″Babeş-Bolyai″ University Cluj-Napoca
Faculty of Biology and Geology

LYCOSIDAE FROM SPECIAL HABITAT COMPLEXES IN NORTH-WESTERN ROMANIA

- Summary of the PhD thesis -

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Keywords: Lycosidae, distribution, Câmpia Careiului, ecology, forests, marshes, grasslands, reproduction, thermal habitats, north-western Romania

Chapter 1. General introduction

1.1. Introduction

Spiders are abundant in various types of terrestrial habitats and are predatory organisms that feed mainly on insects, but also on other arthropods, including spiders (Wise 1993). Several studies have shown that spider species are a suitable model group to highlight changes in the structure, quality of a habitat (Bonte et al. 2006, Blaum et al. 2009, Buchholz 2010) and can be used even in assessing the conservation importance of a region (Cardoso et al. 2004, Scott et al. 2006).

Wolf spiders (Araneae: Lycosidae) are found in wide variety of habitats, do not build webs and capture their prey either by staying in ambush or by actively hunting (Foelix 2011). They usually move on the soil surface, in the leaf litter (Wise 1993), though some species live in burrows dug into the ground (Bonte et al. 2006). The structure and composition of wolf spider assemblages change along with modifications in vegetation cover, humidity of habitat, sand dynamics, anthropogenic stress etc. (Zulka et al. 1997, Bonte et al. 2006, Buchholz 2010, Horváth et al. 2012). Within lycosids there are species that prefer natural habitats as well as species with a preference for disturbed habitats (Buchar & Růžička 2002, Kovács et al. 2009).

Data on populations of Lycosidae in Romania are far from satisfactory. Thus, there is a need to conduct detailed studies on the wolf spider assemblages from different habitats, to examine the variations in their abundance, distribution and activity.

1.2. Aim, structure and objectives of the thesis

The aim of this PhD thesis consisted of obtaining faunistic and ecological data on the spiders from family Lycosidae (order Araneae) from complexes of special habitats from north-western Romania. The results to be presented on the pages of this thesis were gathered during research conducted in 2008-2009 and 2012-2014, thus totalling five years of investigations.

The general objectives of the thesis were:

- to establish the distribution of species of Lycosidae in "Câmpia Careiului" Natura 2000 site (**Chapter 3**);
- to investigate Lycosidae assemblages from different types of forest habitats in north-western Romania (**Chapter 4**);
- to investigate Lycosidae assemblages from different open and semi-open habitats in north-western Romania (**Chapter 5**);
- to investigate Lycosidae assemblages across a forest-grassland ecotone in north-western Romania (**Chapter 6**);
- to pursue the monthly dynamics of individuals, to analyse the sex ratio and to determine the reproductive period of different species (**Chapter 7**);
- to study Lycosidae assemblages active during winter near some thermal waters in western Romania (**Chapter 8**).

1.3. Acknowledgements

The accomplishment of this study was only possible with the aid of many people, to which I would like to thank here. First of all I am grateful to Prof. Dr. Rákosy László for his understanding and support in preparation of this thesis. I also want to thank Mr. Dr. Urák István for his priceless help and patience in identifying the species and for suggesting some useful bibliographic sources. I thank the members of my Guidance Committee: Mr. Dr. Crişan Alexandru, Mr. Dr. Markó Bálint and Mr. Dr. Teodor Lucian Alexandru for their ideas and suggestions that significantly improved this thesis. I also want to thank Prof. Dr. Tomescu Nicolae for leading me to study spiders and for his aid during my PhD study.

The quantitative collections would not have been realised without the voluminous work done by Mr. Dr. Covaciu-Marcov Severus-Daniel and Miss Dr. Ferenţi Sára, to which I thank in this way, along to certain current and former students (BSc and MSc) that helped me in the fieldwork. It is necessary to convey the appropriate thanks to my husband Mr. Dr. Sas-Kovács István also, for his extraordinary patience and support both in the fieldwork and in the making of this thesis, for the creative ideas by which he contributed to this work, for the confidence he had in me.

I am grateful to the anonymous reviewers for the following journals: Archives of Biological Sciences, Journal of Natural History, Turkish Journal of Zoology and Biharean Biologist, for their critical comments and suggestions on the published or pending publication papers, which helped to improve the interpretation of the results of this thesis.

Research in the protected areas was possible due the agreement given by their custodians: Freies Europa Weltanschauung Foundation and Transylvanian Carpathian Society.

Chapter 2. Characterization of the study region

The study region is located in north-western Romania, and from the administrative point of view it belongs to Bihor (its northern part) and Satu Mare counties. In this chapter there are described the areas where, in order to study Lycosidae assemblages, quantitative samples were collected using pitfall traps (fig.1.). Two of the Natura 2000 sites present in the region are also described ("Câmpia Careiului" and "Râul Tur"), because a large part of the investigations were taken in their territory (especially in the "Câmpia Careiului" site).

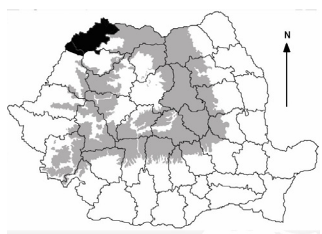


Fig. 1. Position of habitats where quantitative studies on Lycosidae assemblages have been conducted (web source: www.pe-harta.ro – modified)

Chapter 3. Distribution of the Lycosidae species in the "Câmpia Careiului" Natura 2000 site (ROSCI0020)

Results from this chapter in:
Sas-Kovács, É.H., Sas-Kovács, I., Urák, I. (2014): *Alopecosa psammophila* Buchar, 2001 (Araneae: Lycosidae): morphometric data and first record for Romania. Turkish Journal of Zoology, DOI: 10.3906/zoo-1404-11. [IF_{2013}=0.585]
Sas-Kovács, É.H., Sas-Kovács, I. (2014): Note on the distribution of *Geolycosa vultuosa* (Araneae: Lycosidae) in the "Câmpia Careiului" Natura 2000 site, north-western Romania. Biharean Biologist 8(2): art.141204. [$SNIP_{2013}$=0.615]

3.1. Introduction

With 2391 described species (Platnick 2014) the family Lycosidae Sundevall, 1833 represents the fifth largest spider family in the world in terms of species richness. According to the latest national checklist of spiders, that of Weiss and Urák (2000), there were 81 species of Lycosidae in Romania, but nowadays that number has reached 85 due to four species reported as new for Romania's fauna (Urák 2001, Adam 2007, Uruci & Duma 2007, Moscaliuc 2012, Sas-Kovács et al. 2013 – from the results of this PhD thesis).

The "Câmpia Careiului" Natura 2000 site represent a natural area whose general feature is given by the tessellated arrangement of its dry (sand dunes, sandy grasslands) and wet (marshes, wet meadows) habitats (Covaciu-Marcov et al. 2009), which ensures the existence of a diverse fauna with many rare species (Covaciu-Marcov et al. 2009, Ferenți et al. 2012, Hoffmann & Hoffmann-Berei 2014). Determination of species occurring in a given area is the first step to establish the importance of that area for the protection of flora and fauna (van Helsdingen 1997). This chapter presents the distribution of the Lycosidae species in the surveyed habitats of the "Câmpia Careiului" Natura 2000 site.

Specific objectives of the chapter:

i.) to define the species of Lycosidae occurring in the "Câmpia Careiului" site and to establish their distribution in the protected area; ii.) zoogeographical analysis of the identified species; iii.) to analyse the species diversity and co-occurrence.

3.2. Materials and methods

The "Câmpia Careiului" site (ROSCI0020) (47°37′08″ N, 22°11′59″ E) covers an area of 23,597 ha (ROSCI0020-ForStdNat 2000). Samples were collected directly by hand or with tweezers as well as with pitfall traps, fig.2. showing the surveyed zones. Direct sampling was done between April 2012 and June 2014 and several transects were made in every habitat to capture the species. Pitfall traps were used in 11 habitats in the period April to September 2008 and in nine habitats during September 2013-present. Species were identified based on the literature (Tongiorgi 1966, Fuhn & Niculescu-Burlacu 1971, Heimer & Nentwig 1991, Loksa 1972, Roberts 1985, Hepner & Milasowszky 2006, Nentwig et al. 2014), the nomenclature being according to Platnick (2014). The surveyed habitats were divided into five main categories: dunes (with three subcategories), wetlands (with five subcategories), grasslands (with four subcategories), forests (with seven subcategories) and agricultural lands (with three subcategories). For the chorological analysis we used as guide the work of Schröder et al. (2011), the general distribution of species being taken from Platnick (2014).

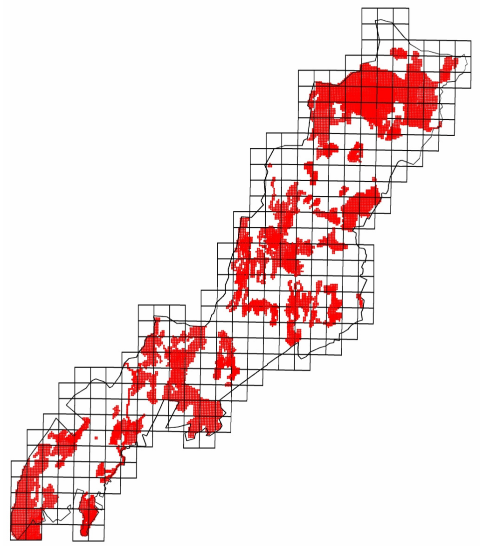


Fig.2. The surveyed zones in the "Câmpia Careiului" site (1x1 km UTM grid, dots represent 100x100 m)

3.3. Results and discussion

Following the investigations carried out during the years 2008, 2012 to 2014 we obtained 312 samples from about 151 habitats and we identified 34 species of Lycosidae within the site (table 1.), representing 40.47% of the species known for the country.

3.3.1. Species of Lycosidae in the "Câmpia Careiului" site – distributional data

Alopecosa accentuata was identified in 19 habitats, belonging to 49 squares and concentrated mainly in the central and northern part of the area (fig.3.), being a quite well represented species in the protected area. *A. cuneata* was identified in only five squares, located in the northern part and at the southern extremity of the area (fig.3.), thus being a rare species in the surveyed site. *A. cursor* was present in 32 squares (fig.3.) in habitats represented by more or less fixed sand dunes, sand pits and in xerophilous grasslands (table 1.). *A. mariae* is a species quite well represented in the protected area, being found in 39 squares (fig.3.). It occurs in the area both in natural habitats and in those subjected to intensive grazing. *A. psammophila* was found in four squares (fig.3.), in two habitats represented by xerophilous sandy grasslands, in Romania the species being reported for the first time during this study. *A. pulverulenta* was identified in 48 squares occupied by various habitats: sand dunes, wetlands, wet and mesophilous grasslands, forest edges, areas with birch, black locust plantations (fig.3., table 1.). One of the best represented species in the investigated protected area is *A. schmidti*, identified in 55 squares (fig.3.). *A. sulzeri* was present only in the traps located in the edge of the oak forest from Foieni (fig.3.), the species in question being considered a bioindicator of well preserved steppe habitats, being common in the edge zone of warm oak forests (Košulič & Hula 2012).

Arctosa leopardus is a fairly common species in the surveyed area being found in 58 squares (fig.3.). It is a regular and abundant inhabitant of the banks of both ditches and various standing waters from the site. *Ar. lutetiana* is a rare species in the area, present in 14 squares (fig.4.) occupied by certain sectors of the oak forest from Foieni. *Ar. perita* is a rare

Table 1. List of Lycosidae species captured in the "Câmpia Careiului" site
[abbreviations: *Species*: *A.=Alopecosa*, *Ar.=Arctosa*, *Au.=Aulonia*, *G.=Geolycosa*, *L.=Lycosa*, *P.=Pardosa*, *Pa.=Pirata*, *Pu.=Piratula*, *T.=Trochosa*, *X.=Xerolycosa*; *Habitats*: A=sand dune ± fixed, B=(dune with) quarry, C=dune with black locust; D=xerophilous grassland, E=wet grassland, F=mesophilous grassland, G=glade; H=marsh, I=ditch, J=pond, K=wet hollow, L=lake (reservoir); M=oak forest, N=mixed forest, O=black locust plantation, P=ash forest; Q=forest edge, R=area with poplar, S=area with birch; T=former vineyard, U=former orchard, V=fallow; *Method of collection* (Mc): a=directly by hand, b=with pitfall traps; *Distribution* (Distr.): c=chorological type (Pa=palearctic, Eur=European, Ho=holarctic, TM=Turano-Mediterranean, EA=European-Central Asian), d=category of elements (Ws=widespread, Eu=European, Es=eastern)]

Species	Habitats																						Mc		Distr.	
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	a	b	c	d
A. accentuata	x	x	x	x	x	x		x							x					x			x	x	Pa	Ws
A. cuneata	x	x	x												x								x	x	Pa	Ws
A. cursor	x	x		x																			x	x	Pa	Ws
A. mariae	x	x	x	x		x			x											x	x		x	x	Pa	Ws
A. psammophila				x																			x		Eur	Eu
A. pulverulenta	x	x	x		x	x		x	x		x	x			x		x		x				x	x	Pa	Ws
A. schmidti	x	x	x	x		x														x	x		x	x	Pa	Ws
A. sulzeri																	x							x	Pa	Ws
Ar. leopardus								x	x	x	x	x											x	x	Pa	Ws
Ar. lutetiana													x				x							x	Eur	Eu
Ar. perita		x		x																		x	x	x	Ho	Ws
Au. albimana								x									x		x				x	x	Pa	Ws
G. vultuosa	x	x	x	x		x																x	x		TM	Es
L. singoriensis		x																					x		Pa	Ws
P. agrestis	x	x		x	x	x			x		x	x										x	x	x	Pa	Ws
P. alacris	x	x						x	x		x		x	x	x	x	x	x					x	x	Eur	Eu
P. amentata								x	x			x											x		Eur	Eu
P. bifasciata	x	x		x				x									x						x	x	Pa	Ws
P. lugubris																x							x		Pa	Ws
P. maisa					x			x	x		x						x						x	x	Eur	Eu
P. nebulosa		x																					x	x	Pa	Ws
P. paludicola									x			x							x				x		Pa	Ws
P. palustris	x	x				x					x									x			x		Ho	Ws
P. prativaga	x				x	x	x	x	x	x	x	x											x	x	Eur	Eu
P. proxima	x	x	x		x	x		x	x		x	x		x									x	x	Pa	Ws
Pa. piraticus		x						x	x		x	x											x	x	Ho	Ws
Pa. piscatorius								x																x	Pa	Ws
Pa. tenuitarsis					x			x	x	x	x												x	x	EA	Eu
Pu. hygrophila								x	x	x	x												x	x	Pa	Ws
Pu. latitans	x	x			x		x	x	x	x	x	x											x	x	Eur	Eu
T. robusta	x																			x				x	Pa	Ws
T. ruricola	x	x			x			x	x		x	x											x	x	Ho	Ws
T. terricola	x	x						x	x		x		x		x		x			x				x	Ho	Ws
X. miniata	x	x	x	x	x	x		x	x		x			x			x			x	x	x	x	x	Pa	Ws

species, identified in only five squares (fig.4.). It is threatened here by loss of typical habitats i.e. areas with bare sand.

