



**Faunistical and ecological studies on the bark-dwelling spiders (*Araneae*)
living on Black Pine (*Pinus nigra*) in urban and forest habitats**

PhD thesis

Roland Horváth

University of Debrecen

Independent Faculties

Debrecen, 2004

1. Introduction

Trees represent well-defined and unique habitats for animals. On the one hand, trees are structurally complex and include several microhabitats (foliage, branch, trunk) Thus, they provide ample opportunity for niche-segregation. On the other hand, trees provide a stable food source for animals dwelling on them. These characters are coupled with a large geographical range in many tree species. All these factors result in a high species richness and diversity of tree-living animal communities. It also follows that arthropod animal assemblages of characteristic species composition are found on trees. In animal assemblages dwelling on trees the arthropod groups represented by the highest number of species are (i) phytophagous organisms consuming the organic material (wood) of the tree, (ii) parasitoids, (iii) predatory arthropods, and (iv) the so-called tourists, i.e., insects that primarily fly and stay on trees only temporarily.

Tree trunks, as a distinctive microhabitat of the tree, are characterised by numerous unique biotic and abiotic environmental factors, which explains why we can also discern separate, so-called bark-dwelling arthropod assemblages. Of the abiotic factors, the structure and colour of the bark and the microclimatic factors closely associated to them have a primary role. For example, in the deeper layers and below the bark, temperature is consistently higher and more even than on the surface of the bark. The different and more even heat conditions of the bark as a potential hiding place well explain the long-lasting or temporary colonisation of numerous arthropods.

Spiders represent a dominant taxon of bark-dwelling predatory arthropods. Well-recognisable adaptation phenomena, which can be observed in bark-dwelling spiders, provide evidence for the evolution of species living on or under the bark. This process is a sequential evolution, in which the relationship between the plant and the arthropod living on it is essentially asymmetric, i.e. not of a coevolutionary type, rather, the animals follow the evolution of the host plant without significantly affecting it. Adaptations of bark-dwelling spiders can be seen in morphology, phenology, and physiology. The factors above and the relatively few publications necessarily warrant the detailed study of these spiders.

My current work describes the results of a faunistical and ecological study of bark-dwelling spiders of Black Pine (*Pinus nigra subsp. nigra*). The study is the most comprehensive of its kind to date. I chose Black Pine because it is very wide-spread in Hungary even though it is not native, and the canopy-dwelling spiders have been surveyed

previously in several locations in Hungary. I conducted the study at seven sampling locations in two large landscape regions of Hungary (Western Hungary and the Great-Plain, see Material and methods).

In my dissertation, I aimed to study the following questions in detail:

- 1a. Which species and in which composition of hunting strategies occur on the bark?
- 1b. What are the typical species of Black Pine?
- 1c. What characteristic differences can be shown between urban and forest habitats? (Study I – V.)

- 2a. Are bark-dwelling spiders sensitive to air pollution?
- 2b. Can differences be detected in species richness and diversity between differently polluted areas in the city of Szombathely?
- 2c. Which species can be considered good indicators of air pollution? (Study II – III.)

3. Does trap exposition time or air temperature have a major role in the movement of spiders under the bark for overwintering? (Study IV)

- 4a. Are there differences in spider communities and their prey animals between urban and forest habitats in different seasons?
- 4b. Can correlations be detected between the number of individuals, species richness and diversity of spiders and the quantitative relations of prey in different areas?
- 4c. Is there a relationship between the number of individuals and species richness of spiders belonging to different guilds and the number of their prey?
- 4d. What correlation exists between the number of prey and the number of individuals of exclusive or facultative bark-dwelling spiders? (Study V)

2. Material and methods

The collection of spiders living on Black Pine took place between 1996 and 2000 in seven sampling locations. At each site, Black Pine was planted shortly after second World War. The sampling localities were as follow:

- (1) Szombathely, Millennium Park (formerly called Gagarin Avenue): This site is a moderately air polluted urban line of trees.
- (2) Szombathely, Paragvári Street: This stand is located along a strongly polluted road with heavy traffic.
- (3) Szombathely, Csónakázó pond: A line of trees located near an artificial lake, with moderate air pollution.
- (4) Kőszeg Mountains, Hörman spring: A planted Black Pine stand with no disturbance, 720 m above sea level in the southern part of the mountain range.
- (5) Kőszeg Mountains, Bozsok: This site is also in the southern part of the mountain range, a planted stand of Black Pine at an elevation of 200 m above sea level.
- (6) Debrecen, Nagyerdő forest: A moderately polluted stand of Black Pine, located 200 m west of Highway 4.
- (7) Debrecen, Fancsika ponds: A moderately polluted stand, mixed with Black Locust (*Robinia pseudo-acacia*), near a pond.

