

Are more bogs better? Comparative studies into Transylvanian peat bog spider (Arachnida: Araneae) assemblages from a conservation biological perspective

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Abstract. Epigeic spider communities of four bogs: Benes, Borsaros, Luci and Mohoş including some of the surrounding forested habitats were investigated in Transylvania (Romania). All these peat bogs are protected natural sites as part of Natura 2000 ecological network. Fifteen sites in the four bogs were concurrently sampled by pitfall traps. The faunistic investigations revealed a rich and variable fauna of the studied bogs with 100 species from 19 families. Open bog habitats were the most species rich, wooded bog areas intermediate and forests proved to be the poorest. Forest habitats markedly differed in their dominant species and in assemblage composition from bog habitats, therefore significant faunal exchange cannot be expected between these habitats. The present study definitely showed the value of small bogs, which in fact showed greater species richness than the two larger area bogs. The effect of geographical distance and habitat interacted. If habitats were very different (forest vs. bog) then habitat difference was decisive, but among bog sites more proximal sites were also more similar in spider species composition. The bogs scattered about a relatively large geographical area and all contributed unique species to the larger scale 'bog species pool' of the region.

Key words: Araneae, peat bog, community, species richness, conservation, area effect.

Introduction

Wetland deterioration and loss is accelerating worldwide; in Europe wetlands are considered the most vulnerable and endangered habitats (Succow 2000). Bogs are one of the most distinctive and specific habitat types of wetlands. They are critical for biodiversity conservation, support many specialised and seriously endangered species of plants and animals (Pop 1960, Cristea et al. 1996, Tanţău et al. 2003, Spitzer & Danks 2006, Păcurar et al. 2011). The most important legislation related to conservation of peat lands in Europe is the Habitats Directive of the European Union (EU) (92/43/EEC).

The spider fauna of the European peat bogs is well understood (Schikora 1994, Koponen et al. 2001, Koponen 2002, Relys & Dapkus 2000, 2001, Relys et al. 2002, Biteniekytė & Relys 2008). Many spider species of these habitats are nowadays considered threatened (e.g. Koponen 1985, Platen et al. 1996, Komposch & Steinberger 1999, Buchar & Ruzicka 2002, Scott et al. 2006).

In the Romanian Eastern Carpathians, there

are more than 25 oligotrophic peat bogs. These are known as glacial refuges for rare, relic plant species, with high conservation value (Pop 1960, Mohan et al. 1993, Cristea et al. 1996, Coldea 1997, Goia & Fărcaş 1997, Tanţău et al. 2003, Păcurar et al. 2011). The results of some recent studies have shown that these bogs have also an interesting spider fauna with many rare species (Gallé & Urák 2001, 2002, 2006, Urák & Samu 2008). However, previous papers have only dealt with the spider assemblages of individual locations.

The aim of present study was to investigate relationships between epigeic spider communities of four isolated peat bogs and surrounding habitats. We asked questions relevant to conservation ecology: a) Are spider assemblages in smaller bogs more impoverished? b) Which habitat type is the primary source of high bog spider diversity? c) Which is more important habitat similarity or geographical isolation/distance in determining spider assemblage similarities? We hope that answering these questions will not only provide a more comprehensive view about the spider communities and their relation to habitats, but will help to make

the right conservation decisions, too.

Material and methods

Study areas

Peat lands from Benes (Benés-láp) is the largest accumulation of peat in the lower basin of the river Olt, occupying an area of approximately 100 ha (Păcurar et al. 2011). From this, according to a decision of the County Council of Harghita, 4 ha are protected as a nature reserve area. This protected area, part of the Lower Ciuc Basin Natura 2000 site (ROSCI0007, Bazinul Ciucului de Jos), is located between the river Olt and the village Vrabia (N 46°12'55", E 25°54'05") at an altitude of 642 m. Several rare glacial relict plant species of high conservation interest (*Betula humilis*, *Alnus glutinosa*, *Salix pentandra*, *Saxifraga hirculus*, *Ligulaia sibirica*, *Drosera anglica*, *Eriophorum latifolium*, *E. angustifolium*, *Trollius europaeus*, *Equisetum limosum*) are present here (Pop 1960, Rațiu & Gergely 1981). The studied open bog areas are characterized by *Salicion cinereae* - *Calamagrostio-Salicetum cinereae* Soó et Zólyomi in Soó 1955, *Carici flavae* - *Eriophoretum latifolii* Soó 1944 and *Molinio* - *Salicetum rosmarinifoliae* Magyar ex Soó 1933 associations with ground layer dominated by *Sphagnum* (Szabó A. pers. com.).

