The effect of exposition time and temperature on spiders (*Araneae*) overwintering on the bark of black pine (*Pinus nigra*)

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running headline: Horváth et al.: Time and temperature effects on spiders

Abstract

The effect of exposition time (time between the installation of traps and the collection of spiders) and autumn air temperature on spiders overwintering on tree bark was studied in a planted black pine forest (Pinus nigra) near Debrecen (east Hungary). We collected spiders from traps fixed 2 m high on tree trunks once every five days for 50 days in 1999 and 2000. We collected 957 spiders belonging to 15 species and 1 species determined to the genus level in the two years combined. In 1999, the diversity and number of spiders increased with exposition time but were not influenced by temperature when data were combined for each sampling time. This was because temperature was low in the middle of the sampling period, but increased again at the end, which weakened its effect. However, the diversity and number of individuals continued to increase even when temperature increased at the end of the sampling period. In 2000, the number of individuals increased by exposition time because we found individuals of Philodromus margaritatus in very high numbers on the last sampling occasion. There were no other differences in 2000 because temperature was constantly high during the sampling period. Our results suggest that the movement of spiders to the bark is a characteristic process and that the diversity and number of spiders continue to increase in the autumn even when temperature slightly increases. This process, however, can be delayed if temperature is constantly high during the study period.

Key words: bark-dwelling spiders, species richness, diversity, number of individuals

INTRODUCTION

In temperate zones, poikilotherm animals are faced with the challenge of surviving extreme cold periods. Invertebrate species have evolved a number of ways to tackle this problem. Spiders, for example, can use hibernacula (shelters for overwintering), develop cold resistance or adapt their metabolism to a lower level to reduce the effect of cold (Kirchner 1987). Spiders living in the vegetation or on the soil use various hibernacula, such as leaf litter, grass tussocks, rocks, caves or houses, bird nests, upper vegetation, or crevices on the bark of trees (Engelhardt 1964, Schaefer 1977, Balkenhol & Zucchi 1989, Gajdos 1991). The microclimate of these microhabitats can be milder than that of the general habitat, which enable spiders to survive the winter.

Spiders can overwinter either as eggs, juveniles or adults. Adult and juvenile spiders can use a silken sac to enhance the insulation of the hibernacula or just simply stay immobile at the hibernacula. Species that use silken sacs can stay there throughout the winter, whereas others can leave the sac during favourable conditions to feed. Under favourable conditions juveniles can even speed up their development to reach adulthood earlier (Kiss & Samu 2002).

The bark of trees is one of the most important overwintering microhabitats of spiders. Exclusive bark-dwelling spiders use the bark throughout

the year and occur only on the bark, whereas facultative bark-dwelling species use the bark only for certain periods (e.g. for overwintering) but spend most of the year in the foliage or on the branches (Wunderlich 1982). Facultative bark-dwelling spiders are usually found on the bark only between November and April (Horváth et al. 2001). These species use the bark only for overwintering and move to the bark only when air temperature drops substantially (Horváth & Szinetár 1998). The movement of spiders to and from the bark is a characteristic process of overwintering. The movement can occur rapidly if the conditions change quickly, in contrast, it can happen over a longer period if the conditions deteriorate less rapidly. In spite of the importance of the movement of spiders to the bark, there are no data available on how (i.e. at what temperatures and how fast) the movement occurs.

The aim of our study was to determine how exposition time (between the installation and collection of traps) and changes in air temperature in the autumn affect the movement of spiders to the bark before overwintering. Specifically, first we were interested in whether there is a correlation between air temperature and species richness, number of individuals and diversity of spiders. Second, our aim was to determine the temporal characteristics of the movement, i.e., to find out whether time affects the species richness, number of individuals and diversity of spiders.

MATERIAL AND METHODS
Study area and sampling

We collected spiders using belt traps fixed on trunks of black pine (*Pinus nigra*) at the Fancsika water reservoir near Debrecen, eastern Hungary (UTM: ET 56 A4). The forest is a 3-ha planted stand of black pine (70%) and black locust (*Robinia pseudoacacia*) (30%) (Fig. 1.).

