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SPIDER ABUNDANCE IN RELATION TO NEEDLE DENSITY IN SPRUCE

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ABSTRACT. The effect of micro-habitat change, caused by needle-loss, on spiders living in spruce (*Picea abies*) was examined in a field experiment. Abundance and size distribution of spiders on spruce branches were recorded at the start and at the end of the experiment. All spiders and approximately 24% of the needles were removed from the experimental branches. In the control branches, the needle density was left unaltered but the spiders were removed. There were no initial differences in the spider community on the selected branches. Spiders were collected after seven weeks of colonization on control and needle-thinned branches, respectively. The mean density of spiders was significantly lower on needle-thinned branches (78%) than on control branches. This was shown to be an effect of reduced density of large (length ≥2.5 mm) spiders, but not of small (≤2.5 mm) ones. However, the total size distributions did not differ between the branch categories. The field experimental data confirm earlier results in laboratory studies and natural populations.

In Scandinavia, spiders are one of the dominating groups among the spruce-living (*Picea abies*) arthropods (Hågvar & Hågvar 1975; Askenmo et al. 1977; Jansson & von Brömssen 1981; Gunnarsson 1983, 1988, 1990; Suhonen et al. 1992). Several studies on the spider fauna in SW Sweden have shown that Linyphiidae and Thomisidae are predominant among families. Some common species are, e. g., *Pityohyphantes phrygianus*, *Neriene peltata*, *Philodromus* spp., *Diaea dorsata*. Other common families are Theridiidae, Araneidae, Tetragnathidae, Clubionidae, Dictynidae, and Uloboridae (refer to Norberg 1978; Gunnarsson 1983, 1988 for details). However, there are reasons to suspect that long-term changes in the spider community occur, and that this process indirectly is caused by man (Gunnarsson 1988, 1990).

Coniferous forests in several parts of central and northern Europe are severely affected by air pollution (Blank 1985; Andersson 1986; Schulze 1989). The accelerated needle-loss observed in polluted areas has been interpreted as a symptom of increasing stress. The architecture of the trees is altered by the decreasing needle density which makes the canopies and the branches "thinner" (Westman & Lesinski 1986). These changes may affect the tree-living fauna indirectly as plant structures are important in providing living-space (Lawton 1986). Vegetation structure has been suggested as a major factor in determining the abundance and diversity of plant-living arthropods (May 1978; Southwood 1978; Morse et al. 1985; Lawton 1986). The relationship between vegetation structure and spider community is especially well documented (e. g. Duffey 1962; Colebourn 1974; Hatley & MacMahon 1980; Robinson 1981; Rypstra 1983; Greenstone 1984; Gunnarsson 1988, 1990, 1992).

Indirect effects of air pollution, mediated by needle-loss in spruce, have been observed in natural spider populations in SW Sweden. Earlier studies showed that the abundance, size distribution and taxonomic composition were affected by the needle density, i. e., indirectly related to air pollution effects (Gunnarsson 1988, 1990). There is, however, no evidence for any toxic effects of acid precipitation on spiders (Gunnarsson & Johnsson 1989).

Here, we examine the effects of needle density in spruce on the abundance of spiders in a field experiment. The accelerated needle-loss was simulated by removal of approximately 25% of the needles from experimental branches. Any difference in spider abundance should be possible to attribute to the experimental manipulation of needle density since all spiders were removed from the branches at the start of the experiment. The prediction is: lower spider density on the needle-thinned branches than on the controls. An earlier two-month field experiment showed low densities on needle-thinned branches (Gunnarsson 1990). However, this experiment was performed in fall and confounding factors could have influenced the results, e. g., spiders may

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Table 1.—Data on the control and experimental, needle-thin, spruce branches at the end of the field experiment. Means are given as kg dry weight; n = 15 in all cases. *Before needle removal 51.3%; **7.7%.

	Control		Experimental	
	Mean (kg)	(SD)	Mean (kg)	(SD)
Total branch-mass	0.333	(0.059)	0.263	(0.055)
Twig-mass	0.178	(0.039)	0.162	(0.032)
Needle-mass	0.154	(0.029)	0.102	(0.026)
Needle percentage	46.5	(4.5)	38.4*	(3.3)**

leave if needle-thinned branches are suboptimal for winter survival. In a summer experiment we examined whether needle-density effects are dependent on season or not.