Aulonia albimana is a rare species in the surveyed protected area, identified in nine squares (fig.4.). The occupied habitats are represented by forest edges, area with birch and a marsh located near the oak forest from Foieni (table 1.). *Geolycosa vultuosa* occurred in 19 squares, most of them located within a radius of 3-4 km (fig.4.). The occupied habitats are mainly represented by xerophilous grasslands and to a lower extent by sand dunes and fallows. There is a possibility that the species will spread in the site due to the intensive grazing of many grasslands which creates favourable habitats for *G. vultuosa*. *Lycosa singoriensis* was found in a single square (fig.4.) occupied by a portion of the sand pit near Valea lui Mihai, a sand pit that has both wet and dry sectors. *L. singoriensis* is an extremely rare and vulnerable species in the area, which requires strict protection.

Pardosa agrestis is a common species in the protected area, identified in 71 squares (fig.4.) and occupying different habitats, both dry and wet ones. *P. alacris* is the best represented species in the investigated site, being identified in 144 squares (fig.4.). The occupied habitats are various, but prevail the forests (e.g. oak, ash, black locust) (table 1.). *P. amentata* has been identified in 24 squares of the site (fig.4.). In the protected area *P. bifasciata* is quite rare; it occurs in 18 squares (fig.4.). The main occupied habitats are sand dunes, especially those with rich herbaceous vegetation, and xerophilous grasslands. *P. lugubris* was found in three squares (fig.5.) which belongs to a single habitat, namely the ash forest near Urziceni, which is a natural forest reserve (ROSCI0020-ForStdNat 2000). *P. maisa* is a rare species, present in nine squares (fig.5.), the occupied habitats having in common the presence of moisture. It was reported from the first time in Romania, in the "Câmpia Careiului" site, following research undertaken during this PhD study (Sas-Kovács et al. 2013). In the surveyed area *P. nebulosa* was found in only one square (fig.5.) occupied by a wet sector of a sand pit, where ponds are formed during rainy periods. *P. paludicola* is a rare species in the site, identified only in four squares (fig.5.). *P. palustris* is a moderately common species in the protected area, occurring in 35 squares (fig.5.). *P. prativaga* is quite well represented, being identified in 54 squares (fig.5.); the species preferred habitats are those that have high humidity. The distribution points of *P. proxima* are quite numerous in the surveyed area, the species being found in 56 squares (fig.5.). The occupied habitats belong to four categories and ten subcategories (table 1.), the individuals of the species being more numerous in certain wetlands such as ditches and marshes.

Pirata piraticus was identified in 30 squares of the area (fig.5.), covered by marshes, ditches, wet hollows and moist shores of a lake. *Pa. piscatorius* is a rare species in the site, identified in only four squares (fig.5.), but taken into account that the occupied habitat (Vermeş Marsh) is a natural reserve (ROSCI0020-ForStdNat 2000) its presence in the area should be ensured. *Pa. tenuitarsis* was identified in 21 squares of the study area (fig.6.) and it inhabits the vegetation from the shores of both natural marshes and artificial ditches. *Piratula hygrophila* was identified in 18 squares (fig.6.), in humid habitats with arboreal vegetation. *Pu. latitans* is fairly well represented, being identified in 48 squares (fig.6.) occupied by three habitat categories, with the prevalence of wetlands.

Trochosa robusta is a rare species in the protected area, identified in only seven squares (fig.6.). *T. ruricola* is better represented as it occurs in 41 squares (fig.6.). *T. terricola* is an even better represented species in the site, occupying 51 squares (fig.6.). *Xerolycosa miniata* is one of the most common species of Lycosidae in the investigated area, being identified in 72 squares (fig.6.). The species prefers open and dry habitats (Szinetár & Keresztes 2003), which are characteristic to this Natura 2000 site.

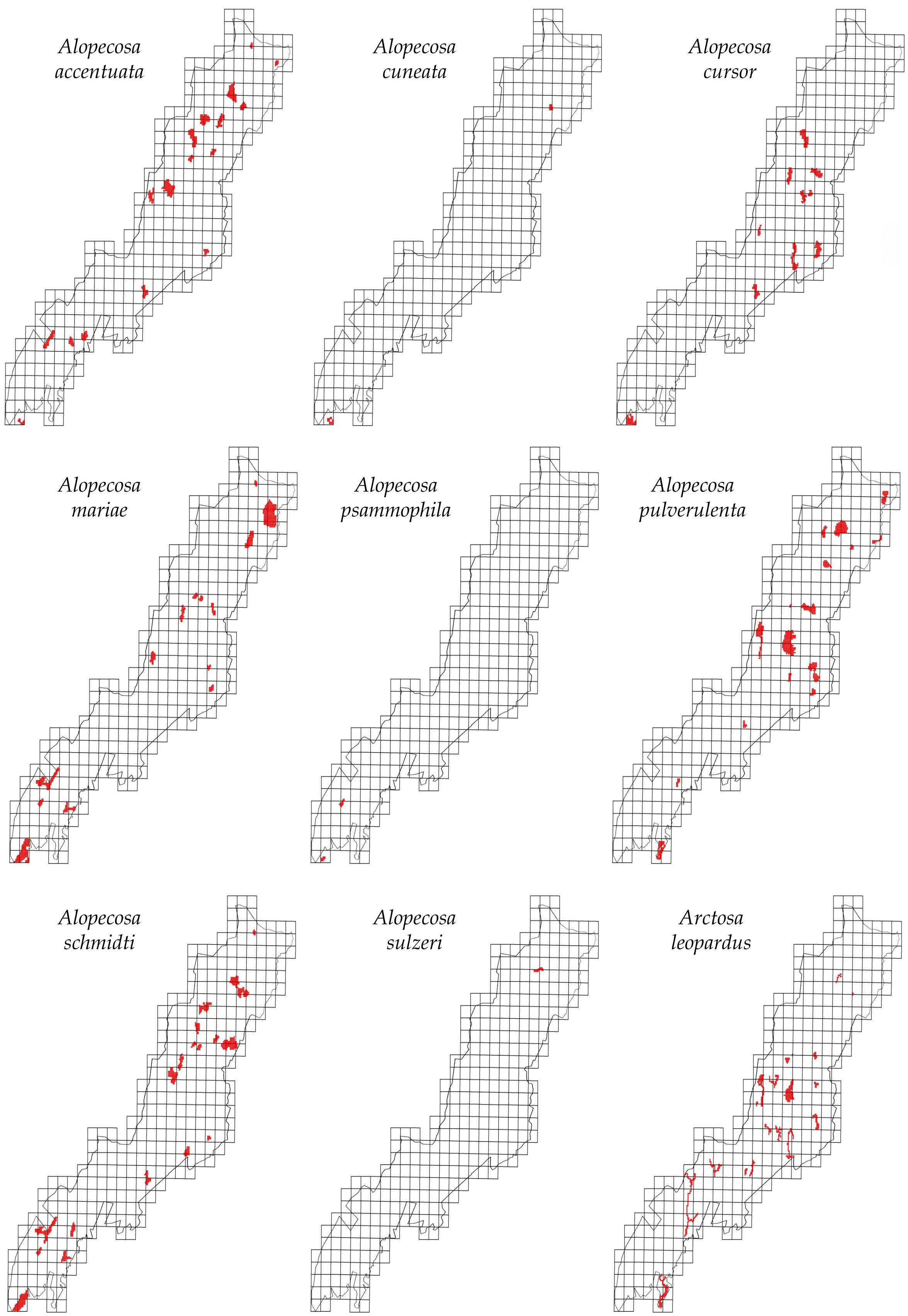


Fig.3. Distribution of *Alopecosa accentuata*, *A. cuneata*, *A. cursor*, *A. mariae*, *A. psammophila*, *A. pulverulenta*, *A. schmidti*, *A. sulzeri* and *Arctosa leopardus* in the "Câmpia Careiului" site (1x1 km UTM grid, dots represent 100x100 m)

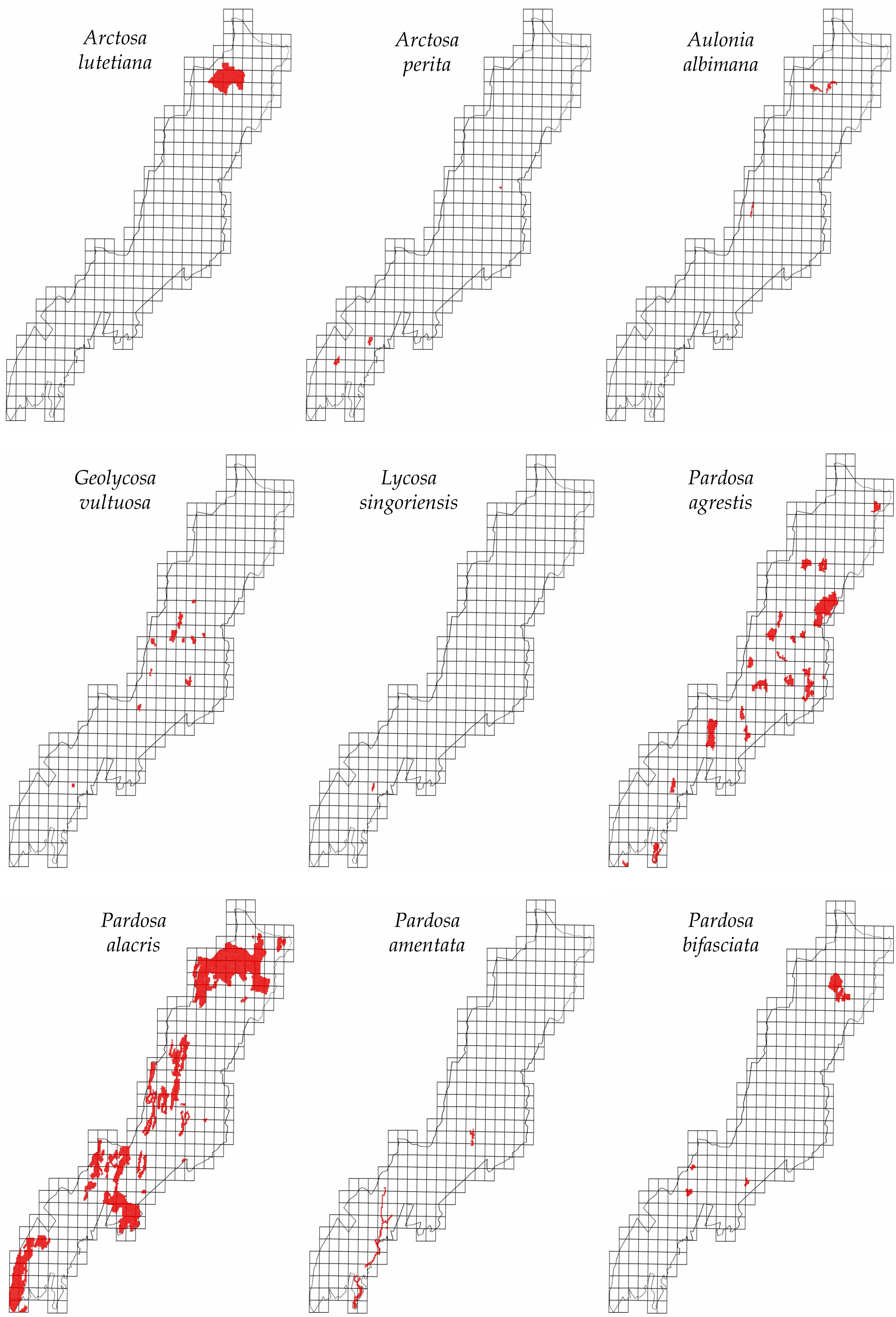


Fig.4. Distribution of *Arctosa lutetiana*, *Ar. perita*, *Aulonia albimana*, *Geolycosa vultuosa*, *Lycosa singoriensis*, *Pardosa agrestis*, *P. alacris*, *P. amentata* and *P. bifasciata* in the "Câmpia Careiului" site (1x1 km UTM grid, dots represent 100x100 m)

