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Regional variation in spider diversity of Flemish forest stands

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Abstract
In total, 55423 adult spiders (250 species) were collected in pitfall traps throughout a year of sampling in 56 forest stands in Flanders (northern part of Belgium). Three different regions were compared according to spider diversity in deciduous and pine forests. The total number of species and individuals of spiders did not differ regionally. However, the richness of endangered stenotopic forest species was significantly higher in the forest of the loam region than in the forests of the loamy sand and Campine region. This result confirms the high nature value of the forests of the Flemish loam region previously demonstrated for plants and carabid beetles. High priority should be given to their conservation.

Key words: spider diversity, forests, stenotopic forest species, Flanders, Belgium, geographical regions

INTRODUCTION

Human activities have caused severe changes in composition and diversity of most known ecosystems (including forests) and in their faunas (Tack et al. 1993; Barnes et al. 1998). The exploitation of forested areas in Western Europe began already some 5 to 7000 years ago (Tack et al. 1993). These anthropogenic influences lead to a reduction of total forest cover, the conversion of natural forests into simplified monocultures of mainly exotic tree species and to a severe fragmentation of remaining forests (Harris 1984; Warren & Key 1989; Saunders et al. 1991; Peterken 1996). Forest fragments are now isolated from each other by intensively managed agricultural land, industrial areas, roads and urban settlements. Nevertheless, these 'artificial' woodlands can in due time evolve into semi-natural woodlands and even into more or less natural woodlands (Peterken 1996). Semi-natural woodlands in Flanders cover nowadays only about 3% of the region; forest cover of exotic tree species cover about 5% (Hermy 1989). Also, in Flanders most forests are small and fragmented. The average area of a forest unit is 19.2 ha, but almost 70% of the forests are less than 10 ha and 14% even less than 1 ha (Anonymous 1998). In spite of earlier efforts (Maelfait et al. 1990, 1991), the nature value of Flemish forest stands as concerns their invertebrate fauna was until recently only very fragmentarily known. To increase this knowledge, a project was initiated to evaluate the quality of forest stands by means of several invertebrate taxa, including spiders. All sampled forest stands were also characterised with respect to soil, litter, vegetation and tree cover parameters (De Vos 1998, 1999a,b). The first results concerning the spiders caught during this extensive sampling campaign in forests distributed over the whole region of Flanders, were given in De Bakker et al. (1998, 2000). This paper presents results concerning the observed diversity of spider assemblages and its regional variation. A future contribution will discuss the possibilities of spiders to be used as bio-indicators for evaluating forest site quality.

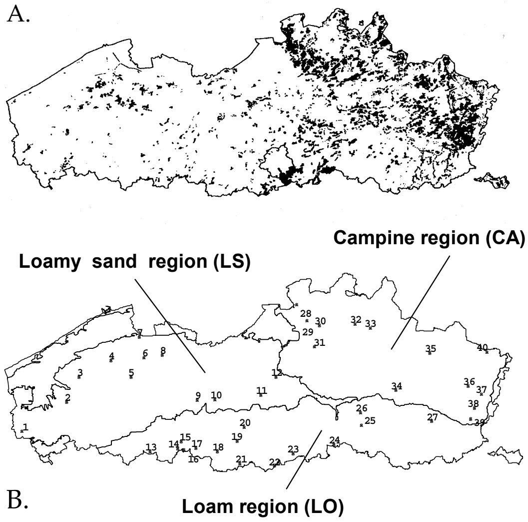

Fig. 1. Present forest cover in Flanders **(A)**, and sampled forests per geographical region **(B)** (cf. Table 1).

