Macedonian Journal of Ecology and Environment
Vol. 19, issue 1
pp. 15-21
Skopje (2017)
eISSN 1857 - 8330
Original scientific paper
Available online at www.mjee.org.mk

Ecology and distribution of the araneocenosis in the Skopje and Malesh valleys in the Republic of Macedonia

Екологија и дистрибуција на аранеоценозата во Скопската и Малешевската Котлина во Република Македонија

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Data concerning ecology and distribution of Araneae of Skopje and Malesh valleys in Macedonia are presented. In average, 48.96 ind.$\cdot$traps^{-1} were collected from six habitats, with pitfall traps in the period of April - August 2014. Their structural characteristics were assessed by using indices of richness, diversity, homogeneity and dominance. The structure of the spider community inhabiting Malesh and Skopje valleys differs with highest species richness in the agrarian, and highest relative abundance in the riparian habitat, while the index of dominance reached highest values in the open area near the pine forest. Wandering spiders, Lycosidae and Gnaphosidae, were by far the most abundant and species rich families. In general, noticeable differences of the araneocenosis inhabiting six different habitats were registered, mainly as a result of differences in the altitudes, climate and dominant vegetation types.
Key words: community structure, Araneae, structural indices

Презентирани се податоци што се однесуваат на екологијата и дистрибуцијата на Araneae од Скопската и Малешевската Котлина. Во просек, колекционирани се 48,96 инд$\cdot$замка$^{-1}$ од шест хабитати со ‘pitfall’ замки во периодот април-август 2014 година. Нивните структурни карактеристики се оценети со користење на индекси на богатство, диверзитет, хомогеност и доминација. Структурата на заедницата на пајаци од Малешевската и Скопската Котлина се разликува со највисоко видово богатство во аграрниот, и најголема релативна абундантност во рипарискиот хабитат, додека индексот на доминантност ги достигнува највисоките вредности во чистинката до боровата шума. Пајаците скитници, Lycosidae и Gnaphosidae, се фамилии со најголемо видово богатство и абундантност. Генерално, регистрирани се забележливи разлики помеѓу аранеоценозите од сите шест хабитати, главно како резултат на разлики во надморската височина, климата и доминантниот вегетациски тип.
Клучни зборови: структура на заедница, Araneae, структурни индекси

Introduction

The order Araneae is the largest arachnid order with more than 45000 recorded species from 114 families. They play an important role in most terrestrial ecosystems, because they are abundant, ubiquitous, generalist predators (Wise 1993). Spiders are sensitive to changes in habitat structure, including vegetation complexity and microclimate characteristics (Uetz 1991), and can be used as indicators when comparing the biodiversity of different habitats. The spider fauna of Macedonia and the Balkan Peninsula is relatively well researched due to the efforts of arachnologists from different countries: Stojićević (1907), Drensky (1929), Nikolić & Polenec (1981), Deltschev (1999, 2013), Komnenov (2002, 2003, 2014). However, the data of the order Araneae is mostly faunistic and there are few papers with comparative ecological analyses (Stefanovska et al. 2008; Cvetkovska-Gjorgjievska 2015).

The aim of this study was to analyze the structure of the spider assemblages inhabiting localities from two different areas in the Republic of Macedonia.

Study area

Skopje valley is a low altitude valley (270-290 m a.s.l.) in the northern part of Macedonia. Climate is temperate-warm, with average annual temperature of 12.2°C and semi-arid with annual rainfall of 515 mm. Cinnamon forest soils dominate which are suitable for the development of thermophilic and xerophilic vegetation (Lazarevski 1993; Filipovski et al. 1996).

Malesh valley is a high-altitude region of 900 m a.s.l. and is located in the eastern part of Macedonia. It covers the area of the river Bregalnica up to the gorge above v. Razlovci. It is surrounded by the Malesh Mts. and parts from Golak and Plachkovica mountains, and is only open to the north. This valley is part of the cold continental climate zone with an annual average temperature of 8.7°C, and an annual rainfall of 672.2 mm. Forests of *Quercus petraea* developing on brown forest soil dominate this valley (Lazarevski 1993; Filipovski et al. 1996).