Trunk-traps were made of waved cardboard (15 × 120 cm) and were fixed 2 m above the ground on the trunk by tape. Belts were placed around the trunk, their waved surfaces facing the trunk and covering the whole perimeter of the tree, as a kind of artificial bark with the real bark under the traps (Horváth et al. 2001). There were two trapping periods. In the first collection pe-

riod we installed 100 trunk-traps on 26 October, 1999, out of which we removed 10 every five days. The last 10 traps were collected on 15 December, 1999. Because in 1999 every spider species could be collected by using 50 traps (Honti 2002), in the second period we installed 50 trunk-traps on 19 October, 2000 and removed them by five traps every five days, and the last traps were collected on 8 December, 2000. Traps were installed on trees other than those used in 1999. We aimed to conduct the study for 50 days in both years, and to end the study by mid-December because spiders usually move to the bark by this time.

Traps were removed at 12:00 noon on each occasion. Spiders were identified by species using standard keys (Loksa 1969, 1972; Heimer & Nentwig 1991; Roberts 1995). We used the nomenclature of Platnick (1997) during the identification.

Air temperature was measured at a permanent meteorological station ca. 2 km from the study site by the Department of Meteorology at the University of Debrecen, and we used the values measured at 12:00 noon on each collection day.

Data analyses

Data from the two years were treated separately. We first checked for the normality of average species richness, diversity and number of individuals using Kolmogorov-Smirnoff tests. If data showed normal distribution, we analysed samples collected during different sampling times using one-way analyses of variance
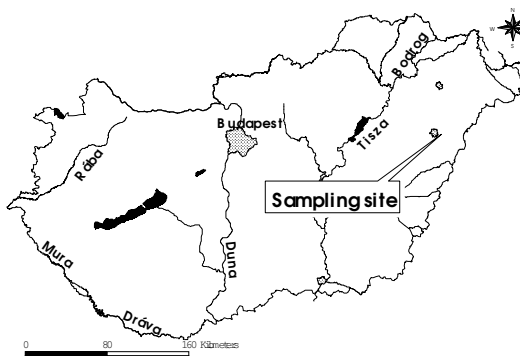

Fig. 1. Geographical location of the sampling site.

(ANOVA). When the data did not meet parametric assumptions, we used non-parametric tests, i. e., Kruskal-Wallis tests (Barta et al. 2000, Kuehl 1994). We used multiple regression models to evaluate the effects of exposition time and temperature on combined species richness, diversity and number of individuals at the same time (Barta et al. 2000). In these analyses, data were combined so that all spiders collected at any one sampling day were considered as one set and species richness, diversity and number of individuals were calculated for each sampling day. This way one data point represented one sampling time in each year, thus we had ten data points for each multiple regression model for each year. Exposition time was considered a continuous, quantitative variable in both ANOVA-type and regression-type analyses (Kuehl 1994). Statistical analyses were carried out by using Statistica 5.1 for Windows (StatSoft, Inc. 1995) and NuCoSA 1.05 (Tóthmérész 1993) software packages.

RESULTS AND DISCUSSION

During the study a total of 957 individuals belonging to 15 species and 1 species determined to the genus level were trapped (Table 1.). Temperature varied between 1.0 and 14.6 ºC in 1999 and between 8.2 and 20.6 ºC in 2000 (Fig. 2.).

When data from each trap collected at one sampling time were considered separately in 1999, there was no difference in average species

Table 1. *Number of individual spiders (female/male/(juvenile)) collected in 1999 and in 2000. Facultative bark-dwellers are marked with a letter "F" after the species name and exclusive bark-dwellers are marked with an "E".*