Spiders were collected by 15-cm-wide belt traps made of waved cardboard and fixed on the trunk ca. 3 m high with their waved surfaces inwards. The belt traps covered the entire circumference of the tree and functioned as an artificial bark. Prey organisms were collected by 5-cm-wide traps made of nylon foil and the outer surfaces of which were treated with a glue of the type Soveurode aerosol (Sovilo Co.). The collection of both spiders and prey took place around 12:00 noon with calm wind conditions.

In the processing of data I used the following statistical methods and software: Kolmogorov-Smirnoff test, Levene-test, hierarchical cluster analysis (Matusita index and Ward-Orlóci fusion method), IndVal (Indicator Value) method, independent-samples t-test and paired t-test, non-metric multidimensional scaling (NMDS) (using Bray-Curtis similarity function), one-way and two-way analysis of variance (ANOVA), Kruskal-Wallis test, simple and multiple linear regression, Pearson correlation, NuCoSA 1.05, Statistica 1.5 for Windows, IndVal 2.0, SPSS 9.0 for Windows.

3. Results and discussion

1a. In the study period between 1996 and 2000 a total of 7744 individuals were found which could be identified to the species-level in 59 taxa, to the genus-level in 22 taxa, to the subfamily-level in one case and to the family-level in 4 taxa. Of the species collected,

Clubiona leucaspis Simon, 1932 was found to be new to the fauna of Hungary. Besides this, the species *Cheiracanthium mildei* L. Koch, 1864 is also worthy of mentioning, since it is a typical southern-European fauna element. In Hungary it occurs in larger numbers in cities which have a warmer climate than natural habitats and in orchards of the Great-Plain of Hungary. Of the spider guilds, web-builders were represented by the highest number of species (29 species). They were followed by diurnal hunters (15 species) and nocturnal hunters (14 species). Only a small part of the species detected belonged to exclusive bark-dwellers, and most of them were facultative bark-dweller or species occurring on the bark accidentally. The highest number of species occurred in moderately polluted urban areas (Millennium Park, Csónakázó pond). At the other localities, the number of species shows relatively small differences, with the exception of Hörman spring. The latter area had a low species richness, which can be explained by the fact that collections were made at this locality for only one year, in 1996.

1b. Species characteristic to Black Pine are: *Dipoena melanogaster* (C. L. Koch, 1837), *Theridion mystaceum* L. Koch, 1870, *Theridion pinastri* L. Koch, 1872, *Lathys humilis* (Blackwall, 1855), *Clubiona leucaspis* Simon, 1932, *Philodromus longipalpis* Simon, 1870, *Philodromus praedatus* O. P.-Cambridge, 1871, *Dendryphantas rudis* (Sundevall, 1833), *Macaroeris nidicolens* (Walckenaer, 1802).

1c. Urban and forest localities separated relatively well in each season and urban localities proved more species-rich. Reasons for this can be the warmer climate of cities, lower predation pressure by birds, denser foliage and higher prey availability. At the same time, the sampling locality in Kőszeg Mountains sharply separates from all other sampling localities in the summer and autumn, when exclusive bark-dwelling species can be found in highest numbers on the trunk. The reason for this has to be sought in the unique species composition of the mountain range, which can be explained by the special topographic and climatic conditions of the mountain range. Undoubtedly the habitat itself as well as the surrounding habitats have a relevant role in this phenomenon.

2a. I conducted the effect of air pollution on spiders in two, differently polluted urban line of trees (moderately polluted: Millennium Park, heavily polluted: Paragvári Street) in 1996 and in 1998. The studies unambiguously proved that there is a detectable relationship between the abundance of spiders and the extent of air pollution.