Spiders were collected from six localities comprising six different habitat types (Tab. 1). The first three localities (L1-L3) belong to Skopje valley, while L4-L6 belong to Malesh valley.

Submitted: 09.01.2017
Accepted: 06.03.2017

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Table 1. Characteristics of the studied habitats

Locality	Habitat	Elevation	Coordinates	Dominant vegetation
L1	ruderal	293 m a.s.l.	N42°01.827'; E021°23.110'	*Erigeron canadensis*, *Cichorium intybus, Malva sylvestris*
L2	agrarian	285 m a.s.l.	N42°02511'; E021°22.238'	*Vitis vinifera*, *Brassica oleracea*
L3	riparian	272 m a.s.l.	N42°02.040'; E021°22.000'	*Salix alba*, *Xanthium strumarium*, *Trifolium pretense*
L4	Pine forest	926-938 m a.s.l.	N41°44.546'; E022°51.280'	*Pinus sylvestris, Juniperus communis*
L5	Ecotone	924-932 m a.s.l.	N41°44.539'; E022°51.307'	*Pinus sylvestris, Juniperus communis*
L6	Open area	924-932 m a.s.l.	N41°44.539'; E022°51.307'	*Achilea millefolium, Ononis spinosa, Galium verum, Hypericum purpurea*

Material and Methods

The pitfall method was used for the collection of material. This is the most efficient method for the collection of terrestrial invertebrates, because it is a cheap and simple method, with which a large quantity of samples from different invertebrate taxonomic groups can be collected and their relative abundance calculated (Southwood & Henderson 2000; Ausden & Drake 2006). One linear transect of 50 m was set at each locality, with a distance of 10 m between traps to prevent eventual interference. Six such transects were set, one at each locality, with a total of 30 pitfall traps. The traps were plastic cups with a diameter of 85 mm and volume of 300 ml. As a preserving liquid, a formalin-vinegar solution was used in a ratio 1:7. The material was collected monthly in the period 1 April - 30 August 2014.

Collected spiders were analyzed taxonomically and ecologically (classified to species level by Prof. Christo Deltschev and Prof. Stoyan Lazarov from the Institute of Zoology at the Bulgarian Academy of Sciences). The German key Spinnen Mitteleuropas: ein Bestimmungsbuch (Heimer & Nentwig 1991) and the online key Araneae – Spiders of Europe (Nentwig et al. 2017) were used for the determination of the material. The classification of spiders in different functional guilds was made according to Cardoso et al. (2011).

Relative abundance of spiders was presented as ind.·trap^{-1} and the dominance structure was calculated by the formula of Balogh (1958):

$$D = \frac{a_i}{\sum_{i=1}^{n} a_i} * 100$$

where: n is number of families, a_i –number of individuals from the i - family, while $\sum_{i=1}^{n} a_i$ is the total number of individuals of Araneae. According to Balogh (1958), families that are present with more than 10% of the individuals are dominant (D), from 5-9,9% are subdominant (SD), from 1-4,9 % are recendent (R), less than 1% are subrecendent (SR).

Structural characteristics of the spider community were determined by analyzing the structural indices: index of richness – d; Shannon-Wiener index of diversity – H'; index of homogeneity – $J_{(e)}$ and index of dominance – DI:

- **Index of species richness - d** (according to Margalef 1958):

$$d = \frac{S-1}{\ln N}$$

where n is the number of present species, N is the total number of individuals

- **Index of diversity - H'** (according to Shannon-Wiener, from Glowacinsky 1975):

$$H' = \sum_{i=1}^{s} p_i \ln p_i \quad p_i = \frac{n_i}{N}$$

where n_i is the number of individuals from i - species, and N is the total number of individuals

- **Index of homogeneity $J_{(e)}$** (according to Pielou 1966):

$$J_{(e)} = \frac{H'}{\ln S}$$

where H' is Shannon-Wiener's s index of diversity and S is the number of present species.