Borsáros raised-bog (Borsáros-borvízláp) is about 7 km of Miercurea Ciuc, between the right side of the river Olt and the village Sâncrăieni (N 46°18'38", E 25°50'25); lies at 651 m altitude. One hectare from this bog is nature reserve, according to a decision of the County Council of Harghita. This protected area is part of the Lower Ciuc Basin Natura 2000 site (ROSCI0007, Bazinul Ciucului de Jos). High conservation value plant species of this bog are *Alnus glutinosa*, *Betula humilis*, *Salix pentandra*, *Saxifraga hirculus*, *Ligulaia sibirica*, *Drosera anglica*, *Eriophorum latifolium*, *E. angustifolium*, *Comarum palustre*, *Parnassia palustris*, *Menyanthes trifoliata*, *Lysimachia thyrsoiflora*, *Meesea hexasticha* (Pop 1960, Cristea et al. 1996). Present studies were carried out in *Salicion cinereae* - *Calamagrostio-Salicetum cinereae* Soó et Zólyomi in Soó 1955 and *Sphagno* - *Caricetum rostratae* Steffen 1931 plant associations with *Sphagnum* ssp. on ground layer falling in the 'open bog' habitat category (Szabó A. pers. com.).

Luci peat bog (Lucs-tőzezláp) is the biggest oligotrophic peat bog in Transylvania. The bog is in the Harghita Mts. (120 ha, N 46°18'03", E 25°43'14"), between the Pre-luca Tălharului peak (Tolvajos-tető) and the village Sântimbru-Băi (Szentimrei Búdösfürdő), about 12 km from Sâncrăieni (Csíkszentkirály), at a 1080 m altitude. It is a protected natural area, part of the Natura 2000 ecological network (ROSCI0246, Tinovul Luci). The following habitat patches were distinguished here: (i) central open bog without trees (with the exception of some sporadic dwarfed pine and birch trees) belonging to the dominant association *Eriophoro vaginati-Sphagnetum recurvi* Hueck 1925 (hereafter called the 'Luci bog'); (ii) wooded bog with Scots pine and dense blueberry bushes (surrounding of the open central part of the bog), mostly described as *Vaccinio-Pinetum sylvestris* (*betuletosum nanae*) Kleist 1929

(referred to as 'Luci pine'); (iii) spruce forest that surrounds the bog, with a dense moss layer, where the dominant association is *Piceetum sphagnoso-Polytrichetosum* Soó 1944 (referred to as 'Luci spruce') (Tanțău et al., 2003).

Mohos peat bog (Mohos-tőzezláp) is a protected natural area and part of the Natura 2000 ecological network (ROSCI0248, Tinovul Mohos - Lacul Sf. Ana). It is located in the central area of the East Carpathian massive (N 46°07'57", E 25°54'10"), in one of the twin volcanic craters of the Puciosu (Ciomatu) massive, northeast of Sfânta Ana lake, at 1050 m altitude. The total area of the bog is 80 ha. Present studies were carried out in four different habitats: (i) the central active bog area, divided in two microhabitat types, one corresponding to the *Sphagnetum magellanicum* (Malcuit 1929) Kästner & Flösser community (with *Scheuchzeria palustris* and *Andromeda polifolia* found next to peat bog lakes) and the other more peripheral *Eriophoro vaginati-Sphagnetum recurvi* Hueck 1925 association (hereafter together called the 'Mohos bog'); (ii) the wooded bog area with the characteristic occurrence of birch, located at the upper part of the water-course, where the dominant plant association is the *Vaccinio-Betuletum pubescentis* Libbert 1933 (referred to as 'Mohos birch'); (iii) the peripheral wooded bog area with Scots pine, situated at the eastern part of the mean water-course, where the dominant plant association is *Vaccinio-Pinetum sylvestris* Kleist 1929 em. Matuszkiewicz 1962 (referred to as 'Mohos pine') (Tanțău et al. 2003); (iv) the forest dominated by beech, which surrounds the peat bog at the east and south-east side, with the dominant plant association *Symphitocordati-Fagetum* Vida 1963 (referred to as 'Mohos beech') (Frink J. pers. com.).