| FAMILY/Species	1999	2000
DYSDERIDAE		
Harpactea rubicunda "F" (C. L. Koch, 1838)	0/0/(0)	0/0/(1)
THERIDIIDAE		
Anelosimus vittatus "F" (C. L. Koch, 1836)	0/0/(4)	0/0/(0)
Steatoda bipunctata "F" (Linnaeus, 1758)	13/2/(1)	3/0/(1)
Theridion blackwalli "F" O. P.-Cambridge, 1871	0/0/(1)	0/0/(0)
T. mystaceum "E" L. Koch, 1870	0/0/(3)	0/0/(0)
T. tinctum "F" (Walckenaer, 1802)	0/0/(4)	0/0/(0)
ARANEIDAE		
Gibbaranea bituberculata "F" (Walckenaer, 1802)	0/0/(2)	0/0/(0)
Nuctenea umbratica "E" (Clerck, 1757)	46/0/(10)	6/0/(1)
DICTYNIDAE		
Dictyna sp.	0/0/(2)	0/0/(0)
ANYPHAENIDAE		
Anyphaena accentuata "F" (Walckenaer, 1802)	0/0/(38)	1/0/(0)
CLUBIONIDAE		
Clubiona pallidula "F" (Clerck, 1757)	0/0/(92)	0/0/(3)
GNAPHOSIDAE		
Scotophaeus scutulatus "E" (L. Koch, 1866)	0/0/(0)	0/0/(1)
PHILODROMIDAE		
Philodromus spp. (*aureolus*) "F"	0/0/(77)	0/0/(17)
Philodromus spp. (*margaritatus*) "F"	0/0/(519)	0/0/(100)
THOMISIDAE		
Misumenops tricuspidatus "F" (Fabricius, 1775)	0/4/(4)	0/0/(0)
SALTICIDAE		
Marpissa muscosa "E" (Clerck, 1757)	0/0/(0)	0/0/(1)
Ó	59/6/(757)	10/0/(125)
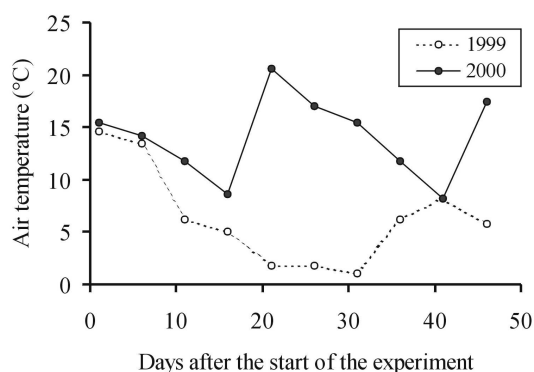
Fig. 2. Air temperature measured at 12:00 noon at a meteorological station 2 km from the study site on each sampling day during the sampling period in 1999 and in 2000.

richness among collection times (Kruskal-Wallis H_9=5.59, N=100, NS; Fig. 3.A). There were also no differences among sampling times in either average diversity (ANOVA, $F_{9,99}$=1.20, NS; Fig. 3.B) or average number of individuals ($F_{9,99}$=1.63, NS; Fig. 3.C).

However, when data were combined for each sampling time in 1999, combined species richness was marginally significantly influenced by temperature but not by sampling time (multiple regression, R^2=0.44, $F_{2,7}$=2.73, NS; temperature: t_7=2.33, P=0.053; exposition time: t_7=1.02, NS; Fig. 4.A). However, the combined diversity of spiders was influenced by exposition time but not by temperature (R^2=0.73, $F_{2,7}$=9.38, P<0.011; exposition time: t_7=3.33, P=0.010; Fig. 4.B; temperature: t_7=0.71, NS). Exposition time also affected the combined number of individuals, whereas temperature did not (R^2=0.64, $F_{2,7}$=6.17, P<0.028; exposition time: t_7=3.43, P=0.011; Fig. 4.C; temperature: t_7=1.06, NS).

These results suggest that combined species richness increased as temperature decreased, but because temperature increased slightly toward the end of the sampling period (Fig. 2.), its effect was only marginally significant. However, because temperature was low in the middle of the sampling period, spiders appeared on the bark in higher numbers and higher diversity at this time, and the increased combined diversity and number of individuals did not change even after the slight increase of temperature at the end of the

sampling period. In other words, spiders that moved to the bark during the middle of the sampling period did not move back from the bark at the slight increase of temperature, which may have resulted in our observation that combined diversity and number of individuals were affected by exposition time but not by temperature. During the period when temperature decreased (sampling time 1 to 7, Fig. 2.), the number of individuals increased as time passed and temperature decreased (R^2=0.85, $F_{2,4}$=11.14, P=0.023; exposition time: t_4=4.21, P=0.014; temperature: t_4=3.22, P=0.032). However, the effect of temperature on the diversity of spiders was not significant, unlike that of exposition time (R^2=0.85, $F_{2,4}$=10.99, P=0.024; exposition time: t_4=3.15, P=0.035). The latter result indicates that although more spiders appeared on the bark during the cooling period, the increase can be attributed to the appearance of individuals of only a few species. This was supported by the finding that species richness did not change with time or temperature during the cooling period (R^2=0.39, $F_{2,4}$=1.27, NS).

The findings that average diversity and number of individuals did not differ among sampling times, whereas combined diversity and number of individuals increased during the sampling period also suggest that the use of the averaged variables obscured the differences that may have had biological relevance. It is also possible that the size of the traps was too small for the type of patchiness observed. However, we chose 15-cm-wide traps because our previous experience suggested that this size is adequate to detect differences, and because we used this traps in a previous study (Horváth et al. 2001).