MATERIAL AND METHODS

Every forest stand was sampled using three pitfall traps emptied at approximately fortnightly intervals during a complete year cycle (April 1997 - April 1998). As can be seen in Fig. 1 and Table 1, the 56 sampled stands were localised in 40 forests more or less evenly distributed over the three main geographical regions of Flanders (the northern part of Belgium). The region indicated in Fig. 1 as the 'Loamy sand region' (LS) consists of sandy and sandy-loam soil. The forest complexes are small and often quite young. On the more sandy soils pine stands occur, otherwise most forests are deciduous. Only deciduous forest stands have been sampled in this region. The soils of the 'Loam region' (LO) consist of silt also deposited during the Pleistocene era. Mainly due to historical reasons (e.g. hunting areas for the nobillity) but also to relief (more slopes and hills), older and larger deciduous forests occur here. Pine forest stands are very exceptional; only deciduous stands have been sampled. The 'Campine region' (CA) occupies the northeast of Flanders. Niveo-eolian, pleistocene sands cover it. In general, soils are distinctly podsolised so that they have an endured horizon of illuvial humus and/or iron at about 30 to 40 centimetres below the surface. This gives the typical Campine soils the characteristics of being both sandy and waterlogged, with water accumulating above the impermeable horizon of the soil profile. Hence, we find in the still existing natural areas a fine mosaic of very dry sandy areas and dunes intermixed with lakes, marshes and peat bogs. Until the nineteenth century the region was almost completely covered by heathlands, which had developed under a balanced agro-pastoral system. Although there are still important remnants of heathland, most of this semi-natural habitat type was turned into pine tree plantations (*Pinus sylvestris*) at the end of the 19th and the beginning of the 20th century, especially on the drier soils. This was done to fulfil the demands of the mining industry. Deciduous forest occurs or has been planted on the wetter soils.

Statistical analyses were done with the program STATISTICA (StatSoft 1997).

RESULTS

In total, 55423 adult spider individuals were caught representing 250 different species. This is a very large number of species considering that the Belgian and Flemish fauna contain 689 and 604 known species respectively (Maelfait et al. 1998). Of the 604 Flemish species, only 291

Table 1. Classification and characteristics of sampled forest stands. Sn./Fn.: stand/forest number, cf. Fig. 1. Tree %: tree cover. LS, LO, CA: regions cf. Fig. 1. DECI: deciduous forests; PINE: pine forests.

Sn.	Fn.	Type	Tree %	Main tree species
1	1	LS_DECI	90	*Quercus robur, Acer pseudoplatanus*
2	2	LS_DECI	75	*Quercus robur*
3	7	LS_DECI	80	*Quercus robur, Fraxinus excelsior*
4	3	LS_DECI	85	*Fagus sylvatica*
5	4	LS_DECI	90	*Quercus robur, Fagus sylvatica*
6	3	LS_DECI	100	*Quercus robur, Acer pseudoplatanus*
7	3	LS_DECI	50	*Populus x canadensis*
8	5	LS_DECI	70	*Quercus rubra, Fraxinus excelsior*
9	5	LS_DECI	70	*Fagus sylvatica, Quercus robur*
10	6	LS_DECI	80	*Fagus sylvatica*
11	8	LS_DECI	90	*Quercus robur*
12	9	LS_DECI	90	*Quercus robur, Fagus sylvatica*
13	9	LS_DECI	90	*Fraxinus excelsior*
14	10	LS_DECI	80	*Quercus robur*
15	11	LS_DECI	90	*Fagus sylvatica*
16	12	LS_DECI	80	*Alnus glutinosa*
17	13	LO_DECI	100	*Fagus sylvatica*
18	14	LO_DECI	70	*Fraxinus excelsior, Alnus glutinosa*
19	14	LO_DECI	80	*Fagus sylvatica*
20	15	LO_DECI	80	*Quercus robur*
21	16	LO_DECI	50	*Fagus sylvatica*
22	16	LO_DECI	80	*Populus x canadensis, Salix* sp.
23	17	LO_DECI	80	*Populus x canadensis*
24	18	LO_DECI	90	*Quercus rubra, Castanea sativa*
25	19	LO_DECI	80	*Fagus sylvatica*
26	19	LO_DECI	90	*Betula* sp.
27	20	LO_DECI	90	*Betula* sp., *Quercus robur*
28	21	LO_DECI	70	*Quercus robur*
29	21	LO_DECI	80	*Quercus robur*
30	22	LO_DECI	90	*Fagus sylvatica*
31	23	LO_DECI	90	*Fagus sylvatica*
32	23	LO_DECI	50	*Quercus robur, Carpinus betulus*
33	23	LO_DECI	100	*Quercus robur, Carpinus betulus*
34	23	LO_DECI	80	*Fagus sylvatica*
35	24	LO_DECI	85	*Quercus robur*
36	24	LO_DECI	90	*Betula* sp.
37	24	LO_DECI	50	*Fagus sylvatica*
38	25	LO_DECI	90	*Quercus robur*
39	26	LO_DECI	85	*Quercus robur, Q. petraea*
40	27	LO_DECI	60	*Populus x canadensis*
41	28	CA_PINE	75	*Pinus sylvestris*
42	28	CA_PINE	30	*Pinus sylvestris*
43	29	CA_PINE	70	*Pinus sylvestris*
44	30	CA_PINE	70	*Pinus sylvestris*
45	31	CA_PINE	80	*Pinus sylvestris*
46	32	CA_PINE	80	*Pinus sylvestris*
47	33	CA_PINE	75	*Pinus nigra* ssp. *laricio*
48	34	CA_PINE	70	*Pinus nigra* ssp. *laricio*
49	35	CA_PINE	70	*Pinus sylvestris*
50	35	CA_PINE	60	*Pinus sylvestris*
51	36	CA_PINE	60	*Pinus sylvestris*
52	37	CA_DECI	60	*Fraxinus excelsior*
53	38	CA_DECI	80	*Fagus sylvatica*
54	39	CA_DECI	1	*Betula* sp.
55	40	CA_DECI	70	*Betula* sp., *Quercus robur*
56	40	CA_DECI	70	*Betula* sp., *Alnus glutinosa*