METHODS

The study site is part of a vast coniferous forest situated about 25 km E of Göteborg in SW Sweden. The predominant tree is spruce (*Picea abies*) of various sizes. Fifteen experimental trees were selected using random numbers, and two branches – one control and one experimental – in each tree were randomly selected up to a height of 2 m above the ground. The branches in the same tree and at the same height were assumed to be approximately equal micro-habitats for the spiders (Gunnarsson 1990).

The field experiment was performed between the 1 June and 5 August 1991. All spiders on experimental and control branches were removed by enclosing the needle-carrying parts of spruce branches in plastic sacks and then shaking the branches vigorously. The contents of each sack were examined in a white bowl and the spiders collected were preserved in 70% ethanol. The branches were then examined and any remaining webs or spiders were removed. One of the branches on each tree was used with its natural needle density as control. In the other branch, on average, 24.3% (±8.3% SD, n = 15) of the needles were removed to produce a needle-thinned branch. This needle-loss is similar to that observed in "slightly" damaged forests in Sweden (Andersson 1986). The removal was done by hand picking; and in order to simulate the field situation, the needle density reduction was higher on the inner parts of the branch than on outer parts. The removed needles were brought to the laboratory for weighing.

After seven weeks, the branches were cut directly into plastic sacks, which were sealed and brought to the laboratory where they were stored at 4 °C until examination. The branches were cut into small pieces and each piece was shaken and carefully examined over a white bowl. The spiders obtained were stored in ethanol. The branches were dried at +85 °C for 24 h. Each branch was divided into two fractions, needles and twigs, which were weighed separately.

The spider densities were related to the dry twig-mass (numbers/twig-mass in kg). This means that the experimental needle density reduction did not influence the density estimates.

The body length (from abdomen to carapace, excluding chelicerae and spinnerets) of all spiders were estimated with a ocular micrometer on a stereo microscope. Two length categories were distinguished: "small" (<2.5 mm) and "large" (≥2.5 mm) spiders (Askenmo et al. 1977; Gunnarsson 1983, 1988, 1990).

Two-tailed non-parametric tests were used because of non-normal data. Means are given together with their standard deviations (SD). The statistical tests were the Wilcoxon matched-pairs signed-ranks test (Wi), the Mann-Whitney *U*-test (M-W), and the Kolmogorov-Smirnov two-sample test (K-S) (STATVIEW SE software, version 1.04).

RESULTS

Before the start of the experiment, the mean percentage of needles in experimental branches was 51.3% *vs.* 46.5% in controls (Table 1). The spider mean abundances were 91.1 and 100.1, respectively (Table 2). There was no significant difference between these abundances (Wi, $z = -0.734$, $n = 15$, $P > 0.4$). Moreover, there were no density differences of large and small spiders (delimiting length 2.5 mm) between experimental and control branches (Table 2; Wi, $n = 15$, large: $z = -1.14$, $P = 0.26$; small: $z = -0.45$, $P = 0.65$). The mean length (M-W, $z = -1.35$, $n_1 = 270$, $n_2 = 224$, $P = 0.18$) and the size distribution (K-S, $z = 0.98$, $P = 0.33$) were similar in experimental and control branches before the start of the experiment.

Table 2.—Spider mean abundances (numbers/kg dry twig-mass) in control and experimental branches before the start of the experiment and at the end of a seven week experimental period. "Large spiders" refers to body length ≥2.5 mm, and "small spiders" refers to body length <2.5 mm. n = 15 in all cases.

	Before experiment				End of experiment			
	Control branches		Experimental branches		Control branches		Experimental branches	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
All spiders	100.1	(36.4)	91.1	(30.1)	111.9	(38.7)	87.8	(23.1)
Large spiders	42.5	(23.9)	33.1	(18.5)	46.9	(23.2)	35.5	(20.7)
Small spiders	56.9	(21.7)	58.0	(20.7)	65.4	(23.0)	52.3	(19.6)

The removal of needles from treated branches resulted in a mean needle percentage of 38.4% (needle-mass/total branch-mass × 100), based on dry weights. The mean percentage of needles on control branches was 46.5% (Table 1).

After seven weeks of the experiment, the mean abundance of spiders in the control branches was 111.9 spiders per kg dry twig-mass *vs.* 87.8 in the needle-thinned, experimental branches (Table 2). This 22% reduction on experimental branches was statistically significant (Wi, $z = -1.99$, $n = 15$, $P = 0.047$). The mean abundance of large spiders (≥2.5 mm) on needle-thinned branches was 35.5 spiders per kg dry twig-mass, and on control branches it was 46.9 (Table 2). The difference was highly significant (Wi, $z = -2.67$, $n = 15$, $P = 0.0076$). However, the abundance of small spiders (< 2.5 mm) was similar on the branch categories at the end of the experiment (Table 2; Wi, $z = -1.08$, $n = 15$, $P = 0.28$).

