

The canopy spiders (Araneae) of the floodplain forest in Leipzig

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Abstract: The canopy spiders of the floodplain forest in Leipzig have become a focus of ecological studies in recent years. In 2006 we sampled 30 tree canopies in the 'Burgau' nature reserve with pyrethrum knock-down fogging, recording 502 adult spiders belonging to 48 species and 11 families. Based on these data and the results of a previous fogging study, the studied spider community was dominated by forest and forest-edge species with a preference for the shrub and canopy strata as well as by spiders of the web spider feeding guild. The community structure was typical for arboreal spider communities from northern temperate forests but very different from communities in the tropics. Species richness and evenness were similar to the old growth near-primary Białowieża Forest in Poland. The checklist of 96 canopy spider species of the floodplain forest of Leipzig includes 54 additions to the spider fauna of Leipzig and vicinity by recent canopy studies and eight first canopy records for Leipzig from our field work. The theridiid *Dipoena torva* (Thorell, 1875) was recorded for the first time in Saxony. The floodplain forest of Leipzig sustains a large and species-rich arboreal spider community and is thus a valuable habitat for a large proportion of endangered species (12%).

Zusammenfassung: Die Baumkronenspinnen (Araneae) des Leipziger Auwaldes. Die Spinnen der Baumkronen des Leipziger Auwaldes wurden in den vergangenen Jahren ein Schwerpunkt ökologischer Forschung. Im Jahr 2006 untersuchten wir 30 Baumkronen im Naturschutzgebiet „Burgau“ mithilfe der Insektizid-Baumkronenbenebelung und erhielten dabei 502 adulte Spinnen aus 48 Arten und 11 Familien. Basierend auf diesen Daten und Ergebnissen einer früheren Benebelungsstudie fanden wir, dass die untersuchte Spinnengemeinschaft von Wald- und Waldrandarten mit Präferenz für die Strauch- und Kronenschicht dominiert war. Auf Gildenniveau dominierten die Netzspinnen. Die Gemeinschaftsstruktur war typisch für eine arboreale Spinnengemeinschaft der nördlichen temperaten Wälder aber sehr verschieden von Gemeinschaften in den Tropen. Artenvielfalt und Evenness waren ähnlich dem Urwald von Białowieża in Polen. Aufgrund der Baumkronenforschungen in Leipzig beinhaltet die Baumkronen-Checkliste der 96 Spinnenarten des Leipziger Auwaldes 54 Erstnachweise für Leipzig und Umgebung. Acht Arten wurden erstmals durch unsere neuen Feldarbeiten in Leipzig nachgewiesen, die Kugelspinne *Dipoena torva* (Thorell, 1875) dabei erstmals in Sachsen. Der Leipziger Auwald beherbergt eine große und artenreiche arboreale Spinnengemeinschaft und ist ein wertvolles Habitat für einen großen Anteil gefährdeter Arten (12 %).

Keywords: arboreal spiders, canopy fogging, community structure, diversity, Germany, Leipziger Auwald

Increasing efforts in canopy research in Central Europe during the last 15 years have revealed large and species-rich arthropod communities in tree canopies, providing the basis for addressing advanced questions of ecological research, such as the importance of canopy diversity for ecosystem function and ecosystem services (FLOREN & SCHMIDL 2008, FISCHER & PFEIFFER 2010). Previous research focused on community structure and diversity (GUTBERLET 1996, SCHUBERT 1998, BLICK & GOSSNER 2006, OTTO & FLOREN 2007, FLOREN et al. 2008), autecology (SIMON 1997, FINCH 1999, BLICK & GOSSNER 2006), stratification (SIMON 1995, 2001, SCHU-

BERT 1999, GRUPPE et al. 2008) and the effects of anthropogenic disturbance or forest management on canopy arthropod communities (SCHUBERT 1998, OTTO 2004, GOSSNER & AMMER 2006, FLOREN et al. 2008).