- **Index of dominance - DI** (according to Karr 1971):

$$DI = \frac{Y_1 + Y_2}{Y} * 100$$

where Y_1 is the abundance of the first dominant species, Y_2 is the abundance of the second dominant species, and Y is the total abundance of the community.

The similarity of spider abundance between six different localities was compared with Bray–Curtis UPGMA cluster analysis, with paired grouping as an algorithm, by using the program PAST.

Results

Altogether 1327 individuals (48.96 ind.·trap^{-1}) belonging to 19 families, 54 genera and 100 species were collected and their structural characteristics as well as spatial variation were analyzed. The list of species will be presented in a faunistic paper at a later date. Of all specimens 1224 (92.24%) were in the adult stage and 103 (7.76%) were juveniles and were excluded from the analysis. According to Cardoso et al. (2011), the collected spiders belong to seven functional guilds: sheet web spiders (Agelenidae, Pisuaridae, some representatives of Linyphiidae), space web spiders (Titanoecidae, Theridiidae), orb weavers (Araneidae, Tetragnathidae), specialist spiders (Zodariidae, Dysderidae, Phrurolithidae), ground hunters (Gnaphosidae, Liocranidae, Lycosidae, Miturgidae, Dictynidae), other hunters (Clubionidae, Philodromidae, Salticidae) and ambush hunters (Thomisidae). Of all the families present, Lycosidae (25 species, 31.08 ind.

trap^{-1}) and Gnaphosidae (25 species, 9.6 ind.·trap^{-1}) have the highest species richness and relative abundance (Tab. 2), while nine families (Agelenidae, Araneidae, Clubionidae, Dictynidae, Miturgidae, Phrurolithidae, Pisuaridae, Tetragnathidae and Zodriidae) were present with only one or two species and low abundance. *Zelotes* (10) followed by *Pardosa* (8) and *Alopecosa* (7) are the genera with the highest number of species (Tab. 2).

The average species diversity of araneocoenosis did not change significantly between localities. The localities in Skopje valley (L1-L3) had higher species richness (71) than those in Malesh valley L4-L6 (58) (Fig. 1). The lowest values (19) were registered in L4, while highest number of species was registered in L2 (41) and L5 (37) due to the highest share of *Pardosa* (5) and *Zelotes* (6) species.

Table 2. Structural characteristics of the spider families and genera. Abbreviations in the column 'Dominance symbol': D - dominant , SD - subdominant, R - recendent and SR - subrecendent (after Balogh 1958)

Families/Genera	Number of species	Abundance (ind.·trap^{-})	Dominance (%)	Dominance symbol
Agelenidae	1	0.04	0.08	SR
Tegenaria	1	0.04	0.08	SR
Araneidae	2	0.08	0.16	SR
Cercidia	1	0.04	0.08	SR
Hypsosinga	1	0.04	0.08	SR
Clubionidae	1	0.04	0.08	SR
Clubiona	1	0.04	0.08	SR
Dictynidae	1	0.04	0.08	SR
Lathys	1	0.04	0.08	SR
Dysderidae	3	0.28	0.57	SR
Dysdera	1	0.08	0.16	SR
Harpactea	2	0.20	0.41	SR
Gnaphosidae	25	9.6	19.61	D
Civizelotes	1	2.16	4.41	R
Drassodes	1	0.08	0.16	SR
Drassyllus	3	1.36	2.78	R
Gnaphosa	1	0.4	0.82	SR
Haplodrassus	4	2.08	4.26	SR
Micaria	2	0.12	0.25	R
Phaeocedus	1	0.04	0.08	R
Trachyzelotes	2	0.44	0.90	R
Zelotes	10	2.92	5.96	SD
Linyphiidae	8	0.76	1.55	SR
Diplocephalus	1	0.04	0.08	R
Diplostyla	1	0.04	0.08	R
Neriene	1	0.08	0,16	R
Oedothorax	1	0.4	0.82	R
Paliduphantes	1	0.04	0.08	R
Prinerigone	1	0.08	0.16	R
Tenuiphantes	1	0.04	0.08	R
Trichoncus	1	0.04	0.08	R
Liocranidae	4	0.36	0.74	R
Agraecina	1	0.08	0.16	R
Agroeca	2	0.24	0.49	R

Table 2. Structural characteristics of the spider families and genera (continuation).