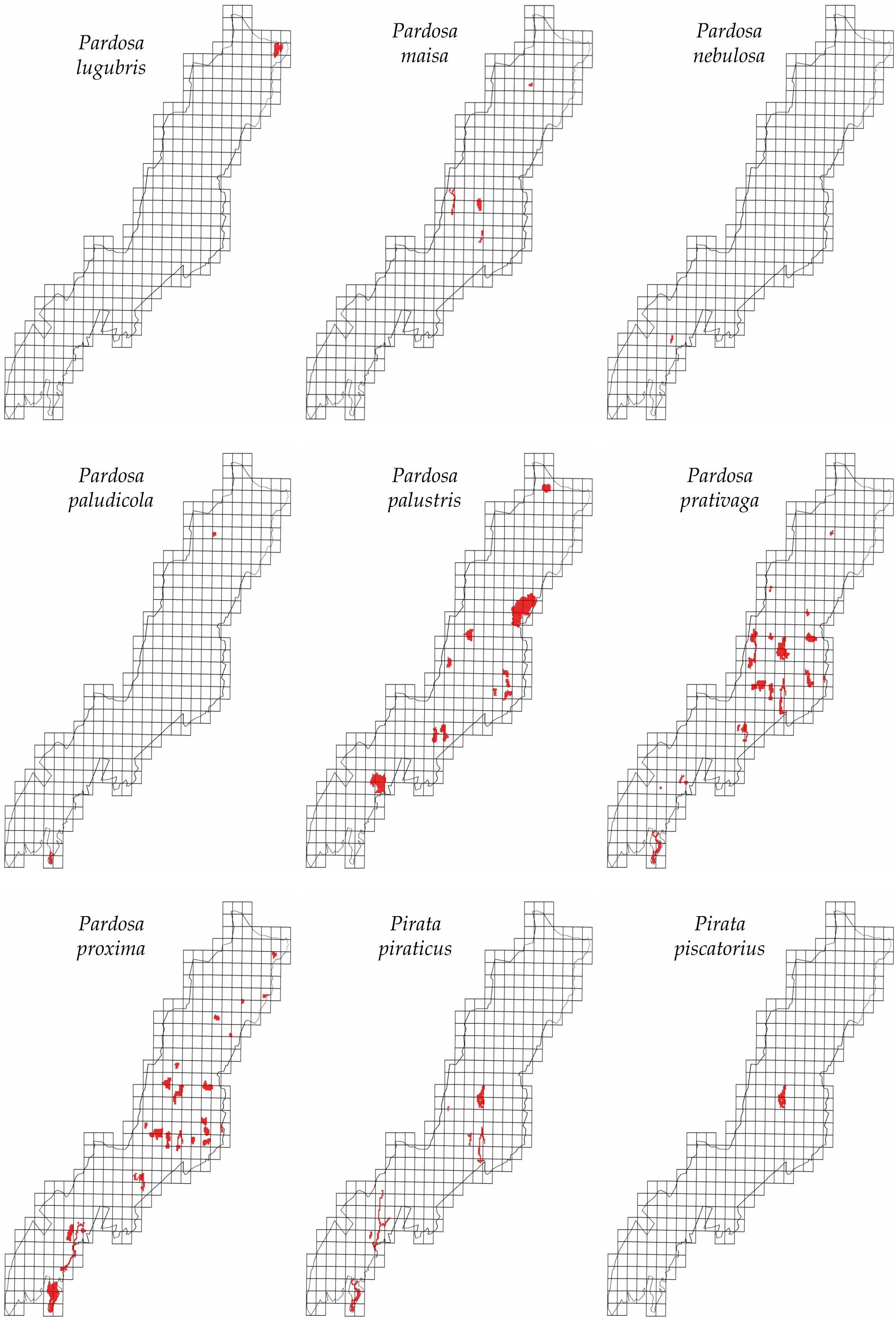
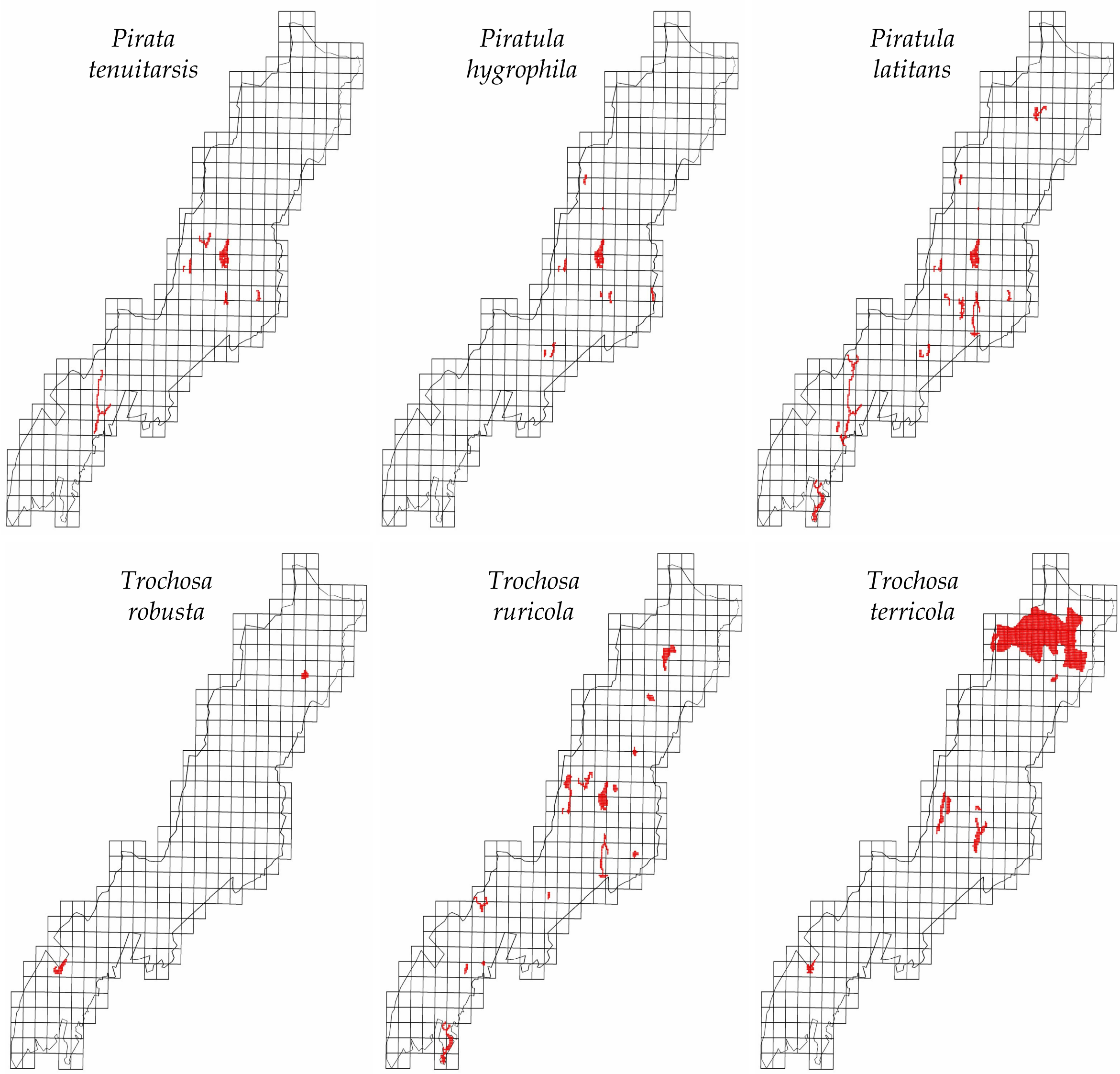


Fig.5. Distribution of *Pardosa lugubris*, *P. maisa*, *P. nebulosa*, *P. paludicola*, *P. palustris*, *P. prativaga*, *P. proxima*, *Pirata piraticus* and *Pa. piscatorius* in the "Câmpia Careiului" site (1x1 km UTM grid, dots represent 100x100 m)



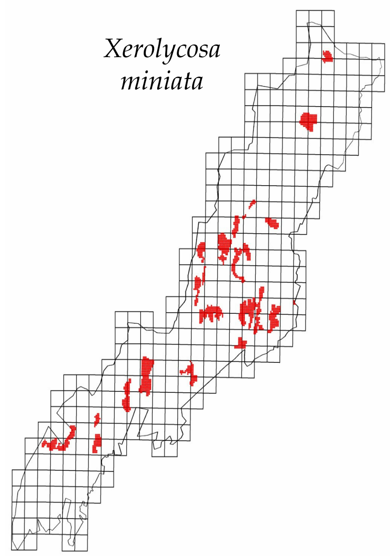


Fig.6. Distribution of *Pirata tenuitarsis*, *Piratula hygrophila*, *Pu. latitans*, *Trochosa robusta*, *T. ruricola*, *T. terricola* and *Xerolycosa miniata* in the "Câmpia Careiului" site (1x1 km UTM grid, dots represent 100x100 m)

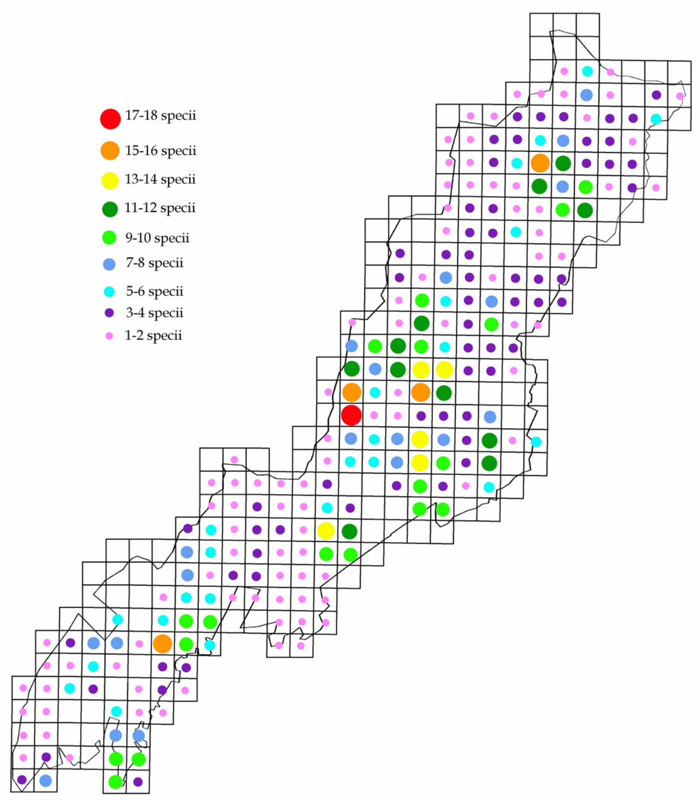
3.3.3. Zoogeographical analysis of the Lycosidae species from the study area

According to their current distribution, the 34 species of Lycosidae that were identified in the protected area "Câmpia Careiului" can be classified into five chorological types grouped into three categories: widespread, European and eastern elements (table 1.). The first category is the best represented, comprising 25 species.

3.3.4. Habitat categories, species diversity and co-occurrence

Sand dunes and wetlands were the richest in species of Lycosidae, each category being inhabited by 22 species (by 64.70% of all determined species). The lowest number of species was identified in the agricultural lands, whilst grasslands and forested areas have a mean position (table 1.).

The areas with the highest species diversity are those located in the centre of the area near Scărişoara Nouă (three squares), in the northern part of the area west of Foieni locality (one square) and in the southern part of the area west of Valea lui Mihai (one square), with 15-18 species of Lycosidae / 1x1 km square (fig.7.).



3.4. Conclusions

- We have identified 34 species of Lycosidae in the "Câmpia Careiului" Natura 2000 site, of which two species (*A. psammophila* and *P. maisa*) are reported for the first time in Romania. 73.52% are open habitat species, 8.82% are forest specialists and 17.64% are generalist species. A percentage of 38.23% of the species are xerophilous and 35.29% hygrophilous.
- The identified species of Lycosidae can be classified into five chorological types grouped into three categories: widespread (73.52%), European (23.52%) and eastern (2.94%) elements.
- The richest in species of Lycosidae are the zones located in the centre of the area near Scărişoara Nouă, in the northern part of the area west of Foieni locality and in the southern part of the area west of Valea lui Mihai, with 15-18 species of Lycosidae / 1x1 km square.
- Based on our field observations, in accordance with other studies (Buchholz 2010, Szatmari 2012, Horváth et al. 2013), in order to preserve and conserve the Lycosidae

assemblages we recommend the following management measures for dry sandy grasslands: increasing the connectivity of habitats, preventing the expansion of herbaceous and woody, adventive and invasive plants, maintaining vegetation-free patches through moderate grazing.

Chapter 4. Wolf spiders (Araneae: Lycosidae) in forest habitats from north-western Romania

Results from this chapter in:
Sas-Kovács, É. H., Urák, I., Cupşa, D., Sas-Kovács, I., Ferenți, S., Rákosy, L. Wolf spider (Araneae: Lycosidae) assemblages of a deciduous forest in north-western Romania. Submitted to Entomologia Generalis. [IF2013=0.286]

4.1. Introduction

Spiders are important elements of forest ecosystems because acting as predators they decrease the number of detritivores (Wise 2004), have the potential to reduce the number of some pests (Jennings et al. 1990) and are involved in maintaining a balance of insect communities (Ziesche & Roth 2008).

Given the fact that wolf spiders are a major component of ground-dwelling spider assemblages (Pearce et al. 2004, Horváth et al. 2012) and that their species richness is a good indicator of the overall spider species diversity, at least concerning boreal and arctic areas (Marusik & Koponen 2002), the aim of this study was to investigate the lycosid assemblages in several forest types from north-western Romania.