Sampling and analysis

Spiders were sampled between 4th May 2003 and 12th October 2003 by pitfall traps (400 ml volume plastic jars) filled with ethylene-glycol solution as a preservative, mixed with some drops of detergent to enhance spider retention.

In the bogs we distinguished habitat patches, which were areas that represented one habitat type. Within a habitat patch we had one or two sites which were sampled by transects of five traps. Traps in a transect were linearly set out with 5 m distance between traps. In the four bogs there were nine habitat patches investigated, some of them with two sites. In total we had 15 sites each with a transect of traps (i.e. a total of 75 traps). The traps were emptied every month, altogether for 5 times (Table 1).

The species were determined using various keys (Roberts 1985, 1987, Heimer & Nentwig 1991). The nomenclature of spiders follows Platnick (2013). The material is deposited in the arachnological collection of the Department of Environmental Sciences, Sapientia Hungarian University of Transylvania.

To investigate the effect of habitat type on species richness, initially we fitted a linear mixed model using JMP v. 6 (SAS Institute 2005). Species richness was logarithm transformed to obtain normality. The model con-

Table 1. The sampled peat bogs, their location, site names and the habitat types. Area refers to bog area (wooded + open parts) without peripheral forest, the numbers in brackets refer to the area of the central open bog.

Bog name	Geographical coordinate	Altitude (m)	Area (ha)	Site name	Habitat type
Benes	N 46°12'55"	642	4 (4)	Benes bog 1	open bog
	E 25°54'05"			Benes bog 2	open bog
Borsaros	N 46°18'38"	651	1 (1)	Borsaros bog 1	open bog
	E 25°50'25"			Borsaros bog 2	open bog
Luci	N 46°18'03" E 25°43'14"	1080	120 (20)	Luci bog 1	open bog
				Luci bog 2	open bog
				Luci pine 1	wooded bog
				Luci pine 2	wooded bog
				Luci spruce 1	forest
				Luci spruce 2	forest
Mohoş	N 46°07'57" E 25°54'10"	1050	80 (40)	Mohoş bog	open bog
				Mohoş birch	wooded bog
				Mohoş pine 1	wooded bog
				Mohoş pine 2	wooded bog
				Mohoş beech	forest

tained the main effect 'habitat' and the random effect 'bog', which was found negligible and removed, because its variance ratio was less than 0.1, by which the model shrank to one-way ANOVA. Requirements of the fitted model was checked by plot diagnosis.

We performed Non-Metric Multidimensional Scaling (NMS) indirect ordination on species-location data applying Bray-Curtis distance measure using PCOrd 5. Ordination results were varimax rotated before depicting on graph (McCune & Mefford 2006). Shannon diversity index (Shannon 1948) was calculated for each site, and diversity measures were correlated with ordination scores of NMS axis 1 (after varimax rotation).

To test for relationship between dissimilarity matrices of sites in the species space and distances in the physical space, we applied Mantel test using PCOrd 5, where test probability was calculated with Monte-Carlo method (McCune & Mefford, 2006).

Sites were classified using Horn's overlap index for abundance data (Horn 1966). We have applied an Indicator Species Analysis (Dufrene & Legendre 1997) at three levels of this classification. Indicator species were regarded significant, if the probability of receiving higher indicator value in Monte Carlo simulation was below 0.1.