are safe or at low risk. Of the remaining 313 species, 36 are insufficiently known and 8 are presumably extinct. The remaining 269 species are rare in Flanders because they are either stenotopic species occurring in few types of threatened habitats (206 species) or of which Flanders is at the southern, northern or western limit of their geographical range (species that are restricted geographically: 63 species). Of the 206 stenotopic species, 41 are bound to particular forest types (stenotopic forest species); the other 165 stenotopics normally thrive in a few types of other threatened habitats, like heathland, oligotrophic grasslands and others (stenotopic non-forest species). In our sampling campaign we found 24 of the 41 stenotopic forest species and 38 stenotopic non-forest species, e.g. species bound to riverbanks, heathlands and marshes. In Fig. 2 the number of individuals and species caught per forest stand is shown. The number of individuals caught during a complete year cycle has as range (minimum-maximum per stand) per region: loamy sand: 408-1486, loam: 387-1601, Campine: 606-1628. There is also no obvious difference between the discerned regions as concerns the number of species caught, with respective ranges: loamy sand: 36-61, loam: 28-75 and Campine: 40-75. The number of individuals of special species caught (sum of stenotopic forest and non-forest species and geographically restricted species) is on average higher in the loam region. In Fig. 3 it can be seen that the number of stenotopic forest species is markedly higher in the loam forests than in the other two regions. This difference is even more pronounced if the numbers of individuals of these stenotopic forest species are considered (Fig. 3, below). The difference between the regions was analysed in more detail by means of an analysis of variance (ANOVA) on log-transformed numbers, in which the regions were treated as independent variables. For the Campine region a distinction was made between deciduous (CA_DECI) and pine forest stands (CA_PINE). In the other two regions only deciduous forest stands were sampled