The floodplain forest of Leipzig is one of the largest and most valuable floodplain forests in Europe and Germany (MÜLLER 1995). Large parts of this forest are therefore protected and represent suitable study areas for ecological research. With the installation of the Leipzig Canopy Crane (LAK – Leipziger Auwaldkran) in 2001, the floodplain forest in Leipzig has also become a focus of canopy research (HORCHLER & MORAWETZ 2004, UNTERSEHER et al. 2007). A number of canopy studies investigated the diversity and structure of tree-specific arthropod communities in the canopy, including Heteroptera (ARNDT et al. 2007), Neuroptera (GRUPPE 2007), Coleoptera

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(ARNDT & HIELSCHER 2007, SCHMIDT et al. 2007, FLOREN & SPRICK 2007), and Lepidoptera (FRÖHLICH et al. 2007).

In the first arachnological canopy study, spiders were collected from the crowns of six European ash trees (*Fraxinus excelsior*) by GERHARDT (2003) using flight-interception traps. The resulting list of 30 species was later extended to 88 species by STENCHLY (2005) and STENCHLY et al. (2007) using stem and branch collectors and flight-interception traps on 25 trees and insecticide fogging of 21 trees.

Further information on the arboreal spiders of the floodplain forest of Leipzig is needed to adequately describe community structure, assess the functional role of the spiders in the canopy stratum and evaluate the importance of the floodplain forest of Leipzig as a refuge for endangered spider species.

Based on its habitat characteristics, size and status of a historically old forest, the floodplain forest of Leipzig is expected to harbour a spider community comparable to other valuable forest regions in Central Europe. We test this hypothesis by comparing community composition, guild structure and species diversity with data from studies in Białowieża Forest, the most valuable of the European remnant forests and habitat of a species-rich arboreal spider community (OTTO 2004, OTTO & FLOREN 2007). We also aim at making research on, and comparisons to, the arboreal spiders in the floodplain forest of Leipzig more feasible by providing a checklist of the spider species so far recorded from the canopies in Leipzig. Finally, we wish to assess the value of the canopy stratum as a habitat for endangered spider species in Leipzig.

Material and Methods

The study was conducted in the 'Burgau' nature reserve (size 2.7 km²), which is situated within the 50 km² large floodplain forest extending through the city of Leipzig from south to north-west (MÜLLER 1992, 1995, JANSEN 1999). The soil in this forest consists of alluvial clay and river gravel. The temperate climate in the transition zone between a maritime and continental climate is characterised by warm summers and an annual mean temperature of +8.4° C. Annual precipitation is low (516 mm) due to the Harz mountains to the west (JANSEN 1999).

The forest is a natural old-growth forest. Historically, it was used as a coppice and clay was extracted from its western part. Contemporary forestry practice in the 'Burgau' favours oak species and single-tree log-

ging. Since 1959, the 'Burgau' has been a protected forest, becoming a nature reserve in 1961 (JANSEN 1999). The forest consists of the ash-elm floodplain forest (Fraxino-Ulmetum), which is typical for this forest. The characteristic trees are species of oak (*Quercus robur*, *Q. petraea*), ash (*Fraxinus excelsior*), hornbeam (*Carpinus betulus*), elm (*Ulmus minor*), lime (*Tilia cordata*) and maple (*Acer pseudoplatanus*, *A. platanoides*).

Between 23rd and 24th June in 2006, 30 trees were sampled within the forest quadrants 126a, 127b and 128a (N 51.36589°, E 12.29662°) approximately 1 km west of the study site of STENCHLY et al. (2007). The sampling scheme included eleven pedunculate oaks (*Q. robur*), nine sycamore maples (*A. pseudoplatanus*), nine European ash trees (*F. excelsior*) and one elm tree (*Ulmus* sp.). Samples were taken by insecticidal knock-down ('canopy fogging') as described by FLOREN & SCHMIDL (2003) and FLOREN (2010). A solution of 1 % natural pyrethrum dissolved in highly refined white oil was used as the active agent, reducing spatiotemporal disturbance to a minimum. Collecting funnels (plastic sheets with suspended edges) below the tree canopies covered at least 80-90 % of the tree-crown projection. Within two hours after fogging arthropods dropped onto the collecting sheets. All arthropods were preserved in 70 % ethanol. Adult individuals were determined to species using the usual sources (see NENTWIG et al. 2003). Nomenclature follows PLATNICK (2010).