Results and discussion

Faunistic results

The epigeic spider fauna was studied in 4 different bogs (Benes, Borsaros, Luci and Mohoş) and their surroundings, in 9 habitat patches (4 open bogs, 3 wooded bogs and 2 forests) containing 15 sampling sites. A total number of 3316 spider specimens, belonging to 100 species from 18 families were registered during the investigation. From the collected spiders *Cnephalocotes obscurus* (Blackwall,

1834) from the Linyphiidae family, collected in the Mohoş peat bog (Urák & Samu 2008), Benes bog (Urák & Máthé 2011) and the Luci peat bog (Urák & Máthé 2013) was a new record for the Romanian arachnofauna. Some other rare species were also identified: *Notioscopus sarcinatus* (O. P.-Cambridge, 1872) from the family Linyphiidae collected in Mohoş peat bog and *Gnaphosa nigerrima* L. Koch, 1877 from the family Gnaphosidae, collected in Mohoş and Borsaros bogs (Urák & Samu 2008, Urák & Máthé 2011). The presence of these species was confirmed recently from other Transylvanian peat bogs (Gallé & Urák 2001, 2002).

Faunistic results can be evaluated by considering the habitat affinities of characteristic and dominant species. Dominant species of the peat bog complex formed a separate group and were well isolated from surrounding communities. The two spruce forest sites around Luci bog were very similar, dominated by *Cybaeus angustiarum* ($\geq 60\%$) whereas *Pardosa sphagnicola* in Luci bog and *Pirata uliginosus* and *Trochosa spinipalpis* in Luci pine were the dominant species. In the Mohoş bog there were also contrasting differences between dominant species of the surrounding beech forest (*Inermocoelotes inermis* and *Coelotes terrestris*) and the dominant species of the bog (*Aulonia albimana* and *Euryopis flavomaculata*). These latter species were not dominant at any other sites. *Trochosa spinipalpis* and *Piratula hygrophila* appear as dominant species in three different sites: *T. spinipalpis* was dominant in Benes bog, Borsaros bog and Luci pine, while *P. hygrophila* was dominant in Borsaros bog, Mohoş birch and Mohoş pine. Over-

all, it can be said that the proportion of bog species decreased and those of woodland species increased along gradients between these habitats, most likely because of shadowing effect of canopy and the presence of litter. The results presented by other authors also showed low similarities between spider communities of peat bogs and surrounding woodland habitats (Schikora 1997, Rupp 1999, Löser et al. 1982, Relys & Dapkus 2002). This supports the assumption that, while buffer forests are important for the physical preservation of the bogs, faunal interactions are very restricted between these habitat types (Relys & Dapkus 2002).

Species richness patterns

The highest numbers of individuals and species were found in Benes and Borsaros bogs, the lowest numbers in 'Luci spruce 2' and 'Mohoš pine 2' (Fig. 1). The number of specimens varied between 77 in 'Mohoš pine 2' and 435 in 'Benes bog 1'. Five species: *Piratula latitans*, *Pocadicnemis pumila*, *Trochosa spinipalpis*, *Walckenaeria atrotibialis*, *Drassyllus pusillus* occurred in all 4 investigated bogs, but no species occurred in all 15 sampling sites. 29 species (29% of species) were represented by only one specimen.

Species richness values were markedly different between the habitats. If we distinguish three main habitat types, such as open bog, wooded bog and forest habitats (Table 1), then it is apparent that open bog is the habitat with the highest spe-

cies richness (Fig. 2). Statistically the effect of habitat type was highly significant (one-way ANOVA, effect of species number: $F=7.104$, $d.f.=2.12$, $P=0.009$), and in a contrast analysis open bog richness was significantly higher than richness of other habitat types ($d.f.=1,12$, $F=12.554$, $P=0.004$).