Specific objectives of the chapter:

i) to describe the composition and structure of lycosid assemblages in the investigated habitats; ii) to determine the existence of possible differences in the number, relative abundance, diversity of wolf spiders between habitats; iii) to determine the degree of similarity of the analyzed forest areas.

4.2. Materials and methods

The study of wolf spider assemblages was conducted in 12 habitats belonging to two categories: 'edge' (three oak forest edges, one mixed forest edge) and 'forest' (four oak forests, two mixed forests, two plantations), located in the vicinity of eight localities in Satu Mare county (table 2.). Spiders were collected using pitfall traps, during 2008 (habitats: Liv_liz, Liv_stj, ScN_sal, Foi_stj and Foi_liz) and 2009 (habitats: PoC_liz, PoC_am, Cuț_pin, Scd_am, Cru_stj, Săr_stj and Săr_liz).

To evaluate the effectiveness of the surveys we calculated seven nonparametric estimators of species richness using EstimateS software version 9.1.0. (Colwell 2013). Based on their values we determined the degree of inventory completeness and compared the species richness between habitats by constructing rarefaction curves rescaled to the number of individuals. The rank-abundance curves (Whittaker plots) were used to compare the patterns of species abundance between investigated habitats (Magurran 2004). The studied Lycosidae assemblages were also described using the Shannon diversity index (H), the equitability (J), the similarity indices Jaccard and Bray-Curtis and ordination using non-metric multidimensional scaling (NMS), all these analyses being performed with PAST program version 2.17c (Hammer et al. 2001). The significance of the differences between number of individuals and species, diversity, equitability between habitat categories were tested with the non-parametric Mann-Whitney U-test performed with the PAST program (Hammer et al. 2001) as well.

Table 2. The investigated forest habitats, their location, the number of pitfall traps in a habitat, name of habitats

Locality	Geographic coordinates	Altitude (m)	No. of traps / months	Habitat name (abbreviation)	Habitat type
Poiana Codrului (SM)	47°36'58.56" N, 23°14'52.34" E	279	4	Poiana Codrului edge (PoC_liz)	mixed forest (oak and beech) edge
	47° 37'04.09" N, 23°14'31.37" E	272	4	Poiana Codrului mixed (PoC_am)	mixed forest (oak and beech)
Cuța (SM)	47°33′35.25″ N, 22°57′56.71″ E	208	3	Cuța pine (Cuț_pin)	pine plantation
Socond (SM)	47°32′19.01″ N, 22°57′38.34″ E	193	4	Socond mixed (Scd_am)	mixed forest (oak and hornbeam)
Sărăuad (SM)	47°29′01.76″ N, 22°38′33.96″ E	175	4	Sărăuad oak (Săr_stj)	oak forest
	47°29′02.20″ N, 22°38′33.21″ E	152	4	Sărăuad edge (Săr_liz)	oak forest edge
Crucişor (SM)	47°41′09.29″N, 23°16′08.48″E	172	4	Crucişor oak (Cru_stj)	oak forest
Livada (SM)	47°51′00.50″ N, 23°13′46.55″ E	146	5	Livada edge (Liv_liz)	oak forest edge
	47°50′54.05″ N, 23°13′44.37″ E	145	5	Livada oak (Liv_ stj)	oak forest
Scărişoara Nouă (SM)	47°36′28.46″ N, 22°14′50.49″ E	143	3	Scărişoara Nouă black locust (ScN_sal)	black locust plantation
Foieni (SM)	47°43′12.16″ N, 22°18′53.80″ E	140	5	Foieni oak (Foi_stj)	oak forest
	47°43′05.21″ N, 22°18′58.01″ E	136	5	Foieni edge (Foi_liz)	oak forest edge

4.3. Results

We have identified a total number of 19 species of Lycosidae in the 12 habitats, of which only *Pardosa alacris* was found in all sectors. Altogether the forests ('forest') had 15 species and edges ('edge') had 16 species. The number of species found in a habitat varies between 2 and 11, being generally higher for edges (fig.8.). However, the difference between forests and edges concerning species richness is not statistically significant (Mann-Whitney test, $p>0.05$).

The indices estimated 17-21 species of Lycosidae for 'forest' and 16-17 species for 'edge'. The completeness level of the study varies greatly depending both on the habitat and the estimator took into consideration. For Foi_stj all estimators showed that the study was complete, as the level of completeness indicated by them was 100%. The lowest values were obtained for Liv_stj. Rarefaction curves did not show the existence of significant differences in the species richness between 'forest' and 'edge' since the 95% confidence intervals overlapped.

There were captured a total number of 3961 wolf spiders, of which 2326 were adults. Forests edges shelter, with one exception (Săr_liz), a higher number of wolf spiders (fig.8.), but due to this exception the number of individuals is not significantly higher in the edge than in the forest (Mann-Whitney test, p>0.05).

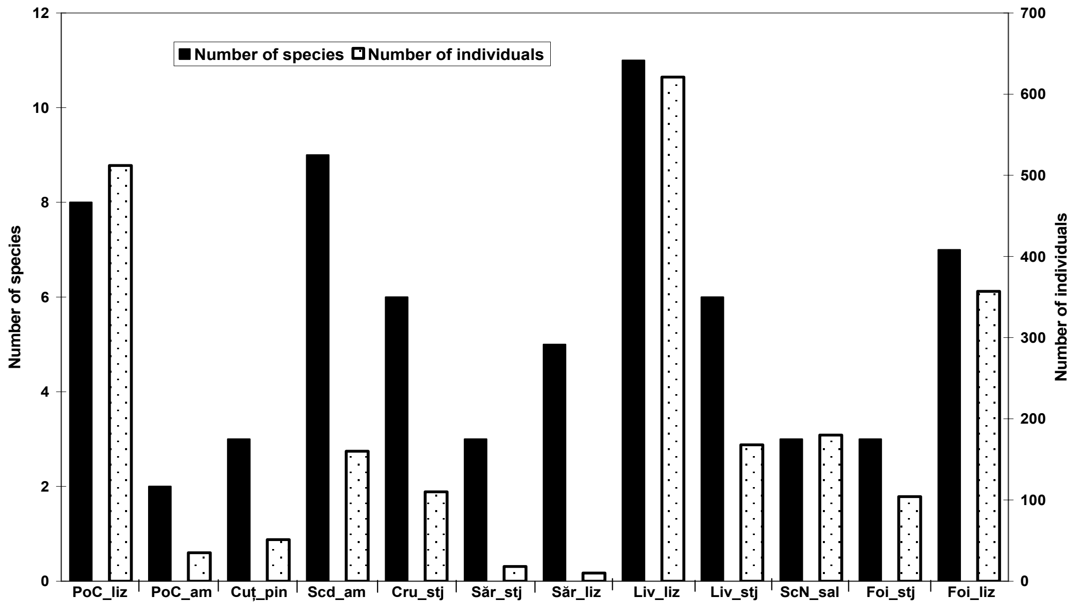


Fig.8. Number of individuals and species in the investigated forest habitats

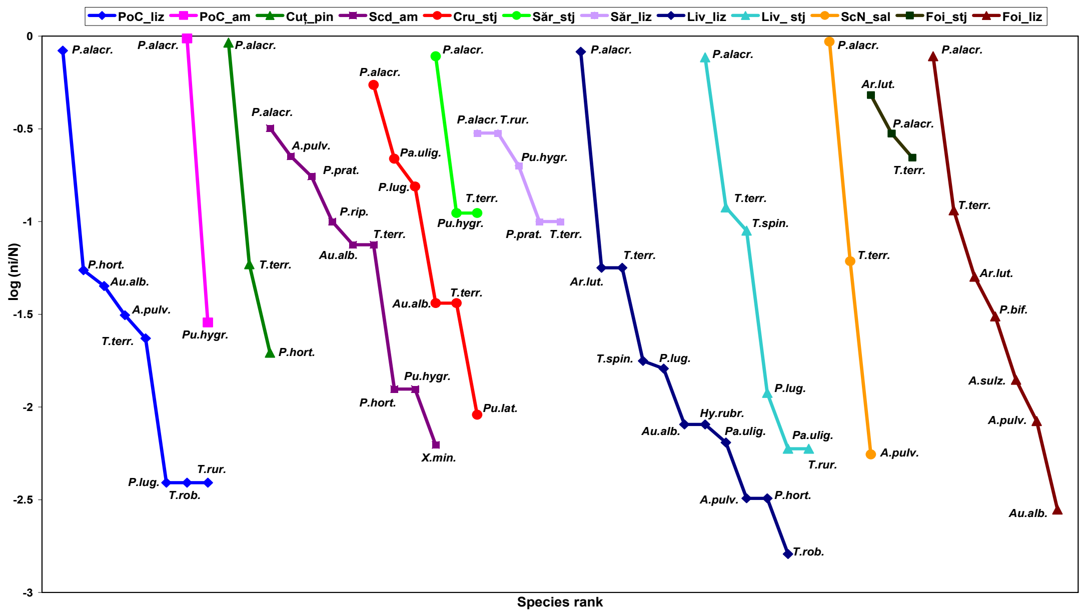


Fig.9. Rank-abundance curves of Lycosidae species recorded in the 12 surveyed forest habitats

The forest specialist species *P. alacris* has the highest relative abundance, being an eudominant species in all investigated habitats. Its strong dominance in the analysed Lycosidae assemblages is clearly visible in the figure that shows the rank-abundance curves (fig.9.), as well as the fact that this lead to a steep slope of the curves and hence to a low equitability in most of the habitats, but especially in PoC_am and ScN_sal. *P. alacris* is exceeded in terms of relative abundance only in Foi_stj, by *Ar. lutetiana*.

Diversity (H) was highest in Scd_am (H=1.76), where there were identified nine species of Lycosidae, but none has high numerical abundance and therefore equitability is also quite high in this habitat (J=0.80). According to the Mann-Whitney test the differences between the two habitat categories are statistically significant neither for Shannon diversity index nor for equitability (p>0.05). Nevertheless, 'forest' has a higher diversity and equitability than 'edge' (forest: H=1.41, J=0.52; edge: H=0.87, J=0.31).

According to Jaccard index, the similarity in species composition of the 12 investigated habitats is average and in some cases very small. According to Bray-Curtis index, which takes into account the abundance of species also, the differences between certain habitats are smaller, due to the quantitative dominance of *P. alacris* in almost all of them.

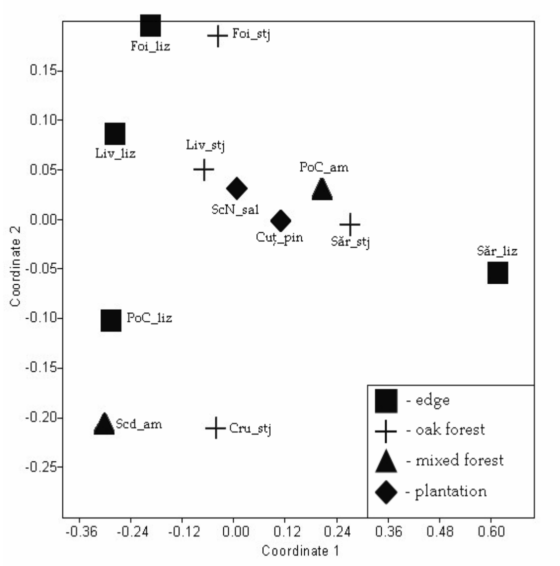


Fig.10. Ordination of wolf spider assemblages of the investigated forest habitats using non-metric multidimensional scaling (NMS)

4.4. Discussion

There are studies that report spider communities with higher species richness in the edge zone, especially when edges have a thick strip of shrubs (Downie et al. 1996, Horváth et al. 2002), which seems that was obtained by the present study as well, forests altogether sheltering 15 species and edges altogether 16 species of Lycosidae. However, for the 'forest' habitat category the estimators consider the existence on average of three more Lycosidae species, while for 'edge' of at most one more species. This fact along with the observation that the rarefaction curve for 'edge' has reached an asymptote and that for 'forest' has not, suggest more that the surveyed forests are richer in species of Lycosidae and not the edges. However, if Scd_am is removed from analyses, the difference between forests and edges becomes significant (Mann-Whitney test, Z=-2.23, p<0.05), edges having higher species richness. Scd_am is a forest under recovery, with young trees thus being suitable for wolf spiders which are favoured by simplified habitats (Jocqué & Alderweireldt 2006), but the other analysed forests are denser and more closed.

Although lycosids are considered species characteristic of open habitats (Jocqué & Alderweireldt 2006), they can still dominate, at least numerically in forests as well (Pearce et al. 2004), especially in the young ones, being rarer in the old, dense and closed ones (Pajunen et al. 1995). Therefore, the low number of individuals and species in certain analysed forests (e.g. PoC_am, Săr_stj) might not necessarily indicate that they were incompletely sampled but rather the fact hat they are mature, old forests and thus inappropriate for wolf spiders.

Indeed, both at Poiana Codrului and Sărăuad the sampled forest interior had more or less old trees, a thick rich leaf litter and lacked herbaceous vegetation.

The rare species found in the investigated habitats include *Hygrolycosa rubrofasciata*, a species attached to bogs or wet meadows (Štambuk & Erben 2002), wet forests (Kronestedt 1996). Four species of Lycosidae were caught only in the edge, which may be related to the abiotic (e.g. light, humidity, temperature) and biotic (e.g. plant composition) factors specific to this zone compared to the forest interior (Jose et al. 1996, Matlack & Litvaitis 1999).

The average similarity values, at least according to the Jaccard index, denote a different composition of the wolf spider assemblages between edge and forest interior. The NMS ordination revealed an incomplete separation of forest and edge habitats (fig.10.). Edges are on the left and the centre part in occupied by five forest interior habitats that have a similar composition of the sheltered Lycosidae communities. Regarding Foi_stj and Foi_liz the arrangement reflects more the physical distance and necessarily the habitat type.