Analyses of species composition, guild structure and diversity are based on a combined dataset of the new fogging data from 30 trees in 2006 and the fogging data of 21 trees of a previous field study in 2003 by A. Floren, which were already included in STENCHLY (2005).

The habitat and stratum preferences of the recorded species were determined based on published data on the ecology of these species (HEIMER & NENTWIG 1991, PLATEN et al. 1999, NENTWIG et al. 2003, BLICK & GOSSNER 2006). Based on their prey-catching behaviour, the species were attributed to four guilds: orb-web weavers, space-web weavers, agile hunters and ambushers (for details on grouping see FLOREN et al. 2008). Red-list species were analysed according to the species in the Red List Germany (BLICK et al. in prep.) and Saxony (HIEBSCH & TOLKE 1996); see appendix for details.

Data were analysed using the R language and environment for statistical computing and graphics (version 2.11.1, R DEVELOPMENT CORE TEAM 2010)

on Ubuntu Linux (version 10.04). Rarefaction curves were computed and plotted using the 'vegan' package for R (version 1.17-4, OKSANEN et al. 2010) with the function 'specaccum' (with the sample-based method 'random' at 1000 permutations). Sample-based rarefaction was used because of tree-wise sampling by insecticidal fogging. Using a modification of the R code (Rodrigo Aluizio pers. comm.), the expected number of species was plotted against the number of individuals to minimize sample-size and abundance effects (GOTELLI & COLWELL 2001). The non-parametric Mann-Whitney U test for unpaired samples was computed using the function 'wilcox.test' in R.

Results

Community composition

Fogging of 30 trees yielded 502 adult spiders with 48 species in 11 families (see Appendix). Combining these data with the fogging data from 2003, the analysis is based on a sample size of 51 trees with 1567 adult spiders with 68 species in 12 families. The 20 most abundant species comprised 88 % of all individuals (Tab. 1); half of the spider community was dominated by the six most abundant species. Individuals of the three most abundant families comprised nearly 81 %

of all individuals (Theridiidae 52.5 %, Linyphiidae 17.5 %, Philodromidae 10.5 %) and 65 % of all species (Theridiidae 25.0 %, Linyphiidae 33.8 %, Philodromidae 5.9 %). Most of the 20 dominant species are common on shrubs, forest edges or in forests (see Appendix); 17 are known to occur regularly on trees; two of them are true canopy species (*Dipoena melanogaster*, *Nigma flavescens*). *Parasteatoda simulans* and *Neriene peltata*, two species of the field layer, were also among these abundant species as well as the epigeic species *Erigone atra*.

A majority of 53 species (78 %), accounting for 1521 of all individuals (97 %), are known from forests or forest edges (Tab. 2). The 12 species (18 %) of open habitats accounted for 2 % of all individuals. Besides, *Parasteatoda tepidariorum* and *Theridion melanurum*, two synanthropic species, were recorded with two and one individuals respectively, as well as the ubiquitous species *Neriene montana* with four individuals.

Regarding stratum preferences, one third of the recorded species (65 % of all individuals) are known to live preferentially in tree canopies. Species of the shrub layer occurred in the canopy in large numbers, too. They comprised 19 % of the species and 13 % of the individuals. A substantial number of field layer

Tab. 1: Dominant species in the tree canopies.

Tab. 1: Dominante Arten in den Baumkronen.