Open bogs proved to be the richest habitats, followed by wooded bogs, and forest were the poorest. This is an opposite trend to what was found in the boreal region, where forest were more species rich than bogs (Kamayev 2012), however, at more southern locations in Europe open bogs were more species rich than forest sites (Biteniekytė & Relys 2008), similarly to our findings. A study of 11 bogs in western England found highest naturalness index of spiders in the open bogs (Scott et al. 2006). In the boreal study uniform oligotrophic bogs were the poorest in spider species and more heterogeneous mesotrophic bogs were more species rich in comparison. This suggests that microhabitat heterogeneity might be a key factor why Central European bogs were so species rich.

While we have hypothesised that according to the island-biogeography theory (MacArthur & Wilson 1967) larger bogs will have higher species richness, this was not the case. Statistical evaluation is difficult, because only four bogs were investigated. If we considered the most comparable open bog habitats, then species numbers were not significantly correlated with the open bog area,

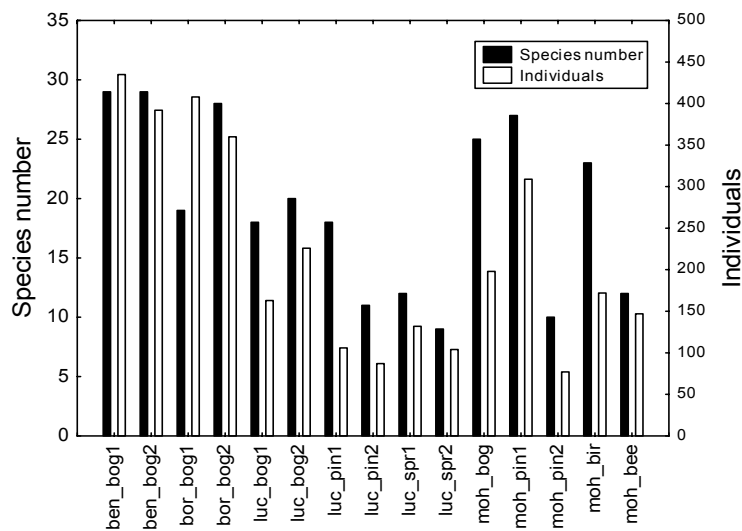


Figure 1. Individuals and species numbers by sampling sites. Site names are abbreviated, containing first three characters of bog name and habitat (see Table 1).

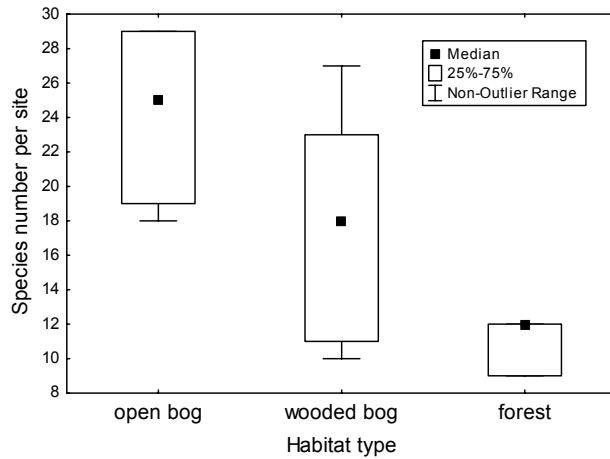


Figure 2. Species richness (number of species) at sites grouped by main habitat type.

but the sign of the relationship was negative ($r = -0.28$, $d.f. = 5$, $t = -0.62$, N.S.). Qualitatively considering the whole data set, the two smaller bogs had overall the highest species richness. Similar “inverse” island-biogeographic phenomenon was observed with herb layer species richness of bogs in Estonia (Liira et al., 2014). Edge effect and spill over from neighbouring habitats are two possible mechanisms that can be responsible for such an inverse relationship (Kajak 2007, Lopes Rodrigues et al. 2014). However, we think that real area effect cannot be deduced from the present data, not only because low number of replicates, but also because bog area was confounded by bog elevation (see Table 1).