2b. Species richness and Shannon-diversity were significantly higher in the moderately polluted sampling locality (Millennium Park) in the winter, spring and autumn. In

the summer, when only exclusive bark-dwelling species occur on the trunk in higher numbers, there was no significant difference between the two areas. The reason for the differences may be that facultative bark-dwellers react much more sensitively to direct and indirect (change in habitat structure and in environmental conditions) effects caused by air pollution, therefore their abundance is lower in the polluted area. I did not find a significant difference between the two sites in the summer because at this time, only the exclusive bark-dwelling species occur in higher numbers on the trunk. Because the bark is presumably a suitable hiding place, these species are only moderately exposed to the direct effects of air pollution, and, furthermore, the effect of air pollution on the microhabitat-structure and microclimate of the bark is also non-significant.

2c. Using the IndVal statistical method, I managed to classify species into three main groups based on their reaction to air pollution: 1) habitat generalists, which occurred in high numbers at both localities and are not sensitive to air pollution (*Keijia tincta* (syn. *Theridion tinctum*) (Walckenaer, 1802), *Nuctenea umbratica* (Clerck, 1757), *Clubiona leucaspis*, *Scotophaeus scutulatus* (L. Koch, 1866), *Philodromus (aureolus)* species group, *Philodromus (margaritatus)* species group); 2) species sensitive to air pollution, which occurred exclusively or in significant numbers only at the moderately polluted area (*Steatoda bipunctata* (Linnaeus, 1758), *Moebelia penicillata* (Westring, 1851), *Lathys humilis*, *Anyphaena accentuata* (Walckenaer, 1802), *Cheiracanthium mildei*, *Clubiona pallidula* (Clerck, 1757), *Salticus zebraneus* [C. L. Koch, 1837]); 3) species that showed a higher density at the polluted area (*Theridion blackwalli* O. P.-Cambridge, 1871, *Theridion mystaceum*). This result shows well that different species react to air pollution in different ways.

3. I studied the effect of exposition time (i.e. time passed between the installation and collection of the traps) and temperature on the overwintering of spiders at the Fancsika ponds in 1999 and 2000. In the series of studies I concluded that with respect to the averaged variables (species richness, diversity and number of individuals) I experienced significant differences among sampling times only in 2000 and even then, only with respect to number of individuals, the reason of which is the increased numbers of one species (*Philodromus margaritatus* [Clerck, 1757]) of the last sampling time. When I combined the collections of one sampling time, then it could be concluded that in 1999, absolute species richness showed a marginal significant with temperature whereas absolute diversity and absolute number of individuals showed a positive significant correlation with exposition time but not with

temperature. In 2000, only the absolute number of individuals showed a significant relationship with exposition time and temperature did not have a detectable effect on the overwintering of spiders even in this year. The reason for this was the constantly high ($\geq 8^{\circ}\text{C}$) temperature, in contrast to 1999, when I also measured much lower temperatures. My results thus show that the migration of the spiders to the bark is a characteristic temporal process, which can be detected by using belt traps. Results from 1999 show that the diversity and number of individuals increased continuously, i.e., when temperature increased only slightly, spiders kept on moving from the foliage to the bark. Results from 2000, however, indicate that this movement of spiders can be delayed if temperature is continuously high during the autumn.

4a. I examined the effect of prey availability on spiders in the summer and autumn of 1999 at three urban habitats (Millennium Park, Paragvári Street, Csónakázó pond), at a mountain forest habitat (Bozsok) and two Great-Plain forest habitats (Nagyerdő forest, Fancsika ponds). There was a significant difference in the species richness and Shannon diversity of spiders among the sampling localities, however, there were no significant differences with respect to seasons and interaction in my studies.

The reason for the differences observed in spider species richness is that species richness was low in the Nagyerdő forest sampling locality. This site is isolated from other plantations of Black Pine by deciduous forests and juvenile spiders spreading mostly by air can be found in smaller proportions than in the other sampling localities.

In the number of individuals I found a significant interaction within the sampling localities and between the seasons, however, there was no such detectable correlation among sampling localities and seasons. The number of individuals increases from summer to autumn in the urban localities due to the appearance of facultative bark-dwelling species. The number of individuals, in contrast, decreases or remains constant in the forest sites. This can be explained by the fact that the canopy is located higher and the foliage is less dense in the forests, and these results in density at the height of our belt traps being lower in the forest than in the urban sites. Furthermore, predation by birds can be stronger in the forest sites, which can also explain why the number of individuals does not increase from summer to autumn in the forest areas.

