				1
Liocranidae								
Agroeca brunnea (Blackwall, 1833)	AgroBrun		R1– R2	8	2			10
Liocranoeca striata (Kulczyński, 1882)	LiocStri		R1– R2			1		1
Lycosidae								
Alopecosa cuneata (Clerck, 1757)	AlopCune		Er	15	17	25	4	61
Alopecosa pulverulenta (Clerck, 1757)	AlopPulv		Er	15	20	98	32	165
Alopecosa sp.	AlopSp.		–	5	4	19	3	31

Table 2 – Continued

Familia/species	Code	RL	BG	Study sites				∑
				1	2	3	4	
Alopecosa taeniata (C. L. Koch, 1835)	AlopTaen	DD	R1– R2	1		2		3
Alopecosa trabalis (Clerck, 1757)	AlopTrab		R1– R2	17	4	11	6	38
Arctosa leopardus (Sundevall, 1833)	ArctLeop		R1– R2			1		1
Aulonia albimana (Walckenaer, 1805)	AuloAlbi		R1– R2	3	7	1	1	12
Hogna radiata (Latreille, 1817)	HognRadi		R1– R2				7	7
Pardosa agrestis (Westring, 1861)	PardAgre		Er	1		7	84	92
Pardosa amentata (Clerck, 1757)	PardAmen		Er			2		2
Pardosa lugubris (Walckenaer, 1802)	PardLugu		Er	11		3	8	22
Pardosa paludicola (Clerck, 1757)	PardPalu		R1– R2			4		4
Pardosa palustris (Linnaeus, 1758)	PardPals		Er	3	7	38	248	296
Pardosa prativaga (L. Koch, 1870)	PardPrat		Er			1	8	9
Pardosa pullata (Clerck, 1757)	PardPull		Er	311	238	267	5	821
Pardosa riparia (C. L. Koch, 1833)	PardRipa		R1– R2	1	1	2	9	13
Pardosa sp.	PardSp.		–	3	8	20	1	32
Piratula hygrophila (Thorell, 1872)	PiraHygr		R1– R2		2			2
Piratula latitans (Blackwall, 1841)	PiraLati		R1– R2	75	18	11		104
Trochosa ruricola (De Geer, 1778)	TrocRuri		Er	49	30	57	99	235
Trochosa sp.	TrocSp.		–	6	7	7	1	21
Trochosa spinipalpis (F. O. P.-Cambridge, 1895)	TrocSpin		R1– R2	16	15			31
Trochosa terricola Thorell, 1856	TrocTerr		Er	50	33	56	14	153
Xerolycosa nemoralis (Westring, 1861)	XeroNemo		R1– R2				387	387
Miturgidae								
Zora silvestris Kulczyński, 1897	ZoraSilv		R1– R2	2				2
Zora spinimana (Sundevall, 1833)	ZoraSpin		Er		1			1
Philodromidae								
Thanatus formicinus (Clerck, 1757)	ThanForm		R1– R2	5	4	1		10
Phrurolithidae								
Phrurolithus festivus (C. L. Koch, 1835)	PhruFest		R1– R2	1			1	2
Phrurolithus minimus C. L. Koch, 1839	PhruMini		R1– R2		1	1		2
Pisauridae								
Pisaura mirabilis (Clerck, 1757)	PisaMira		Er	2				2
Salticidae								
Euophrys aequipes (O. P.-Cambridge, 1871)	EuopAequ		R1– R2	1	3			4
Euophrys frontalis (Walckenaer, 1802)	EuopFron		R1– R2	1	1			2
Euophrys sp.	EuopSp.		–			1		1
Evarcha arcuata (Clerck, 1757)	EvarArcu		R1– R2	2				2
Pellenes tripunctatus (Walckenaer, 1802)	PellTrip		R1		1			1
Sibianor aurocinctus (Ohlert, 1865)	SibiAuro		R1– R2		1	1		2
Tetragnathidae								
Pachygnatha degeeri Sundevall, 1830	PachDege		Er	126	27	294	88	535
Pachygnatha listeri Sundevall, 1830	PachList		R1– R2	2	1	1		4
Theridiidae								
Enoplognatha ovata (Clerck, 1757)	EnopOvat		R1– R2			1		1
Enoplognatha thoracica (Hahn, 1833)	EnopThor		Er	1		1		2
Euryopis flavomaculata (C. L. Koch, 1836)	EuryFlav		R1– R2	1		2		3
Robertus neglectus (O. P.-Cambridge, 1871)	RobeNegl	NT	R1– R2			1	3	4
Thomisidae								
Ozyptila atomaria (Panzer, 1801)	OzypAtom		R1– R2	3	6	4	1	14
Ozyptila sp.	OzypSp.		–	3	6	1	2	12
Ozyptila trux (Blackwall, 1846)	OzypTrux		R1– R2	2	8	6		16
Xysticus acerbus Thorell, 1872	XystAcer		R1	1		1		2
Xysticus bifasciatus C. L. Koch, 1837	XystBifa		Er	13	11	5	2	31

Table 2 – Continued

Familia/species	Code	RL	BG	Study sites				∑
				1	2	3	4	
Xysticus cristatus (Clerck, 1757)	XystCris		Er	7	5	11	6	29
Xysticus erraticus (Blackwall, 1834)	XystErra		R1– R2		6			6
Xysticus kochi Thorell, 1872	XystKoch		R1– R2	1		4	3	8
Xysticus lanio C. L. Koch, 1835	XystLani		R1– R2	1				1
Xysticus lineatus (Westring, 1851)	XystLine	VU	R1	11	7	14		32
Xysticus luctuosus (Blackwall, 1836)	XystLuct		R1– R2		1			1
Xysticus sp.	XystSp.		–	7	10	13	3	33
∑ individuals				888	636	1,136	1,105	3,765

RL = Red List, BG = Bioindicative groups (Er, R1, R1 - R2), Note: 1, 3 = mesophilic meadows; 2 = *Nardetum* pasture; 4 = intensive meadows.