Neither the mean body length of spiders (M-W, $z = -0.61$, $n_1 = 308$, $n_2 = 212$, $P = 0.54$), nor the size distribution (K-S, $z = 0.5$, $P = 0.62$) differed significantly between the pooled specimens of control and needle-thinned branches.

DISCUSSION

The spider abundance on branches with low needle density was lower than on needle-dense branches. This shows that variations in the needle density can influence spider density in natural populations. Alternatively, the process is time dependent and the experimental period may have been too short to allow colonization up to the carrying capacity of spiders on the branches. This was, however, not supported by the spider abundance on control branches. At the end of the experiment, the mean density on the controls was 12% higher than on the same branches before the start of the experiment seven weeks earlier. Also, the results show that the seasonal influence on the process is absent.

Earlier studies support the hypothesis of needle density affecting the spider abundance on spruce branches. A comparison between two spruce stands showed that the density of large spiders (≥2.5 mm) in needle-dense branches was twice the density in needle-thinned ones (Gunnarsson 1988). In a natural population, there was a positive correlation between spider abundance and the proportion of needles in each branch, and in field and laboratory experiments the spider mean abundance decreased in needle-thinned branches (Gunnarsson 1990).

The observed effects on spider populations may be due to at least two different processes: 1) the needle-loss in itself, and 2) the interaction between needle density and bird predation (Gunnarsson 1988, 1990). There is some difficulty in separating these two mechanisms from each other. However, a laboratory experiment suggested that the spider colonization on spruce branches was affected by the needle density in itself. A high needle density resulted in a higher spider density than on needle-thinned spruce branches (Gunnarsson 1990). This was not an effect of predation since spider cannibalism was low and bird predation effects were absent.

In natural spider populations in spruce, bird predation is an important mortality factor in all seasons (Askenmo et al. 1977; Jansson & von Brömssen 1981; Gunnarsson 1983, 1993). This means that the effect of needle density on spider colonization of branches may be interacting with bird predation effects in natural populations. Strong bird predation effects on the spider community in spruce are demonstrated in earlier experiments. In winter, overwintering passerine birds search for food in coniferous trees (Hake 1991; Suhonen et al. 1992). Experimental removal of bird predation on spruce-living spiders during winter resulted in a 20% increase in spider survival (Askenmo et al. 1977; Gunnarsson 1983). Moreover, similar experiments focussing on *Pityohyphantes phrygianus* showed that spider densities on branches without bird predation were two times higher than on controls after summer, and between four and ten times higher after winter (Gunnarsson 1993).

The spiders that colonized the branches in the present experiment may have been affected by bird predation. If predation affected the results, this should not reduce the effect of the low needle density in experimental branches. On the contrary, bird predation may have enhanced the effect of the needle-thinned vegetation structure since spiders may be easier to detect on such spruce branches. This was supported by the significantly lower density of large spiders, but not of small ones, on needle-thinned branches. It is known that birds primarily affect the abundance of large spiders (Askenmo et al. 1977; Gunnarsson 1983), and results similar to those in the present experiment were obtained in natural spruce stands with needle density differences (Gunnarsson 1988).

Spiders search actively to find a suitable micro-habitat for their foraging, egg-production, etc. (Riechert & Gillespie 1986). This process is an interaction with the vegetation structure and Waldorf (1976) suggested that there was size-dependent choice of micro-habitat among spiders in *Mahonia aquifolium*. This means that micro-habitat selection by spider size categories may differ in contrasting environments. In a field experiment, using artificial plants with different fractal dimensions, Gunnarsson (1992) showed that vegetation structure affected the size distribution of spiders. Plants with complicated structure were colonized by a higher proportion of small spiders than were plants with a simpler structure. In spruce branches, however, a needle density reduction similar to that observed in moderately polluted areas (20–30% needle-loss) does not produce a significant change in the fractal dimension (Gunnarsson 1990). However, an interaction between needle density and bird predation may possibly enhance spider size differences in spruce (Gunnarsson 1988, 1990, reviewed in Wise 1993). In a large-scale field experiment, there was some evidence for such an interaction as differences in body size was detected between needle-thinned and control branches in absence of bird predation (Gunnarsson unpubl. data).

To summarize, the results in the present field experiment strengthen the hypothesis of needle density as an important force in determining the spider community in spruce.

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