Families/Genera	**Number of species**	**Abundance (ind.·trap⁻)**	**Dominance (%)**	**Dominance symbol**
Liocranum	1	0.04	0.08	R
Lycosidae	25	31.08	63.48	D
Alopecosa	7	2.72	5.56	SD
Arctosa	3	3.04	6.21	SD
Aulonia	1	0.04	0.08	R
Hogna	1	0.04	0.08	R
Lycosa	1	0.04	0.08	R
Pardosa	8	22.04	45.02	D
Pirtula	2	1.8	3.68	R
Trochosa	2	1.36	2.78	R
Miturgidae	2	0.12	0.25	SR
Zora	2	0.12	0.25	SR
Philodromidae	4	1.84	3.76	R
Philodromus	2	0.12	0.25	SR
Thanatus	2	1.72	3.52	R
Phrurolithidae	1	0.08	0.16	SR
Phrurolithus	1	0.08	0.16	SR
Pisauridae	1	0.12	0.25	SR
Pisaura	1	0.12	0.25	SR
Salticidae	4	0.72	1.47	R
Euophrys	1	0.4	0.82	SR
Pellenes	2	0.08	0.16	SR
Phlegra	1	0,24	0.49	SR
Tetragnathidae	2	0.6	1.23	R
Pachygnatha	2	0.6	1.23	R
Theridiidae	5	0.4	0.82	SR
Asagena	1	0.2	0.41	SR
Crustulina	1	0.04	0.08	SR
Enoplognatha	1	0.08	0.16	SR
Episinus	1	0.04	0.08	SR
Robertus	1	0.04	0.08	SR
Thomisidae	6	2.08	4.25	R
Ozyptila	2	0.64	1.31	R
Xysticus	4	1.44	2.95	R
Titanoecidae	3	0.28	0.57	SR
Nurscia	1	0.2	0.41	SR
Titanoeca	2	0.08	0.16	SR
Zodariidae	2	0.32	0.65	SR
Zodarion	2	0.32	0.65	SR

The relative abundance of spiders was higher in Skopje than Malesh valley (Fig. 2), with araneocenosis in L3 having the highest relative abundance (25.33 ind.·trap^{-1}), and L4 with only 1.84 ind.·trap^{-1} registered. Lycosidae and Gnaphosidae were dominant (Fig. 3), with Lycosidae showing a clear dominance over the other families in L3-L6 (54.35-88.68%), while Gnaphosidae shows a dominance to a lesser extent in L1 and L2, especially L2 where the percentage of captured lycosid and gnaphosid spiders is almost the same (37.58% and 40.61% respectively). The dominance of lycosids is most prominent in L3 where the abundance of gnaphosid species was very low, due to the high percentage of riparian lycosid species like *Pardosa proxima, Arctosa leopardus* and *Piratula latitans*.

On the species level, *Pardosa bifasciata* (6.44 ind.·trap^{-1}) and *Pardosa proxima* (6.56 ind.·trap^{-1}) are the most dominant species with 12% and 12.2% of all individuals, respectively. Namely, *Pardosa bifasciata* was dominant in L6 (60.57%), while *Pardosa proxima* had an occurrence of more than 10% only in L3 (38.32%). Most of the other species had an occurrence of less than 1% of total catch.

Cluster analysis of the spider abundances between the localities showed marked grouping of L1 with L2 and L4 with L5 at approximately 0.42% and 0.24% of similarity, respectively, and clear separation of L3 and L6, thus indicating four types of spider assemblages: riparian spider species, open area species, forest spider species and assemblages inhabiting ruderal and agrarian habitats (Fig. 4). The division into spider assemblages is supported by the fact that 50% of the species (50) are found in one locality, while the rest of 50 species (50%) are found in more than one locality. The presence of such habitat specific species is highest in L3 with 12 riparian species and lowest in L6 with five species that prefer open meadows. The pine forest has six forest species, L1 and L2 have eight habitat specific species each and L5 has five ecotone specific species.