The diversity of spiders was low in the Great-Plain sampling localities and in the heavily polluted urban site, which is primarily a consequence of the *ab ovo* lower species richness and number of individuals in these areas, due to the reasons mentioned above.

4b. By the examination of the entire species community, it was concluded that the spider species richness and number of individuals showed positive relationships with number of prey taxa in Bozsok, however, the correlation in the case of these variables showed negative in the moderately polluted urban localities. These results show that spiders react numerically to prey living on the bark of Black Pine and that prey abundance can be important in the explanation of the abundance of spiders in certain areas. Interestingly, spider species richness showed a positive relationship with prey taxon diversity in the moderately polluted urban localities. These results suggest that there may be many cases when prey abundance can influence the occurrence of spiders and that spiders can affect the abundance of their prey to different extents as a consequence of their hunting strategies.

A positive correlation between the number of spider and prey individuals showed in Bozsok, however, the relationship was negative in the heavily polluted urban locality. In the latter area, air pollution damages the bark of many trees, which are thus more exposed to the herbivorous and pest species. This area provides unfavourable conditions for spiders due to air pollution, which can decrease their abundance especially on trees more exposed to air pollution. These two effects coupled can explain the negative correlation between the number of spiders and prey abundance in this locality.

4c. In the guild-level studies the results showed that there is a detectable correlation between spiders and number of prey individuals only in the case of nocturnal hunters. Because nocturnal hunters do not consume *Diptera* (due to their differing diurnal activity), thus I categorised the number of prey individuals into two groups (all prey found minus *Diptera* and prey animals occurring exclusively on the bark). This distinction was necessary because nocturnal hunters consume “tourists” only to a small extent and feed in the most part with exclusive bark-dwelling prey. The species richness of spiders belonging to this guild showed a positive relationship with the number of prey individuals (in both categorisations) in the moderately polluted urban localities and in Bozsok. However, I found a positive correlation between spider numbers and the number of prey individuals (in both categorisations) only in Bozsok.

In contrast, I did not observe a relationship between the variables with respect to the other two guilds (diurnal hunters, web-builders). One of the reasons for this can be that diurnal hunters were active at the time of collections (12:00 noon) and therefore were present in the traps in small numbers. Females of web-builders, furthermore, are rather sessile animals, therefore, they tend not to move away from the traps. However, most specimens of these species were collected as juveniles, which, similarly to diurnal hunters, hunt on the bark

actively, and as a consequence, I did not manage to detect a correlation with the number of prey in this guild either.

4d. Because exclusive bark-dwelling species can be found on the bark throughout the year, whereas facultative bark-dwellers primarily from autumn to spring (only in very small numbers in the summer), therefore, it was by all means warranted to examine the species of the two groups separately. In the case of exclusive bark-dwelling spiders, I found a positive relationship between number of individuals and number of prey individuals in the Great-Plain forest localities. One reason for why such a correlation could be detected only in these areas is that the number of individuals of these species was highest here, which is a consequence of the massive presence of two species (*Marpissa muscosa* (Clerck, 1757), *Nuctenea umbratica*). The effect of the number of exclusive bark-dwelling spiders in the entire relationship is likely to be less substantial in other areas due to the presence of several facultative species that occur in substantial numbers. Contrastingly, the correlation between spider numbers and prey numbers was negative in the case of the heavily polluted urban locality, which is a consequence of air pollution, as mentioned above. No relationship could be detected between the number of individuals and number of prey in the case of facultative bark-dwelling spiders.

The results of my dissertation show that numerous factors play a role in the formation and distribution of bark-dwelling spider communities, such as the structural diversity of habitat (which includes the foliage of different quality and structure), the productivity of the habitat, climatic conditions, air pollution, the phenomenon of overwintering, the abundance of predators (primarily birds) of spiders, the abundance of prey, and competition and predation among spider species.

My results also provided evidence that different species assemblages characterise the bark-dwelling fauna of Black Pine in different habitats, therefore, bark-dwelling spiders can be suitable subjects of studies of biological monitoring and indication.