Chapter 5. Wolf spiders (Araneae: Lycosidae) in open and semi-open habitats from north-western Romania

Results from this chapter in:

Sas-Kovács, É.H., Urák, I., Sas-Kovács, I. (2013): First record of the rare species *Pardosa maisa* Hippa & Mannila, 1982 (Araneae: Lycosidae) in Romania. Archives of Biological Sciences, Belgrade 65(4): 1605-1608. [IF_{2013}=0.607]

Sas-Kovács, É. H., Urák, I., Cupşa, D., Sas-Kovács, I., Ferenți, S., Rákosy, L. Wolf spider (Araneae: Lycosidae) assemblages of a deciduous forest in north-western Romania. Submitted to Entomologia Generalis. [IF_{2013}=0.286]

5.1. Introduction

Wet habitats are one of the most important habitat types from the conservation point of view (Urák & Máthé 2012-2013), but they are very vulnerable and their number has significantly decreased recently due both to anthropogenic interventions (Bruun & Toft 2004, Urák & Máthé 2012-2013) and climate changes (McMenamin et al. 2008). Natural and semi-natural grasslands represent another category of vulnerable habitats, threatened particularly by intensification of agriculture and abandonment of traditional management practices (Taboada et al. 2011), which lead to alteration and fragmentation of habitats with negative effects on species with specific habitat requirements (Horváth et al. 2013).

The aim of this study was to analyse some Lycosidae assemblages from several marshy habitats both in the hilly and lowland areas of north-western Romania, some of them occupying the depressions between the sand dunes found in the "Câmpia Careiului" Natura 2000 site. We also investigated some grasslands to describe the wolf spider populations sheltered by them.

Specific objectives of the chapter:

i) to describe the composition and structure of lycosid assemblages in the investigated habitats; ii) to determine the existence of possible differences in the number, relative abundance, diversity of wolf spiders between habitats; iii) to determine the similarity level of the analysed open and semi-open habitats.

5.2. Materials and methods

This study was conducted in 13 habitats (marshes and grasslands), located in Satu Mare and Bihor counties, near seven localities, at altitudes between 126 and 198 metres (table 3.). Marshy areas are represented by ten habitats belonging to two categories: 'open marsh' and 'marsh with trees'. Wolf spiders were collected with pitfall traps during 2008 (habitats: Liv_mlb, Ver_mld1, Ver_mld2, Ver_mld3, ScN_mlb1, ScN_mlb2, ScN_paj, Foi_paj and Foi_mld) and 2009 (habitats: Scz_mlb, Cru_paj, Căr_mld and VlM_mld). The sampling activity in the field as well as data processing was performed according to the methodology presented in Chapter 4. In addition, we applied the indicator species analysis method (Dufrêne & Legendre 1997) as it is implemented in the PC-ORD software (McCune & Mefford 1999) to determine species significantly associated with the three habitat types.

Table 3. The investigated open and semi-open habitats, their location, the number of pitfall traps in a habitat, name of habitats

Locality	Geographic coordinates	Altitude (m)	No. of traps / months	Habitat name (abbreviation)	Habitat type
Soconzel (SM)	47°31′47.17″ N, 22°59′07.52″ E	198	4	Soconzel marsh (Scz_mlb)	marsh with trees
Crucişor (SM)	47°41′12.09″ N, 23°16′08.48″ E	158	4	Crucişor grassland (Cru_paj)	mesophilous grassland
Livada (SM)	47°50′51.27″ N, 23°13′46.79″ E	141	5	Livada marsh (Liv_mlb)	marsh with trees
Cărăşeu (SM)	47°43′41.33″ N, 23°06′24.41″ E	130	3	Cărăşeu marsh (Căr_mld)	open marsh
Scărişoara Nouă (SM) – Mlaştina Vermeş	47°37′25.08″ N, 22°14′51.12″ E	138	5	Vermeş marsh 1 (Ver_mld1)	open marsh
	47°37'24.21" N, 22°14'57.78" E	137	4	Vermeş marsh 2 (Ver_mld2)	open marsh
	47° 37'15.44" N, 22°14'52.45" E	139	5	Vermeş marsh 3 (Ver_mld3)	open marsh
Scărişoara Nouă (SM)	47°36′28.50″ N, 22°14′54.96″ E	139	5	Scărişoara Nouă marsh 1 (ScN_mlb1)	marsh with trees
	47°36′23.54″ N, 22°14′55.96″ E	134	4	Scărişoara Nouă marsh 2 (ScN_mlb2)	marsh with trees
	47°36′20.69″ N, 22°14′55.93″ E	136	4	Scărişoara Nouă grassland (ScN_paj)	wet grassland
Foieni (SM)	47°42′46.30″ N, 22°18′50.85″ E	129	5	Foieni grassland (Foi_paj)	dry grassland
	47°42′56.07″ N, 22°18′54.77″ E	127	5	Foieni marsh (Foi_mld)	open marsh
Valea lui Mihai (BH)	47°31′10.22″ N, 22°08′31.60″ E	126	4	Valea lui Mihai marsh (VlM_mld)	open marsh

5.3. Results

We identified a total number of 31 species of Lycosidae in the 13 investigated habitats. There were no species found in all habitats. However, *A. pulverulenta*, *Pu. latitans*, *T. ruricola* and *T. terricola* were identified in all grasslands, *A. pulverulenta*, *P. prativaga*, *Pu. latitans* and *T. ruricola* in all open marshes and *P. alacris*, *Pu. hygrophila* and *T. terricola* were present in all marshes with trees.

28 species of Lycosidae were present in the sampled marshes, 24 species in the open marshes and 18 species in the marshes with trees; grasslands had on the whole 17 species. The number of species found in a habitat varies between 5 and 17 species (fig.11.), on

average being caught 9.92 species / habitat. There is no obvious trend, but if Liv_mlb is removed it can be observed a tendency toward a higher Lycosidae species richness in the open marshes, especially compared to those with trees (fig.11.). Liv_mlb is the habitat with the highest number of species, both observed and estimated. For 'grassland' the indices estimated 19-35 species of Lycosidae and for 'marsh' 30-35 species. Rarefaction curves did not show significant differences in species richness either between 'grassland' and 'marsh' or between the two marsh categories.

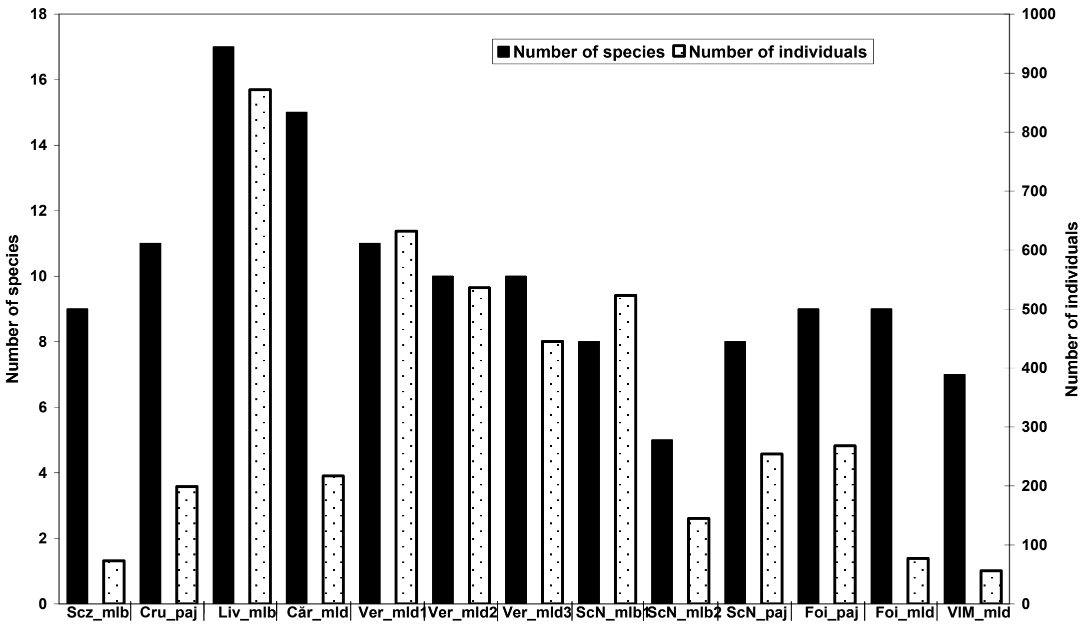


Fig.11. Number of individuals and species in the investigated habitats

The total number of captured wolf spiders is 7150, of which 4297 were adults. The highest number of individuals, i.e. 1679 wolf spiders (of which 872 adults), was collected in Liv_mlb. The number of *P. alacris* individuals was significantly higher in marshes with trees than in open marshes (Mann-Whitney test, $Z=2.42$, $p<0.05$) and in grasslands (Mann-Whitney test, $Z=1.96$, $p<0.05$), and that of *P. prativaga* in open marshes compared to marshes with trees (Mann-Whitney test, $Z=2.45$, $p<0.05$). Significantly more *Pu. hygrophila* individuals were collected in the marshes with trees than in the open marshes (Mann-Whitney test, $Z=2.05$, $p<0.05$) or in the grasslands (Mann-Whitney test, $Z=1.96$, $p<0.05$).

Considering the composition of Lycosidae assemblages from the analysed grasslands and implicitly the identity of dominance classes there are important differences between habitats (fig.12.). *Pu. hygrophila* and *P. alacris* have high relative abundance in the marshes with trees (fig.12.), and *Pu. latitans*, *P. prativaga*, *P. agrestis* and *T. ruricola* in the open marshes (fig.12.).

Marshes taken together has a slightly higher diversity than grasslands, but equitability is higher in 'grassland'. Both diversity and equitability were higher for 'marsh with trees' ($H=1.69$; $J=0.58$) compared to 'open marsh' ($H=1.64$; $J=0.51$). Diversity took the highest value in Căr_mld, where there were identified 15 species but none of them has a very high numerical abundance. The present or absence of arboreal vegetation does not significantly influence diversity of Lycosidae assemblages in the analysed marshes. The value of equitability is highest for the wolf spider communities from Foi_mld, Scz_mlb and VlM_mld.

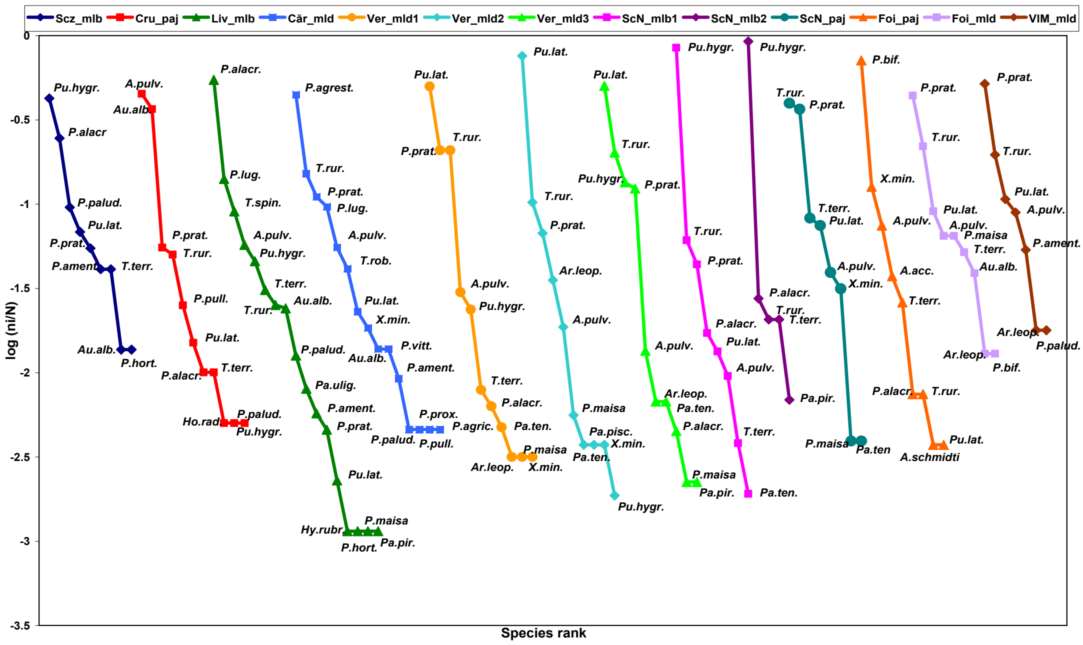


Fig.12. Rank-abundance curves of Lycosidae species recorded in the 13 surveyed habitats

According to the Jaccard index the similarity between 'grassland' and 'marsh' is average (0.45), that between 'marsh with trees' and 'open marsh' being just a slightly higher (0.5). According to the Bray-Curtis index, with few exceptions, the similarity of the wolf spider communities from the analysed habitats is lower than suggested by Jaccard index. According to NMS ordination the marshes with trees are separated from the open marshes, the habitats of the first category occupying the left – centre – bottom part of the chart, the open marshes the upper right part and the grasslands more the right – centre – bottom part of the chart. But the separation of the three habitat categories is not absolute, since Scn_paj is much closer to Foi_mld and VlM_mld than to the habitats of its own category (fig.13.).