When analyzing the structure of the spider community, indices of richness, diversity, homogeneity and dominance were calculated (Tab. 3). Index of dominance (DI) had lowest values in L2 (27.27%), and reached highest values in L6 (76.1%) as a result of high abundance of *Pardosa bifasciata*. Indices of richness and diversity were highest in L2 (d = 2.31, H` = 1.60) and L5 (d = 2.37, H` = 1.62) which contributes to highest values of homogeneity. The araneocenosis in L6 has the lowest indices of richness (1.50) and diversity (0.86), which leads to the lowest homogeneity (0.51) and emphasizes the existence of unfavourable conditions.

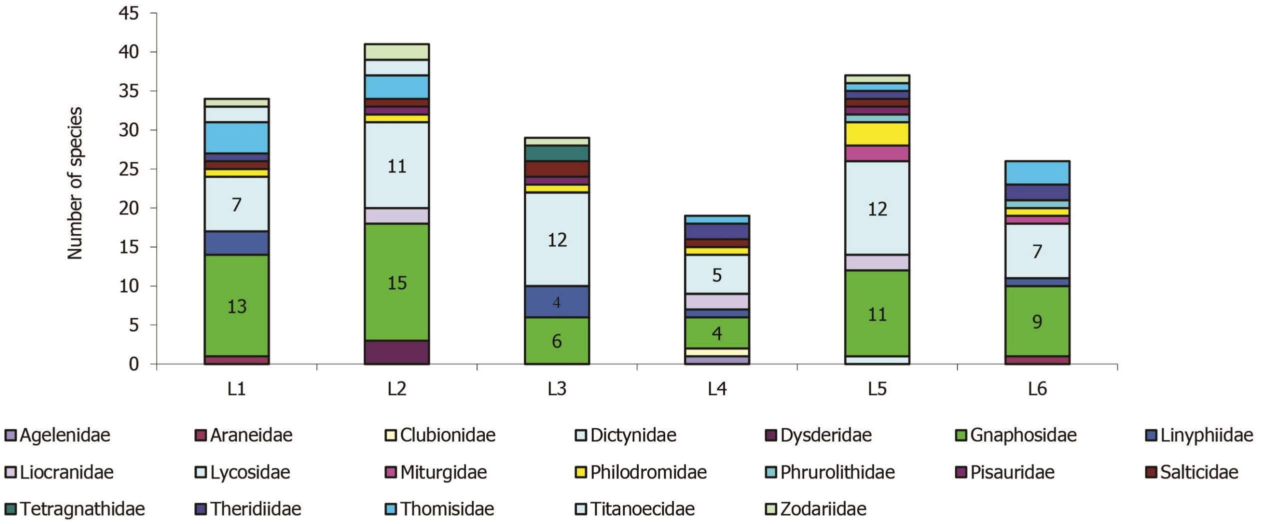

Figure 1. Species diversity of spider assemblages in six different habitats

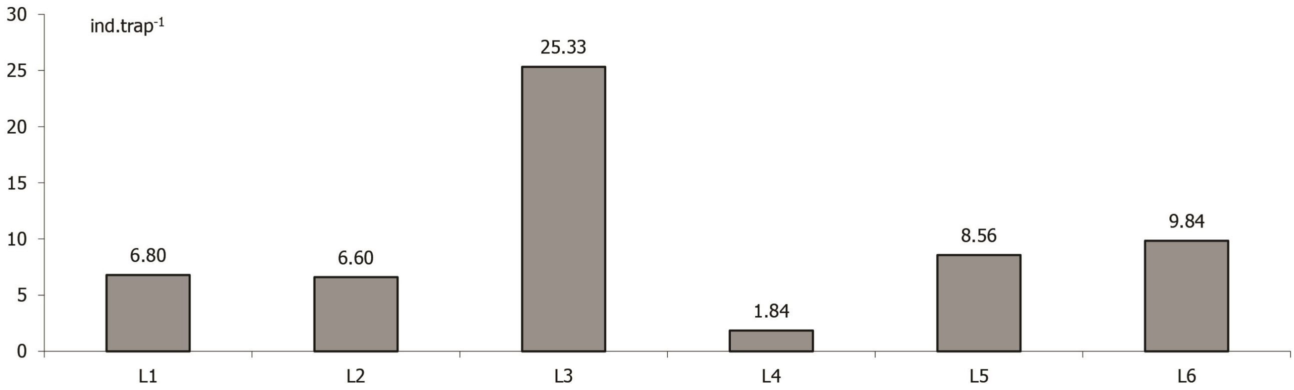

Figure 2. Relative abundance (ind. trap^{-1}) of spider assemblages in six different localities

Discussion