When data from each trap were treated separately in 2000, average species richness was not different among sampling times (H_9=12.23; NS; Fig. 3.D). Similarly, average diversity did not differ among sampling times (H_9=12.23; NS; Fig. 3.E). However, the average number of individuals differed among sampling times (H_9=19.16; P=0.024), mostly because we found more spiders in the last sampling time than on the previous occasions (Fig. 3.F). This was caused by a sudden increase in the numbers of a single species, *Philodromus margaritatus*, in the last sampling time.
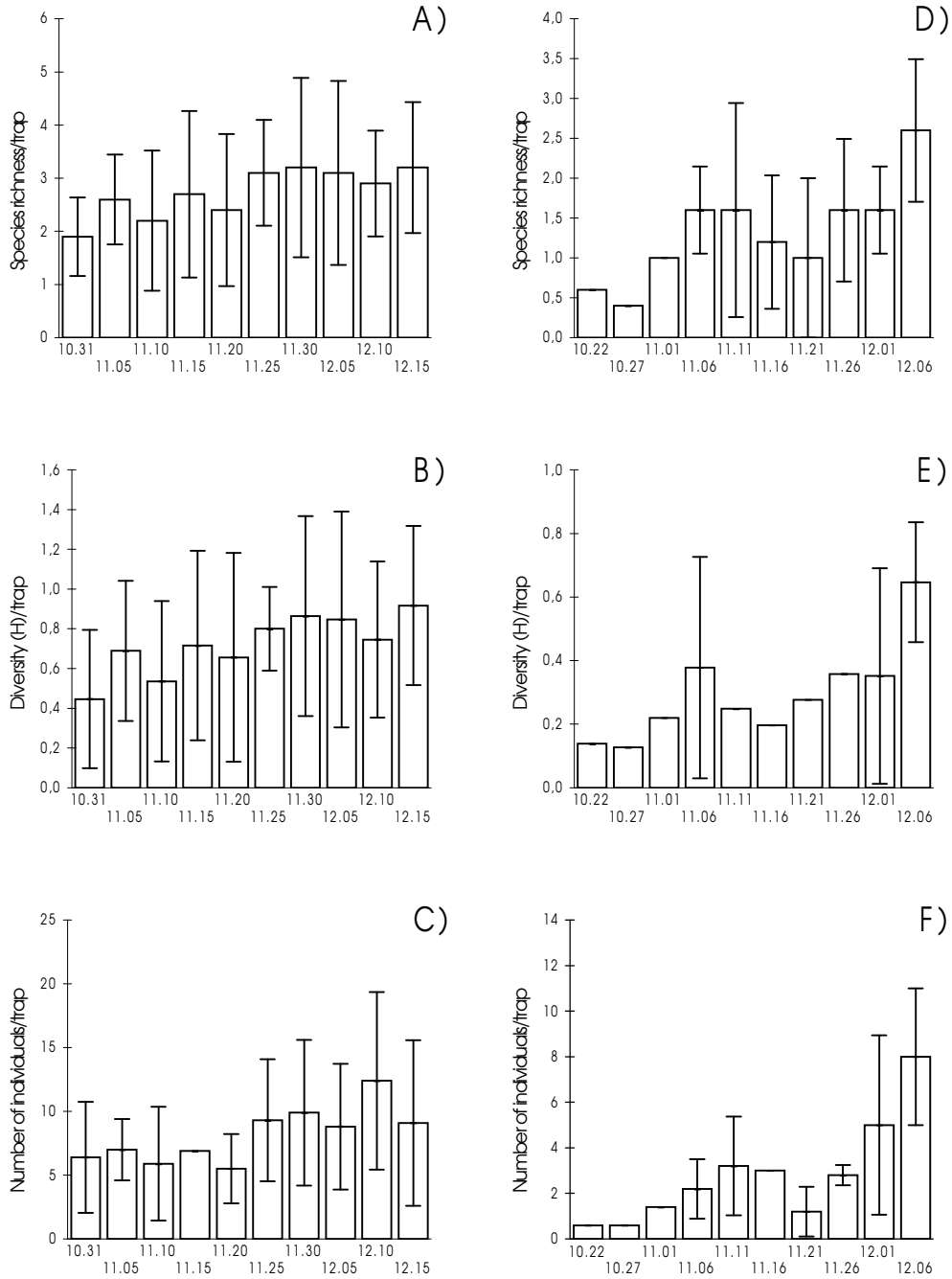
When data from each trap were combined for