Community structure

NMS ordination revealed high similarities between the spider communities belonging to the same habitat type (Fig. 3). The indirect ordination method revealed that habitat identity is an important factor of species composition. Bog habitats appear on the left side of the ordination, mature forest habitats (spruce and beech) are at the right side, while bog habitats wooded with pine and birch take a central position. We have extracted ordination scores for the NMS axis 1, and found that Shannon diversity is highly correlated with this axis ($r = -0.77$; $df. = 1,13$; $F = 18.91$, $P < 0.001$), with spruce and beech communities having the lowest diversity and bog habitats the highest (Fig. 4).

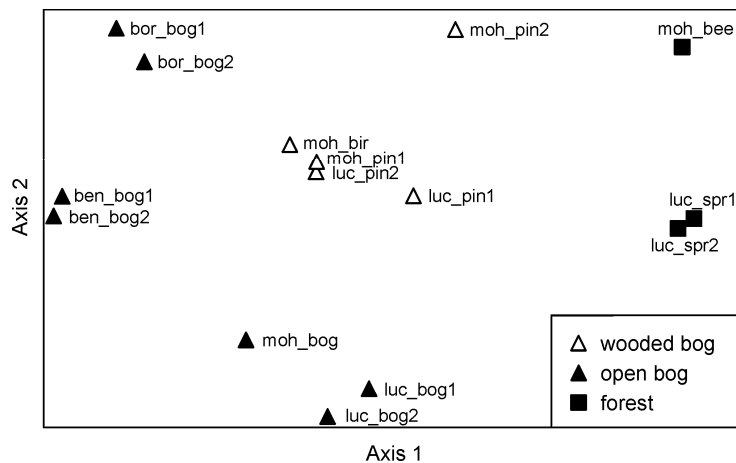


Figure 3. Ordination of the sites by spider species composition, using non-metric multidimensional scaling (NMS). Abbreviation of sites as in Fig. 1.

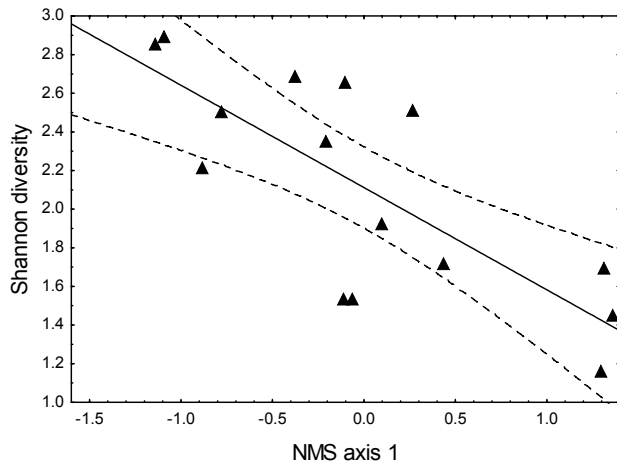


Figure 4. The relationship between the Shannon diversity index at the sites and the ordination scores of NMS axis 1.

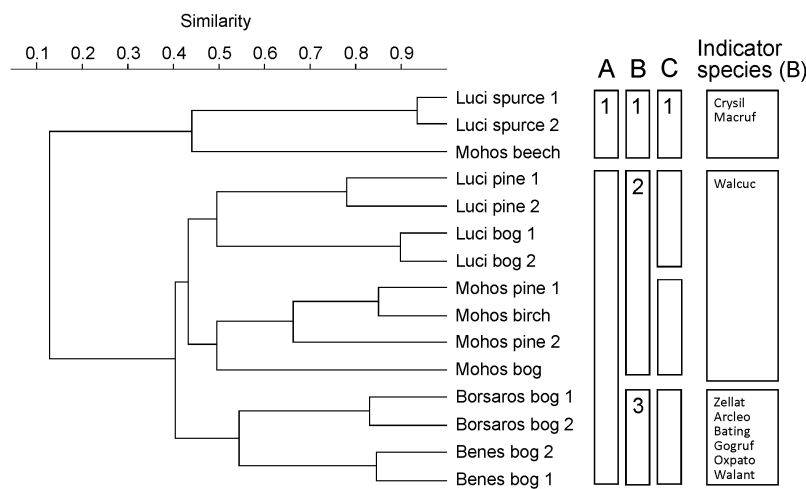


Figure 5. Similarity of studied spider communities (Horn-index) and significant indicator species ($P < 0.1$) at level "B" of the classification. Indicator species for group 1 are the same for all three levels.