In contrast to many studies of biodiversity in Macedonia little research has been carried on the structure and ecology of spider communities. From 100 species recorded in all six localities, many abundant and 47 rare species were registered. Of the rare species 31 (31%) were represented with only one individual (singleton species) and 16 (16%) were represented with two individuals (doubleton species). The percentage of rare species found in this study is similar to the percentage of rare species found in a study done by Scharff et al. (2003) where 29% of the captured Araneae species were singletons and 18% were doubletons out of a total of 66 species. The number of singletons was higher in Malesh (18), compared to Skopje valley (11), with the lowest

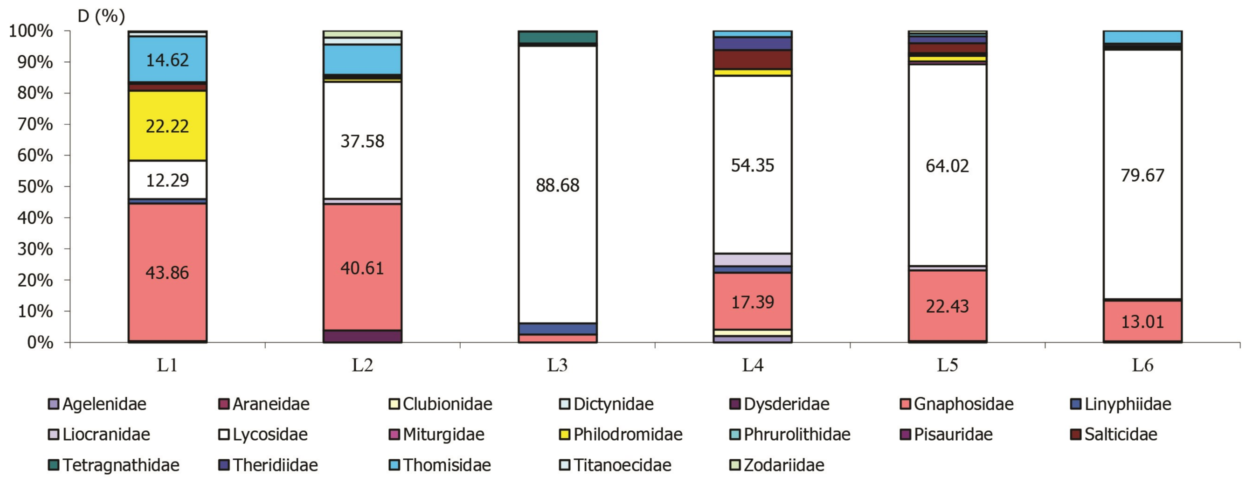

Figure 3. Dominance (%) of spider assemblages in six different localities

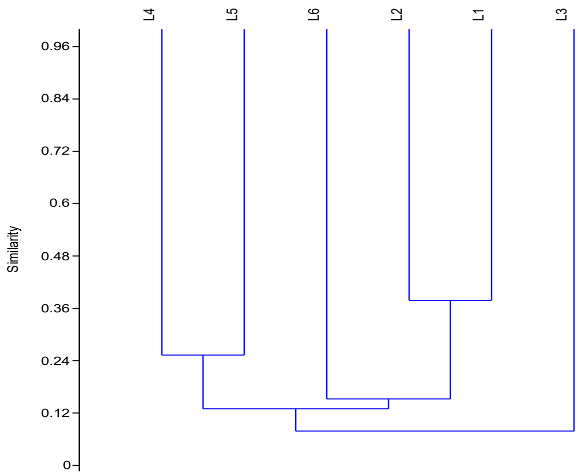

Figure 4. Bray-Curtis similarity analysis of spider assemblages between six different localities