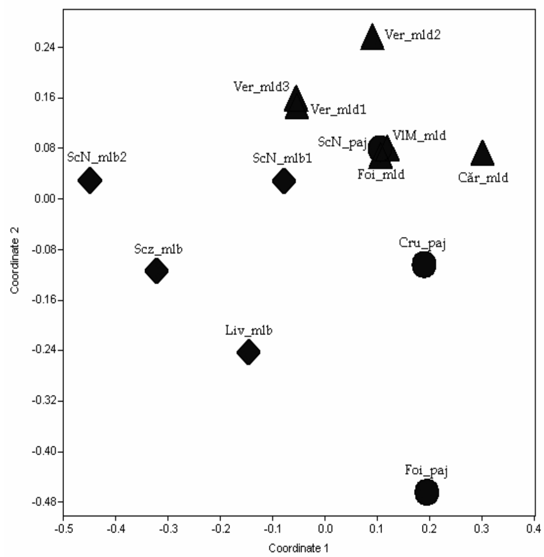


Fig.13. Ordination of wolf spider assemblages of the investigated habitats using non-metric multidimensional scaling (NMS)
[● - grassland, ▲ - open marsh, ◆ - marsh with trees]

Following the calculation of the indicator value of the species, the IndVal procedure assigned two species to 'open marsh' category and two species to 'marsh with trees' category. *Ar. leopardus* and *Pu. latitans* had higher abundance and constancy in the open marshes, which led to over 80% and statistically significant indicator values (IndVal=83.3 for *Ar. leopardus*, IndVal=93.5 for *Pu. latitans*; $p<0.05$). The species *P. alacris* and *Pu. hygrophila* were assigned as indicators of marshes with trees (IndVal=98.2 for *P. alacris* $p<0.01$; IndVal=92.6 for *Pu. hygrophila*, $p<0.05$).

5.4. Discussion

Eight of the identified species are considered indicators for peat bogs and the proportion of these indicator species has been suggested to be a good surrogate for the conservation value of the total invertebrate fauna of such habitats, at least concerning western Great Britain (Scott et al. 2006). *P. maisa* is a new record for the arachnofauna of Romania (Sas-Kovács et al. 2013). It was collected in six (Liv_mlb, Ver_mld1, Ver_mld2, Ver_mld3, ScN_paj and Foi_mld) of the 13 analysed habitats, but only a low number of individuals.

Species richness was generally higher in the marshy habitats than in the sampled grasslands. We did not find significant differences between the two categories of marshes, because both the open ones and the marshes with trees were able to shelter lycosid communities both rich and poor in species, suggesting that other factors and not the level of habitat shading is involved in modelling this issue. Nevertheless, rarefaction curves suggest that grasslands and open marshes have a higher potential than marshes with trees to hold wolf spider assemblages with high number of species.

Open marshes do not differ significantly from those with trees in species number, individuals number, diversity, but there are differences between the habitats of these two categories in terms of the composition of the sheltered lycosid communities. This is more apparent in the identity of the numerically dominant species from them, as it is suggested by the low values of Bray-Curtis index as well. Thus, *Pu. latitans*, *T. ruricola* and *P. prativaga*, although are present in most marshes with trees, have high abundances only in open marshes, being their main species (fig.12.). All three are light-preferring species (Buchar & Růžička 2002). *Pu. hygrophila*, *P. alacris* and *P. lugubris* are numerically dominant in the marshes with trees. The fist one is a shade-preferring species occurring only in wet habitats with bushes or trees (Loksa 1972), its abundance in the above mentioned habitats being therefore consistent with literature data.

The difference between the two marsh categories is well reflected by the low values of similarity indices also, they having only 14 species in common out of the 28 species identified altogether in marshes. The lycosid assemblages of the three grasslands differ greatly, each having a special composition and structure. This is caused, most likely, by the different humidity level of the analysed grasslands which has significant effects on the composition of spider assemblages (Bonte et al. 2002).

In order to maintain diverse Lycosidae assemblages in a region both open well-lit and shaded wetlands are needed, because each category can shelter species rich wolf spider communities, but with a different species composition.

Chapter 6. Wolf spiders across a forest – grassland ecotone from north-western Romania

6.1. Introduction

Ecotones are usually considered to be transition areas between ecological communities (Downie et al. 1996), and Kark and Rensburg (2006) made a more or less exhaustive analysis on their role in ecology, evolution and conservation, also suggesting some future research directions. Perhaps the most important feature of ecotones is given by their potential to serve as a source for the restoration of the communities of neighbouring habitats, if they were disturbed (Magura et al. 2001, Máthé 2006).

In this study we analysed the wolf spider assemblages of a grassland, of an oak forest and of the transition area between them to meet the following objectives:

Specific objectives of the chapter:

i) to describe the composition and structure of the wolf spider assemblages in the three investigated habitats; ii) to determine the existence of possible differences in the number, relative abundance, diversity of wolf spiders between habitats, as well as to determine the similarity level between them.

6.2. Materials and methods

This study was conducted in three habitats located in the vicinity of Săcăşeni village (Satu Mare county). The first habitat is a grassland with rich herbaceous vegetation near an oak forest (47°27′46.68″ N, 22°42′44.27″ E, altitude: 226 m), the second habitat is the edge area of the forest (47°27′48.06″ N, 22°42′42.68″ E, altitude: 226 m) and the third habitat is the oak forest interior (47°27′52.78″ N, 22°42′4340″ E, altitude: 225 m). The distance between habitats was several ten metres. There were placed four pitfall traps in the grassland and in the edge and two traps inside the forest. The study was conducted during 2008, and the traps were installed in early April and emptied in the first week of each month until October. Data processing was performed according to the methodology presented in the previous chapters (4 and 5).

6.3. Results and discussion

We identified a total number of 13 species of Lycosidae, the composition and species number displaying great differences between habitats. The highest number of species i.e. 11 species was identified in the grassland and the lowest one (only two species) inside the oak forest. The visual inspection of rarefaction curves suggests that the number of Lycosidae species is significantly higher in the grassland than in the other two habitats (the 95% confidence intervals do not overlap), but there are no significant differences between edge and forest (the 95% confidence intervals overlap) (fig.14.-a). The rarefaction curve for forest has reached an asymptote which suggest that this habitat do not house other species of Lycosidae, the curve for edge is slightly ascending while that for grassland is clearly ascending, suggesting that new species can be expected if sampling is continued in the habitat (fig.14.-a). The average value of sampling completeness was highest for the forest

(99.92%) for which all estimators suggested the existence of two species of Lycosidae, which is equal to the number of species observed.

Of the identified species *P. alacris* and *P. hortensis* were present in all habitats. *A. sulzeri* and *P. prativaga* were collected only in the grassland-forest ecotone. *P. hortensis* has the highest relative abundance (41.66%) in the grassland (fig.14.-b). *P. alacris* quantitatively prevails in the edge and inside the oak forest (fig.14.-b) being a forest species (Buchar & Růžička 2002). However, it is a member of the Lycosidae assemblage from grassland also. 76.47% of the *P. alacris* individuals from the grassland were males caught during spring, thus in a period when they were in search for sexual partners and they went in the open habitat most likely because of this. The occurrence of this species in open habitats has also been reported by other authors (Gallé 2008, Urák et al. 2010).

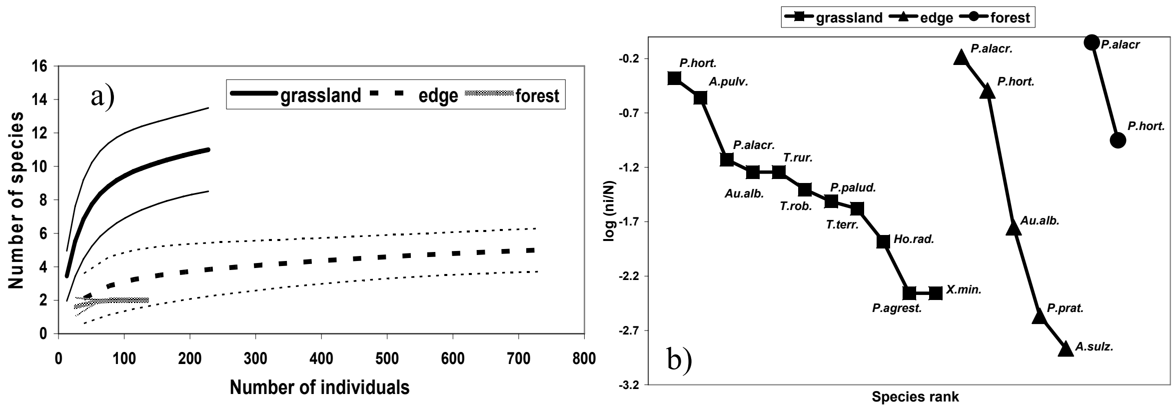


Fig.14. Rarefaction curves (MaoTau function) with 95% confidence intervals for the three analysed habitats (a); Rank-abundance curves of Lycosidae species recorded in the three surveyed habitats (b).

The highest value of diversity and equitability was recorded for grassland (H=1.67; J=0.69). In similar studies the highest diversity was generally obtained for the ecotone (Downie et al. 1996, Gallé & Fehér 2006). In this area the communities of two different habitats overlap which may cause a combination of their diversity, along with the presence of some species exclusively in the ecotone (Downie et al. 1996, Kark & Rensburg 2006). Nevertheless, in the present study both species richness and diversity were greater in the grassland, suggesting that the role of this transition areas differ depending on the taxonomic group took into consideration. Thus, if we consider spiders in general, edges may indeed have a higher diversity, but if we refer to only one family, for example that of wolf spiders (family Lycosidae) it is possible that edges will always have lower diversity than the adjacent open habitats.

The wolf spider communities of the edge and of the oak forest are the most similar (Jaccard=0.40; Bray-Curtis=0.30). Similar to our results, other studies have also obtained a higher similarity between the species composition of forests and edges than between that of edges and adjacent open habitats (Downie et al. 1996, Horváth et al. 2002).

6.4. Conclusions

- The analysed grassland is richer in species of Lycosidae and has a higher diversity compared both to the oak forest and the edge zone.

- In the forest and edge *P. alacris* and *P. hortensis* have the highest relative abundance, and in the grassland *P. hortensis* and *A. pulverulenta*.
- Distinct wolf spider assemblages were identified in the grassland and forest, and the composition and structure of the assemblage from edge is more similar to that from the forest.

Chapter 7. Activity dynamics of some species of Lycosidae

7.1. Introduction

Comparative analysis of monthly quantitative samples allows determining the reproduction period of the spider species, being shown that the pitfall traps method can provide representative models even for the phenology of species with low abundance (Štambuk & Erben 2002). Males are usually active a shorter period of time and produce more marked activity peaks than females, peaks which are considered to indicate the moments of copulation (Chatzaki et al 1998, Štambuk & Erben 2002 and the references cited therein). The higher activity of males is mainly due to the active search of mature females for mating (Moring & Stewart 1994, Foelix 2011) and thus they are caught in higher number by traps (Moring & Stewart 1994, Urák & Máthé 2011).

The monthly sampling with pitfall traps in the habitats investigated in Chapters 4, 5 and 6 of the thesis yielded data on the seasonal activity of males and females of various species of Lycosidae.

Specific objectives of the chapter:

i) to establish the reproductive period of different species of Lycosidae; ii) to analyse the sex ratio, the monthly dynamics of some wolf spider species.

7.2. Materials and methods

Samples were collected using pitfall traps in the habitats presented in Chapters 4, 5 and 6 of the thesis. We analysed the monthly dynamics of only those species of Lycosidae that exhibited a high abundance at least in one of the investigated habitats.

7.3. Results and discussion

The highest number of *A. pulverulenta* individuals was caught in Cru_paj, males being present in high number in the habitat in April, followed by a sharp drop in May, after which they were no longer captured. Females also have higher abundance in April, but they are present in the habitat until June (fig.15.). These results suggest that this species has the reproduction period in early-mid spring. In a study conducted in peatbogs in north-western Croatia Štambuk and Erben (2002) noticed that males of *A. pulverulenta* have an activity peak in mid-May, but in our study this happens in April. These differences may be due to variations in climatic conditions, being related a positive correlation between temperature and activity of spiders (Kotiaho et al. 2000).

Ar. lutetiana is an important component of the Lycosidae assemblage in Foi_stj. It is well-marked the low number of females (1-2/month), although males had a peak in May (33 individuals) (fig.15.). Males were collected in April-July and females in May-September. Therefore it appears that the copulation period of the species occurs in May. The absence of females in traps is due to the fact that they live in underground burrows and do not venture into the epigeon (Dolejš et al. 2010).

In Cru_paj adults of *Au. Albimana* were found from April to August, with the specification that males were present in the samples in April (11 individuals) – May (30 individuals) – June (11 individuals) – July (7 individuals) which suggest that reproduction takes place during May (fig.15.).

In the wolf spider assemblage from Căr_mld *P. agrestis* was the most abundant, a species related to be the dominant one in many agricultural lands and other disturbed areas (Samu et al. 1998, Kiss & Samu 2002). The number of adults increases gradually from 1-6-10 individuals in April-May-June to a maximum of 45 for males of *P. agrestis* and 16 for females in July. It comes out from these data that the species has the reproductive period in mid-summer (fig.15.). A study performed on populations of *P. agrestis* in Hungary led to the disclosure of a bimodal phenology of the species and the formulation of two hypotheses: the existence of two generation or the presence of two cohorts over a year (Samu et al. 1998). The authors of this paper obtained for the species in question two reproductive peaks, in May and August, the one obtained by us laying between these two. Zulka et al. (1997) also obtained a bimodal curve for a population from Austria, with males showing a first activity peak in early May and a second in early-mid July. It is possible that our study began only in April, has not detected a first peak which might had occurred earlier, so more detailed studies are needed in this regard.