While habitat identity was responsible for the coarse patterns in the ordination, a closer inspection reveals that sites physically closer to each other had more similar species compositions. The importance of distance was also shown by the case of the Mohos pine habitat, where sites of the same habitat (pine 1 and 2) were physically further than the distance to a site in another habitat (birch). The ordination of these three sites more reflected the distance structure than actual habitat identity (Fig. 3). As a general test for the importance of physical distance influencing species composition we applied a Mantel test, which indicated significant congruence between species dissimilarity matrix of the sites (Bray-Curtis distance measure) and the

Euclidian physical distance matrix of the sites ($r = 0.294, P = 0.006$).

We have conducted Indicator Species Analysis at three different levels of the habitat classification (Fig. 5). This revealed a strong separation of the spruce-beech forests, which had two constant indicator species: *Cryphoea silvicola* and *Macrargus rufus*. In other habitats only the medium-coarse habitat classification resulted in significant indicator species of the classified habitats, while in even coarser and finer groupings had no indicator species, showing that characteristic habitat distinctions by indicator species occur only at certain similarity levels (Fig. 5).

Site classification and indicator species analy-

sis yielded the same result as ordination. Smaller scale similarity was most strongly influenced by physical proximity. Transects close to each other were always very similar, if wooded and open bog habitats were considered. However, the greatest separation occurred between the forest and the bog habitats, thus significant habitat differences overwrote proximity effects.

The biggest species similarity was registered between the closely located bog sites. From all bog sites situated at higher altitudes (1080 and 1050 m) there was a single common indicator species (*Walckenaeria cucullata*), and the other four sites of bogs situated at lower altitudes (642 and 651 m) had 6 common indicator species (*Zelotes latreillei*, *Arctosa leopardus*, *Bathyphantes nigrinus*, *Gongylidium rufipes*, *Ozyptila atomaria*, *Walckenaeria antica*) (Fig. 5). While overall spider community made a distinction between wooded and open bogs, species that showed strong indicator power at intermediate classification level, seemed to react to altitude. The general similarity between open bogs and wooded bogs and dissimilarity to forest habitats was also found in a Lithuanian study (Biteniekytė & Relys 2008).

Conclusions

The faunistic investigations revealed a rich and variable fauna of the studied bogs, and led to reports of species new to the Romanian fauna or otherwise rare. Some sites shared dominant species, but the Mohoş bog had its distinct dominant species. Dominant and characteristic species of the bog areas were always different from the surrounding mature forests, therefore significant faunal exchange cannot be expected between these habitats.

In terms of spider species richness among the studied habitats open bogs were the richest, wooded bogs intermediate and forest proved to be the poorest. There was a broad similarity between the species composition of open bogs and wooded bogs, while forest assemblages were distinct. Similarity of species composition in the communities of the open bog, pine bog and birch bog was expected, as all of them have a ground layer of *Sphagnum* spp. and other low-growing acidophilous plants. These bogs are habitat islands that provide ultimate refuge, in addition to the many relict plant species, for characteristic spider communities with bog specialist spider species.

In nature conservation the value of small reserves is always a question. The present study definitely showed the value of small bogs, which in fact showed greater species richness than the two larger area bogs. While statistical inference about a reverse species-area pattern could not be drawn because of the confounding effect of altitude, the importance of small bogs is established here.

Distance played a significant role in determining the species composition of bogs. Separateness interacted with habitat similarity in a way, that if habitats were very different (forest versus bog) then habitat difference was decisive, but among bog sites more proximal sites were also more similar in spider species composition.

To sum up, bogs are very species rich habitats which harbour specialist species, with small bogs being at least as rich as bigger ones. The studied bogs scattered about a relatively large geographical area, and all contributed unique species to the larger scale 'bog species pool' of the region, therefore increased protection measures for each and all of them are recommended.

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