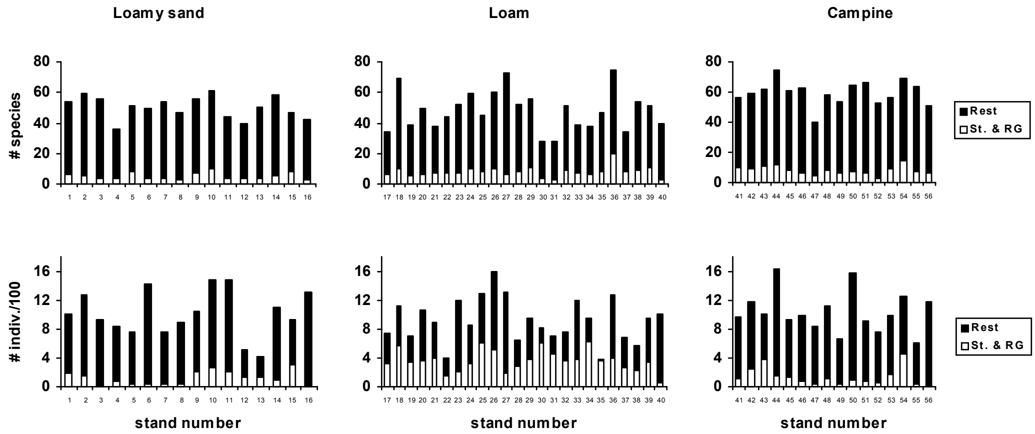

Fig. 2. Total number of spider species, number of stenotopic (St.) and species restricted geographically (RG) caught per forest stand (above); the numbers caught in hundreds of individuals (below).

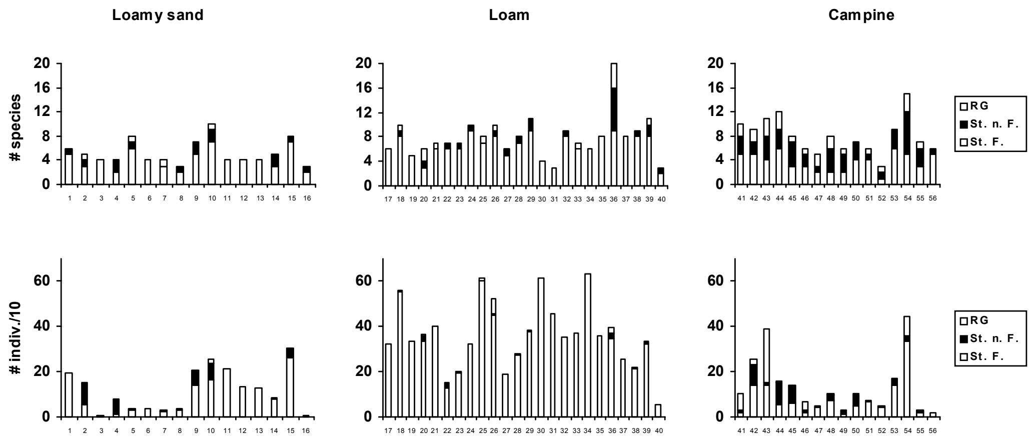

Fig. 3. Numbers of species and tens of individuals of stenotopic forest species (St. F.), stenotopic non-forest species (ST. n. F.) and of species restricted geographically (RG) per forest stand.

(LS_DECI and LO_DECI). For these four forest types it was tested if there were significant differences in the numbers of stenotopic forest species and individuals (St.F.spec., St.F.ind.), in stenotopic non-forest species and individuals (St.n.F.spec., St.n.F. ind.), in species and individuals that are restricted geographically (RG-species, RG-ind.) and in the remaining species and individuals (Rest spec., Rest ind.). All of these eight ANOVAs pointed out significant differences between the considered forest types ($P < 0.05$). The homogenous groups resulting from Scheffé's post-hoc test are shown between brackets after the type of forest in Fig. 4.