Fig. 3. Mean ± SD species richness (A, D), diversity (B, E) and number of spiders (C, F) collected at each sampling time in 1999 (A-C) and in 2000 (D-F). Dates are given in mm.dd format.
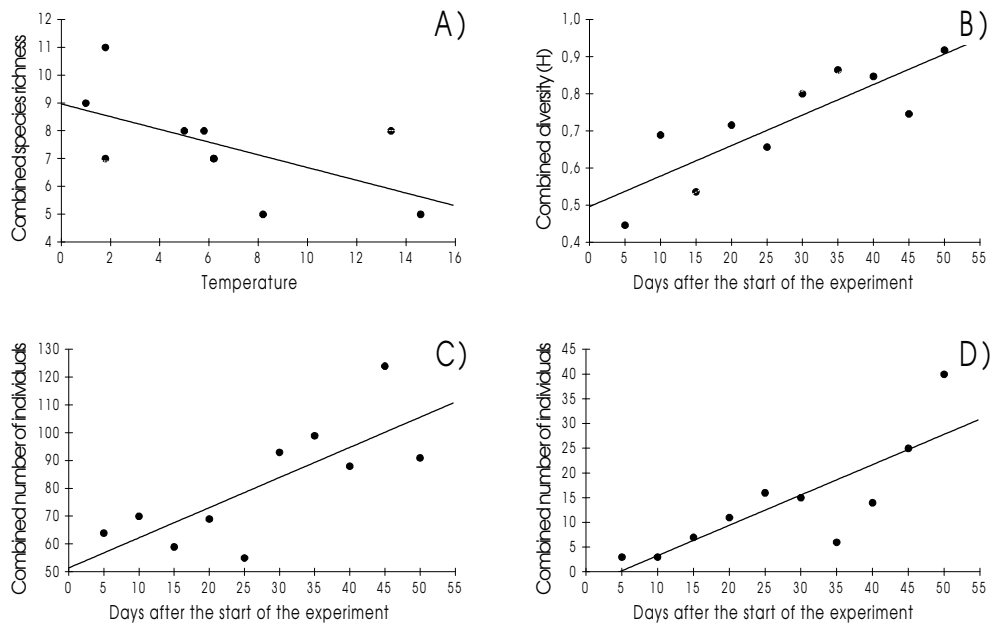
Fig. 4. The relationship between temperature and combined species richness (A), exposition time and combined diversity (B), exposition time and combined number of individuals (C) in 1999, and between exposition time and combined number of individuals in 2000 (D). Lines shown were obtained by multiple linear regression models (see Materials and methods for definition of variables and Results and discussion for statistics).

each sampling time in 2000, combined species richness was not influenced by either sampling time or temperature ($R^2=0.10$, $F_{2,7}=0.40$, NS; exposition time: $t_7=0.18$, NS; temperature: $t_7=0.88$, NS). The combined diversity of spiders was also not significantly affected by either exposition time or temperature ($R^2=0.17$, $F_{2,7}=0.71$, NS; exposition time: $t_7=0.45$, NS; temperature: $t_7=1.12$, NS). However, diversity was influenced by both exposition time and temperature during the second cooling period in 2000 (from sampling time 5 to 9, Figure 2.) ($R^2=0.98$, $F_{2,2}=41.99$, P=0.023; exposition time: $t_2=9.10$, P=0.012; temperature: $t_2=9.16$, P=0.012). The combined number of individuals, however, was significantly influenced by exposition time but not by temperature during the entire sampling period ($R^2=0.68$, $F_{2,7}=7.56$, P<0.020; exposition time: $t_7=3.86$, P=0.006; Fig. 4. D; temperature: $t_7=0.64$, NS). In this case, too, the increase in the number of individuals could be attributed to the sudden increase of one species, *P. margaritatus*, on the bark in the last sampling time. The appearance of this species on the bark was distrib-

uted more evenly in 1999.

The lack of the effect of exposition time and temperature can be explained by the fact that temperature was constantly high during the sampling period (Fig. 2.) and spiders did not move to the bark as they did in 1999. Temperature did not vary much during this period, and was above 10 ºC in eight of the ten sampling times. Spiders are known to be active at temperatures as low as 5 ºC (Bogya 1995), thus it is not surprising that we did not find differences by temperature in 2000, when temperature was above 8 ºC at each collection time.

In summary, our results suggest that the movement of spiders to the bark of trees is a characteristic temporal process, which can be detected by using trunk-traps. The results from 1999 show that spiders continued to increase in diversity and number of individuals, i.e. they moved to the bark of trees from the canopy, even when temperature slightly increased. The results from 2000, however, indicate that the movement of spiders can be delayed if temperature is con-

stantly high during the autumn.

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