number of singleton species registered in L3 (two), while the highest in L1 and L4 (8). Spider community from L1 and L2 strongly differed in composition from the others (Fig. 4). It is worth noting that 10 species were recorded only in L1 and L2 (one lycosid species, one thomisid, one zodariid, six gnaphosid and one titanoicid species) and the species *Civizelotes caucasius* was dominant only in these two localities.

Spider community of Malesh valley, inhabiting the ecotone had the highest species richness compared to pine forest and the clearing. The presence of both vegetation types and consequently the presence of species from both adjacent habitats in the ecotone explains higher number of species in the same. The species richness is complemented by the presence of ecotone specialist species as well. Similar results were obtained during the research of ecotones (Tóth & Kiss 1999; Horváth et al. 2002; Lacasella et al. 2015) where the species richness of spiders peaked in the ecotone zone. On the other hand, the studies of Jose et al. (1996) and Lloyd et al. (2000) had species richness values of the ecotone between the values of the neighboring habitats, while Gallé & Fehér (2006) found no significant differences in species richness among the three habitats. It is important to note that only the studies of Horváth et al. (2002), Gallé & Fehér (2006) and Lacasella et al. (2015) were performed in an ecotone between a forest and an open area, and all of them registered low species diversity in the forest (oak forest, poplar forest and beech forest, respectively).

Overall abundance of spiders did not change significantly between localities, with the exception of the highest and lowest values registered in L3 and L4, respective-

Table 3. Structural indices of the spider assemblages

Locality	d	DI%	H'	J_e
L1	1.84	39.41	1.30	0.66
L2	2.31	27.27	1.60	0.89
L3	1.55	56.28	1.22	0.66
L4	1.22	47.83	0.79	0.63
L5	2.37	53.27	1.62	0.82
L6	1.50	76.11	0.86	0.51

ly. Skopje valley had higher relative abundance of spiders (Fig. 2) mainly due to high abundance of spider community in L3 (riparian habitat).

The abundance of spiders in L1 and L2 was lower than L5 and L6 due to higher trophic capacity of forests. When analyzing community structure, L2 and L5 had the highest values of homogeneity. Also, we can see that the dominance index is highest in L6 as a result of high abundance of the species *Pardosa bifasciata,* which prefers dry meadows representing 60.57 % of all individuals captured. On the other hand, L2 has the lowest index of dominance, because the habitat's complexity can host stable populations of different species. Spider community from L4 was with lowest relative abundance, and as previously stated pitfall trap methodology should be used cautiously because activity and population density influence trap catches.

As previously stated, Lycosidae (19) and Gnaphosidae (21) had the highest species richness in the Skopje valley, while Lyniphiidae was present with only seven species. In addition, during the research of spider community in Skopje valley, Stefanovska et al. (2008) registered the presence of 18 lycosid, 22 gnaphosid and 36 lyniphiid species. Out of those, 12 gnaphosid, 10 lycosid and four lyniphiid species were registered in both studies.

Families Lycosidae and Gnaphosidae had the highest abundance and dominate the communities inhabiting pine forest, ecotone and the open area. In another research of spider community, along an altitudinal gradient on Belasitsa Mt., the most numerous families were Dysderidae, Linyphiidae and Amaurobidae (Cvetkovska-Gjorgjievska 2015). These differences of community composition between Malesh valley and Belasitsa Mt are due to the difference of climate, altitude and vegetation type.

Conclusions

As expected there were noticeable differences in the composition and abundance of the araneocenosis in different habitats due to resource access and the structural complexity of the habitats. This study was performed on a small scale (low number of pitfall traps) and further research needs to be done to better understand the correlation between the structure of araneocenosis and factors influencing the community.

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