In Foi_liz *P. alacris* was present from April to August, the number of males being high in April but reaches the maximum (89 individuals) in May, suggesting that mating occurs in that period (fig.15.-a). The data are, however, slightly different for Săc_liz where the activity of males has a peak in April, but they were also captured during May (306 and 24 individuals, respectively). Females were present in the habitat during April-August, with a peak in May (70 individuals) (fig.15.-b). The situation recorded in this habitat suggests that mating period of *P. alacris* occurs in April. At Foieni samples were collected during 2008, while at Săcăşeni in 2009. Spring of 2008 was very rainy and thus temperatures were also lower than in general, but in April of 2009 it was warm and dry spell. Very likely these variations in temperature and precipitation regime between the two consecutive years caused the recorded differences in the reproductive period of the species between the analysed habitats.

In Foi_paj adults of *P. bifasciata* were found from May to September, males being present in samples only in May-June, reproduction probably occurring during May (fig.15.). Females can be caught all summer, and even during autumn.

P. hortensis has the highest abundance in Săc_liz. For both males and females the highest number of individuals was recorded in April, after which male disappear and females are present sporadically in May-June and August-September (fig.15.). Thus, it can be considered that the mating period is in April. March-April, April-May is the designated period for reproduction in the literature as well (Wiebes 1959, Kiss & Samu 2002).

P. prativaga was found to be the dominant species in many analysed habitats, in Ver_mld1 being captured most of the individuals of this species. In this habitat males were present from April to June with a peak in May, and females from April to August with a peak also in May (fig.16.). These results suggest that the copulation period in this species occurs during May.

In ScN_mlb1 males of *Pu. hygrophila* were captured from April to July with a peak in May, and females from April to September with two activity peaks, one in May and the other

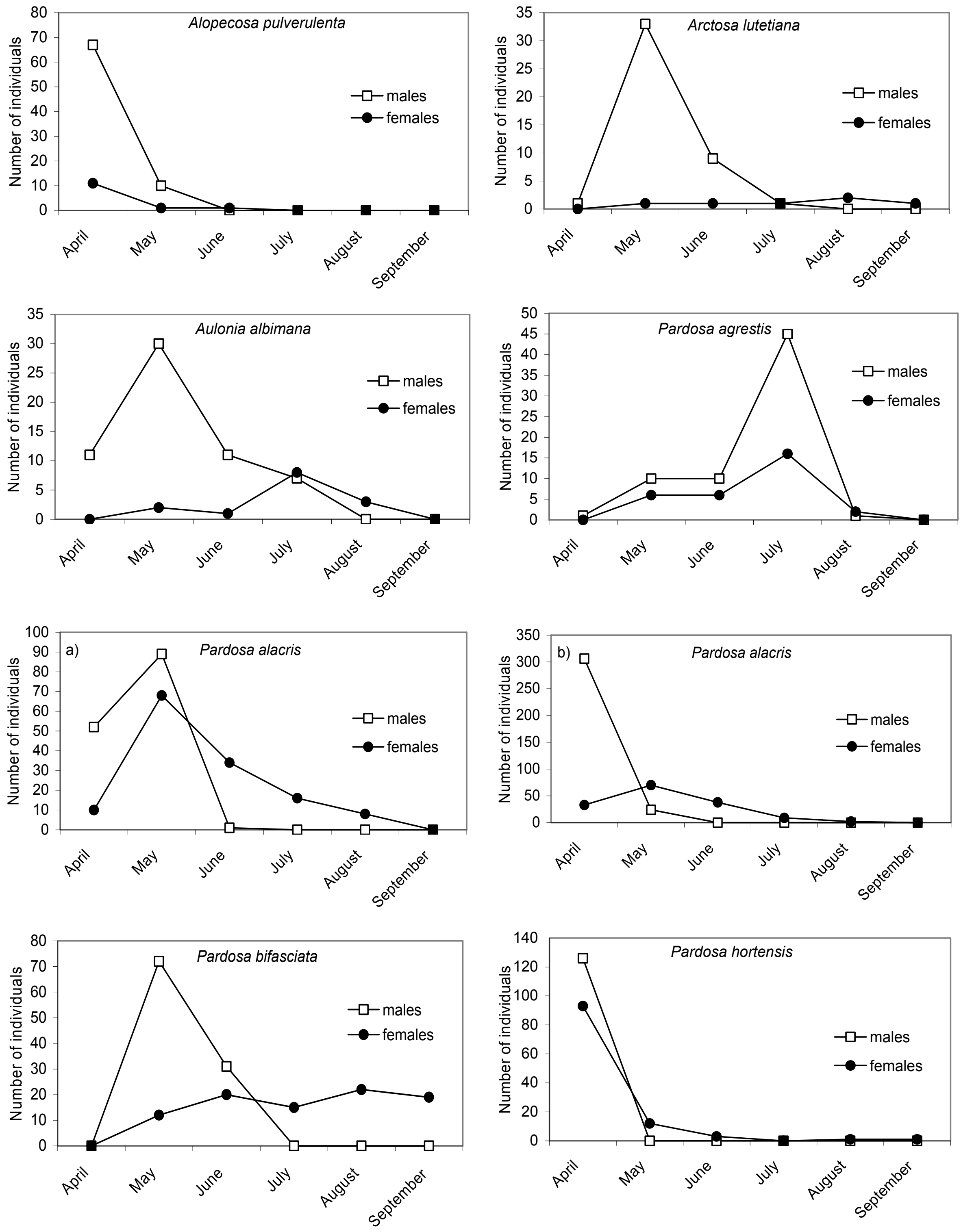


Fig.15. Activity dynamics of *Alopecosa pulverulenta* in the grassland from Crucişor (Cru_paj), of *Arctosa lutetiana* in the oak forest from Foieni (Foi_stj), of *Aulonia albimana* in the grassland from Crucişor (Cru_paj), of *Pardosa agrestis* in the open marsh from Cărăşeu (Căr_mld), of *Pardosa alacris* in the edge zone of the oak forest from Foieni (a) and in the edge zone of the oak forest from Săcăşeni (b), of *Pardosa bifasciata* in the grassland from Foieni (Foi_paj) and of *Pardosa hortensis* in the edge zone of the oak forest from Săcăşeni (Săc_liz)

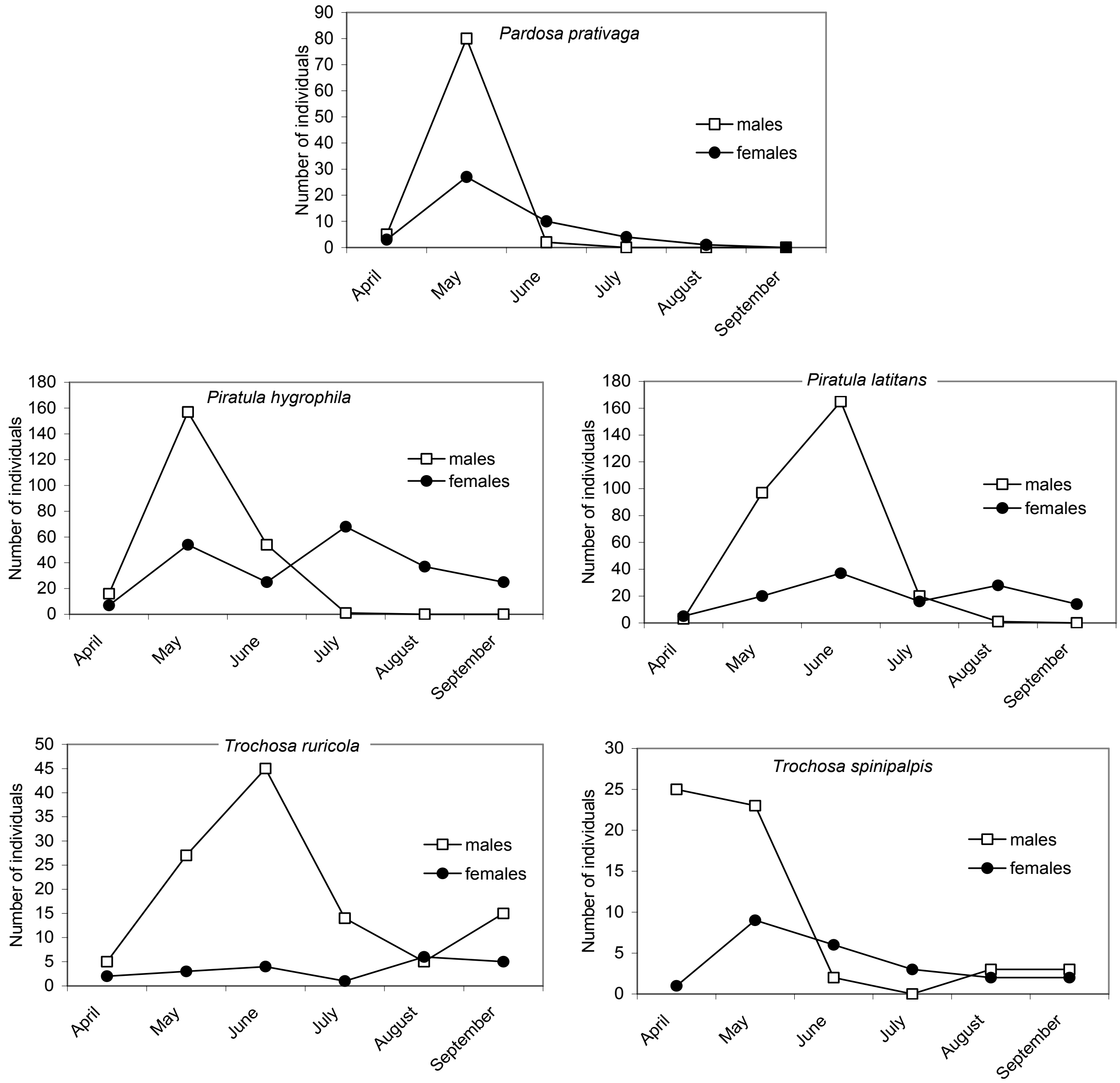


Fig.16. Activity dynamics of *Pardosa prativaga* in the open marsh from Vermeş (Ver_mld1), of *Piratula hygrophila* in the marsh with trees from Scărişoara Nouă (ScN_mlb1), of *Piratula latitans* in the open marsh from Vermeş (Ver_mld2), of *Trochosa ruricola* in the open marsh from Vermeş (Ver_mld1) and of *Trochosa spinipalpis* in the marsh with trees from Livada (Liv_mlb)

in July (fig.16.). These results suggest that the mating period of this species takes place during May.

In Ver_mld1 and Ver_mld3 the number of *Pu. latitans* males reaches the highest value in May (96 and 90 individuals, respectively), while in Ver_mld2 there is a very sharp peak in June (165 males), during May their number being lower (97 individuals) (fig.16.). However, the number of males remains high in June in the other two habitats as well (92 and 77 males, respectively). These suggest that the studied populations of *Pu. latitans* present a prolonged reproductive period which includes a period of two calendar month: May-June.

The number of *T. ruricola* males in Ver_mld1 increases gradually from April to June, then falls in July-August and a less pronounced peak occurs in September (fig.16.). According to literature data *T. ruricola*, like the other species of this genus, is diplochronous, reproduction taking place in April-May (primary copulation period) and June (August)-July (October) (secondary copulation period) (Wiebes 1959, Fuhn & Niculescu-Burlacu 1971). We recorded that the first mating period occurs in May-June and obtained clues on the second, but an extension of the study period is needed to ascertain the existence and period of a second mating.

In Liv_mlb the number of *T. spinipalpis* males is high during spring, decreases during summer, being zero in July after which they begin to reappear in the samples. The number of females is highest in May, and then decreases gradually until September, but they are present throughout the study (fig.16.). These results suggest that the mating period (the main one) takes place during April-May and it is possible that an another copulation occurs after August.

7.4. Conclusions

- Most of the studied species of Lycosidae mate in late spring (in May). A low number of species reproduce earlier in spring (in April), and others later, during summer ((May)-June, July).
- We recorded differences in the reproductive period of some species between both the investigated habitats and years of study, most likely caused by variations in temperature and humidity conditions.
- The two species of the genus *Trochosa* probably have two mating periods: a more pronounced one in April-May for *T. spinipalpis* and in May-June for *T. ruricola*, and a less marked during autumn, probably in September-October for both species.

Chapter 8. Wolf spiders (Araneae: Lycosidae) active during winter in thermal habitats from western Romania

Results of this chapter in:
Sas-Kovács, É.H., Urák, I., Sas-Kovács, I., Covaciu-Marcov, S.D., Rákosy, L. (2014). Winter-active wolf spiders (Araneae: Lycosidae) in thermal habitats from western Romania. Journal of Natural History, DOI: 10.1080/00222933.2014.909070. [IF_{2013}=0.927]

8.1. Introduction

Most spiders spend the cold periods of winter from temperate regions in a certain type of diapause (e.g. diapause in immature or adult stage, see in: Schaefer 1977). They may, however, leave the winter shelters if the environmental conditions become suitable (Huhta & Viramo 1979), winter-activity in spiders being reported previously (Gunnarsson 1985, Vanin & Turchetto 2007). Spiders which are active during the cold season or just in a part of it may feed, mate or migrate to new habitats (Hågvar & Aakra 2006, Hågvar 2010).

Geothermal areas can shelter a diverse terrestrial invertebrate fauna (Boothroyd & Browne 2006) and the presence of spiders in such habitats has been reported previously (Sheppe 1975, Stark et al. 1976, Elmarsdottir et al. 2003). The thermal conditions of a habitat have effect on the activity of both spiders (Foelix 2011) and their potential preys (Frampton et al. 2001).

In this chapter we present the Lycosidae species collected during winter in the vicinity of some thermal waters from western Romania and analyse their influence on the development and reproduction of the respective spider species.