From Fig. 4 we conclude that:

-the number of stenotopic forest species is significantly higher in the loam region than in the pine forests of the Campine region; the numbers of individuals of stenotopic forest species caught in the loam region is significantly higher than the numbers of individuals of the these species caught in the forest stands of the three other forest types;

-the number of stenotopic non-forest species

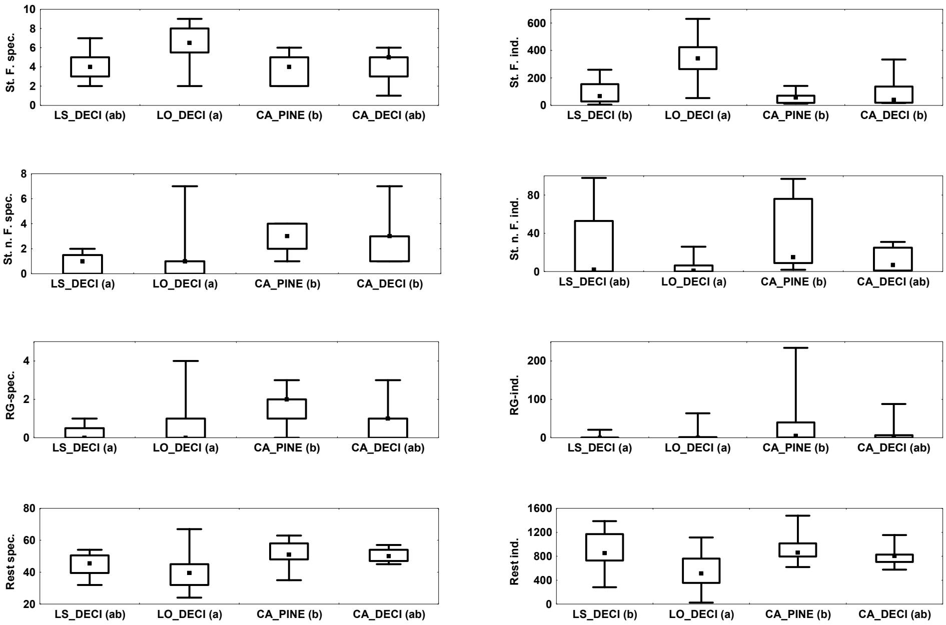

Fig. 4. Median (point), 25 and 75-percentile (box) and minimum and maximum (whisker) of number of species (left) and number of individuals (right) of the discerned species categories. St.F.spec.: stenotopic forest species; St.n.F.spec.: stenotopic non-forest species; RG-spec.: geographically restricted species; Rest spec.: species not covered by other categories (generalists); LS, LO, CA: regions cf. Fig. 1; DECI: deciduous forests; PINE: pine forests. Letters in parentheses: same letter indicates no significant difference.

was highest in the two forest types of the Campine region; the number of individuals of these species is especially high in the Campine pine forests and low in the forests of the loam region;

-a similar result as above was obtained for the geographically restricted species;

-the number of the remaining, more eurytopic species and the number of individuals caught of these species was lower in the forests of the loam region than in the other types.

DISCUSSION

When we consider all spiders together, without making any distinction of degrees of stenotopy or rarity, the richness of the spider faunas of the forest stands was not different from region to region. This global result is caused by two essentially different phenomena compensating each other. In the loam region, the forests are richer in stenotopic forest spiders, but poorer in eurytopic species, geographically restricted species and stenotopic species from non-forest habitats, such as wet or dry heathlands. The reverse is true for the forests of the loamy sand region and the Campine region. This can be understood for the Campine region because of the often quite open nature of the forests. The low tree cover of these forests (Table 1) offers possibilities for the intrusion of species bound to more open habitats, like for instance heathland spiders and geographically restricted species at the northern limit of their geographical range. The extreme fragmentation and small size of the forests in the loamy sand region seems to cause pronounced edge effects with intrusion of open habitat and eurytopic species. The richness of stenotopic forest spiders in the forests of the loam region indicates the high nature value of these forests, implying that a high priority should be given to their conservation. All stenotopic forest spider species are indeed threatened and therefore red listed. The high nature value of the forests of the loam region, as indicated by spiders, complements and strengthens the analogous results obtained for higher plants (Tack et al. 1993) and carabid beetles (Desender et al. 1999).

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