Specific objectives of the chapter:

i) to identify the winter-active species of Lycosidae in the vicinity of geothermal waters; ii) to observe some possible influences of the thermal waters on the development and reproduction of Lycosidae species.

8.2. Materials and methods

The study region is located in western Romania (47°33′-46°20′ N, 22°43′-21°18′ E). There were investigated a number of 22 thermal habitats located inside or in the vicinity of 19 localities (fig.17.). Almost all habitats are ditches supplied by hot water originating either directly from wells or represent wastewater discharged from thermal pools, factories, greenhouses or homes. The study was conducted during December 2011-January 2012 and January-February 2013. Wolf spiders were captured by hand on the banks of ditches from the grassy vegetation. Only those individuals that were actively moving were collected. The nonparametric Mann-Whitney U test was used to detect possible differences in the number of juveniles and subadults, computed in the PAST program version 2.17c (Hammer et al. 2001).

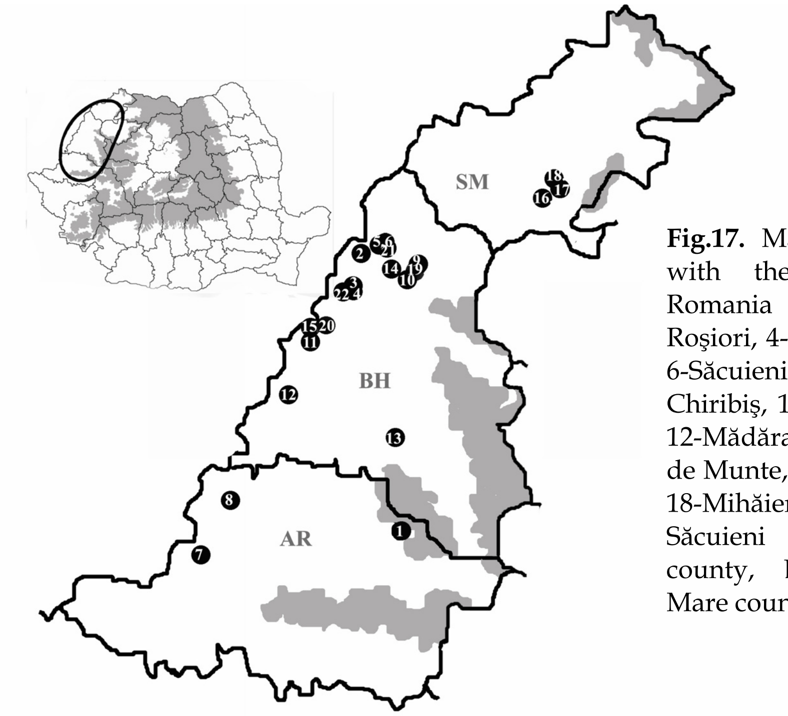


Fig.17. Map of the surveyed localities with thermal habitats in western Romania (1-Moneasa, 2-Ciocaia, 3-Roşiori, 4-Roşiori/Tămăşeu, 5-Săcuieni I, 6-Săcuieni II, 7-Curtici, 8-Socodor, 9-Chiribiş, 10-Chişlaz, 11-Livada de Bihor, 12-Mădăras, 13-Răbăgani, 14-Sânnicolau de Munte, 15-Tărian, 16-Acâş, 17-Beltiug, 18-Mihăieni, 19-Chiraleu, 20-Oradea, 21-Săcuieni III, 22-Tămăşeu, AR=Arad county, BH=Bihor county, SM=Satu Mare county)

8.3. Results

Wolf spiders active during the cold season were found in 21 investigated habitats. The total number of captured individuals is 344, on average 10.42±10.53 wolf spiders / habitat / sampling date. The highest number of spiders captured in a sampling date belongs to the habitat from Chişlaz. Most wolf spiders were collected in January, but this was also the period with the highest number of fieldtrips. Most of the captured individuals were juveniles and subadults. Subadult individuals occurred in habitats in significantly higher number than juveniles (Mann-Whitney test, $Z=2.09$, $p<0.05$).

In ten thermal habitats we found 24 adult individuals belonging to seven species: *Ar. leopardus*, *P. amentata*, *P. proxima*, *Pa. piraticus*, *Pu. latitans*, *T. robusta* and *T. ruricola*. *P. proxima* was the best represented, being captured seven individuals of this species. The female of *Pu. latitans* collected in the thermal habitat from Mădăras in mid January 2012 had an egg sac with 38 eggs. Of the three females of *Pa. piraticus* two were collected at Livada de Bihor in mid February 2013: one of them had a cocoon with 58 eggs and the other carried spiderlings (fig.18.). *P. proxima* and *T. ruricola* were the most common species, being identified in five habitats each, and followed by *Pa. piraticus* present in four habitats. The greatest number of individuals was collected at Chişlaz, but the highest number of species was identified in the habitat from Oradea.

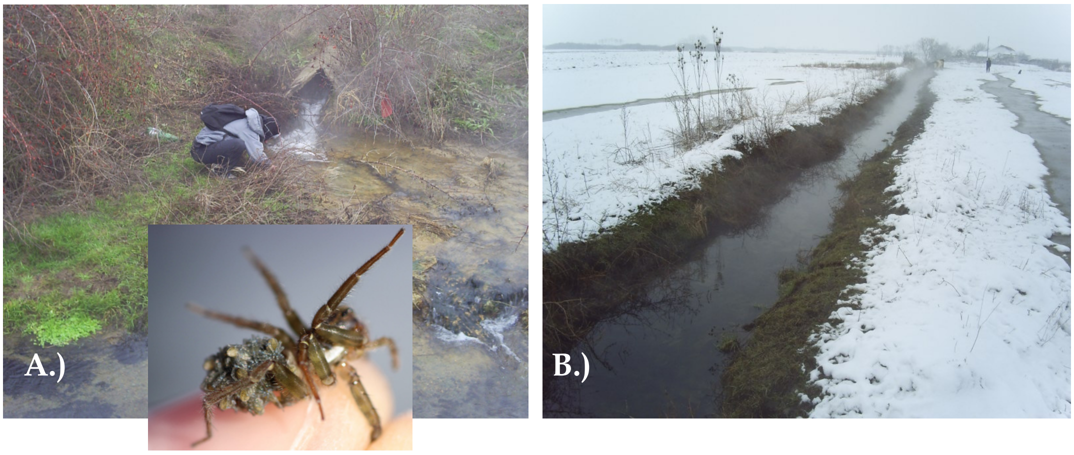


Fig.18. View of some investigated thermal habitats: Livada de Bihor – 02.I.2013, female with spiderlings collected here in 12.II.2013 (A.) and Chişlaz – 29.I.2013 (B.-ditch)

8.4. Discussion

A special microclimate is created on the shores of ditches with flowing warm water that allows spiders to remain active during winter. The best habitats are ditches with relatively high banks with rich herbaceous vegetation, in which the water flow and its temperature are high enough to ensure a proper area for the activity of spiders and their potential preys. Such were, for example the habitats from Săcuieni I and II, Chişlaz (fig.18.), where the number of collected spiders was high.

We have identified females with egg sac and spiderlings, respectively, during winter, which is undoubtedly the most convincing proof of the influence of geothermal water on the life cycle of spiders. According to Hendrickx and Maelfait (2003) adults of *Pa. piraticus* are present during April-September, reproduction taking place from May to August, females with egg sac being found by them in a higher proportion during May and August and in a lower percentage during September. We collected a female of *Pa. piraticus* with egg sac and another one with spiderlings in February (air temperature below 0°C) at Livada de Bihor. It is possible that *Pa. piraticus* inhabits this moist habitat throughout the year, having a continuous development with adult and immature individuals present all the time, possible having more generations in a year, but additional studies are needed to clarify these issues.

The high number of juveniles and subadults of *Pardosa* and *Pirata*/*Piratula* collected is due to the fact that the species of these genera generally overwinter in the immature stage (Kiss & Samu 2002, Hendrickx & Maelfait 2003). The individuals from thermal habitats, remaining active during the cold season also, feed and grow further and will be the first that become sexually active in spring and mate, the larger individuals reproducing at the beginning of the breeding season (Hendrickx & Maelfait 2003).

Chapter 9. Final conclusions

Taking into account the diversity of addressed topics, the final conclusions are arranged in the order of objectives, results and discussion presented in the chapters:

Chapter 3: distibution of the Lycosidae species in the "Câmpia Careiului" Natura 2000 site (ROSCI0020)

- Following the study conducted in 2008-2009 and 2012-2014 (5 years) we have identified 34 species of Lycosidae in the "Câmpia Careiului" Natura 2000 site: *Alopecosa accentuata*, *A. cuneata*, *A. cursor*, *A. mariae*, *A. psammophila* (first record for Romania), *A. pulverulenta*, *A. schmidti*, *A. sulzeri*, *Arctosa leopardus*, *Ar. lutetiana*, *Ar. perita*, *Aulonia albimana*, *Geolycosa vultuosa*, *Lycosa singoriensis*, *Pardosa agrestis*, *P. alacris*, *P. amentata*, *P. bifasciata*, *P. lugubris*, *P. maisa* (first record for Romania), *P. nebulosa*, *P. paludicola*, *P. palustris*, *P. prativaga*, *P. proxima*, *Pirata piraticus*, *Pa. piscatorius*, *Pa. tenuitarsis*, *Piratula hygrophila*, *Pu. latitans*, *Trochosa robusta*, *T. ruricola*, *T. terricola* and *Xerolycosa miniata*. The most common species are: *P. alacris*, *X. miniata* and *P. agrestis*.
- Of the identified wolf spider species 73.52% are open habitat species, 8.82% are forest species and 17.64% are generalist species. A percentage of 38.23% of the species are xerophilous and 35.29% hygrophilous.
- The richest in species of Lycosidae are the zones located in the centre of the area near Scărişoara Nouă, in the northern part of the area west of Foieni locality and in the southern part of the area west of Valea lui Mihai, with 15-18 species of Lycosidae / 1x1 km square.

Chapter 4: wolf spiders (Araneae: Lycosidae) in forest habitats from north-western Romania

- In the 12 investigated habitats (eight forests and four edges) we have collected a total number of 19 species of Lycosidae, of which *P. alacris* was found and presented high abundance in all habitats. We have identified rare species in the Romania's fauna: *Hygrolycosa rubrofasciata* in the edge of the oak forest from Livada and *Alopecosa sulzeri* in the edge of the oak forest from Foieni.
- The number of individuals and of observed species was higher in the edge zones, but the analysed forests have the potential to shelter more diverse wolf spider assemblages, especially the young and humid ones.
- The composition of the Lycosidae communities was, in general, more similar between habitats of the same category, i.e. forests were more similar to each other than to edges.

Chapter 5: wolf spiders (Araneae: Lycosidae) in open and semi-open habitats from north-western Romania

- The lycosid communities of the 13 surveyed open habitats (ten marshes and three grasslands) are composed of a total number of 31 species of which *Pardosa maisa* and *P. vittata* are rare in Romania.
- Species richness was generally higher in the marshy habitats than in the analysed

grasslands. We did not find significant differences between the two marsh categories, as both the open and those with trees were able to shelter lycosid assemblages both rich and poor in species, which suggest that other factors, and not the degree of shading of the habitat, are involved in shaping this aspect.

- Open marshes differ from those with trees concerning the composition of numerically dominant species: *Piratula latitans* and *Pardosa prativaga* in open marshes, *Piratula hygrophila* and *Pardosa alacris* in marshes with trees.
- The wolf spider assemblages of the three grasslands differ greatly, each having a special composition and structure determined by their level of humidity.

Chapter 6: wolf spiders across a forest – grassland ecotone from north-western Romania

- We analysed the wolf spider assemblages of a grassland, an oak forest and of the transition zone between them, and identified a total number of 13 species of Lycosidae.
- The grassland is richer in species of Lycosidae and has a higher diversity compared both with the oak forest and the edge zone.
- In the forest and edge *Pardosa alacris* and *P. hortensis* have the highest values of relative abundance, and in the grassland *P. hortensis* and *Alopecosa pulverulenta*.
- The composition and structure of the assemblage from edge is more similar to that from the forest.

Chapter 7: activity dynamics of some species of Lycosidae

- We have analysed the activity dynamics of 14 species of Lycosidae, over a study period of six months (April-September). Males have shorter activity period (on average 3.16 months) than females (on average 4.40 months).
- Most of the studied species of Lycosidae reproduce in late spring (May) (*Arctosa lutetiana*, *Aulonia albimana*, *Pardosa bifasciata*, *P. prativaga*, *Piratula hygrophila*), and a lower number of species earlier in spring (April) (*Alopecosa pulverulenta*, *Pardosa hortensis*) or later, during summer: *Pu. latitans* ((May)-June), *P. agrestis* (July).
- We recorded differences in the mating period of some species (*P. alacris*) between both the investigated habitats and years of study, most likely due to variations in the temperature and humidity conditions. The size of these differences does not exceed the duration of one month.
- The obtained results can be useful in increasing the efficiency and decreasing the resources allocated to the inventory of wolf spider species of similar regions.

Chapter 8: wolf spiders (Araneae: Lycosidae) active during winter in thermal habitats from western Romania

- On the shores of ditches with flowing hot geothermal water a special microclimate is created that allows wolf spiders to remain active during winter.
- In the 22 investigated thermal habitats in western Romania we have identified seven winter-active species of Lycosidae: *Arctosa leopardus*, *Pardosa amentata*, *P. proxima*, *Pirata piraticus*, *Piratula latitans*, *Trochosa robusta* and *T. ruricola*.
- The reproduction period of some species is modified under the influence of neighbouring hot waters denoted by the capture of females with egg sac and spiderlings during winter.

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