Rank	Species	Family	Samples 2003 n = 21	Samples 2006 n = 30
1.	<i>Paidiscura pallens</i> (Blackwall, 1834)	Theridiidae	193	87
2.	<i>Philodromus albidus</i> Kulczynski, 1911	Philodromidae	120	11
3.	<i>Moebelia penicillata</i> (Westring, 1851)	Linyphiidae	50	56
4.	<i>Anyphaena accentuata</i> (Walckenaer, 1802)	Anyphaenidae	93	3
5.	<i>Platnickina tincta</i> (Walckenaer, 1802)	Theridiidae	75	20
6.	<i>Dipoena melanogaster</i> (C.L. Koch, 1837)	Theridiidae	59	21
7.	<i>Enoplognatha ovata</i> (Clerck, 1757)	Theridiidae	1	76
8.	<i>Theridion varians</i> Hahn, 1833	Theridiidae	57	14
9.	<i>Theridion pinastri</i> L. Koch, 1872	Theridiidae	62	8
10.	<i>Theridion mystaceum</i> L. Koch, 1870	Theridiidae	45	19
11.	<i>Nigma flavescens</i> (Walckenaer, 1830)	Dictynidae	30	24
12.	<i>Entelecara acuminata</i> (Wider, 1834)	Linyphiidae	21	31
13.	<i>Parasteatoda lunata</i> (Clerck, 1757)	Theridiidae	29	5
14.	<i>Tetragnatha montana</i> Simon, 1874	Tetragnathidae	23	10
15.	<i>Araniella cucurbitina</i> (Clerck, 1757)	Araneidae	21	8
16.	<i>Entelecara congenera</i> (O. P.-Cambridge, 1879)	Linyphiidae	23	1
17.	<i>Neriene peltata</i> (Wider, 1834)	Linyphiidae	19	3
18.	<i>Parasteatoda simulans</i> (Thorell, 1875)	Theridiidae	0	21
19.	<i>Tetragnatha obtusa</i> C.L. Koch, 1837	Tetragnathidae	15	4
20.	<i>Erigone atra</i> Blackwall, 1833	Linyphiidae	7	11

Tab. 2: Habitat- and stratum preferences (adult spiders, after HEIMER & NENTWIG 1991, PLATEN et al. 1999).**Tab. 2:** Bindung an Habitate und Schichten (Adulte, nach HEIMER & NENTWIG 1991, PLATEN et al. 1999).

Habitat	Species		Abundance		Stratum	Species		Abundance	
	n	%	n	%		n	%	n	%
Forest	11	16	240	15	Canopy	10	15	466	30
Forest + forest edge	19	28	733	47	Shrubs + canopy	13	19	548	35
Forest edge	23	34	548	35	Shrub layer	13	19	202	13
Open country	12	18	39	2	Field layer	12	18	64	4
Buildings	2	3	3	0.2	Epi-/hypogaeic	11	16	40	3
Ubiquitous	1	1	4	0.3	Mixed types	9	13	247	16
Total	68	100	1567	100	Total	68	100	1567	100

and epi-/hypogaeic species (34 %) were also recorded albeit in low abundances, accounting for 3 to 4 % of all canopy spider individuals collected.

The community was dominated in species (78 %) and abundance (82 %) by web-constructing spiders (Tab. 3). Of these, space-webs weaving spiders contributed the largest proportion of both species and individuals (mostly Theridiidae and Linyphiidae). Agile hunters were the second largest guild, representing 19 % of all species and 18 % of all individuals, respectively. The two most abundant species within this guild were *Philodromus albidus* (Philodromidae, 131 individuals) and *Anyphaena accentuata* (Anyphaenidae, 96 individuals), representing 79 % of all agile hunters.

Red-list species

We recorded eight species from the Red List of Saxony (11.8 % of all species). RL 2: *Entelecara congenera*, RL 3: *Gibbaranea gibbosa*, *Gongyliidiellum murcidum*, *Lathys humilis*, *Micaria subopaca*, RL 4: *Argenna subnigra*, *Episinus truncatus*, *Neriene peltata*. Together, they comprised 4.1 % of all 1567 individuals (see Appendix). According to the updated Red List of Germany (BLICK et al. in prep.) no species from the categories 0–3 were recorded from the studied canopies. *Rugathodes instabilis* (Theridiidae), as a near-threatened species ('Vorwarnliste'), was recorded in 2003. The endangerment status of three of the recorded species cannot be sufficiently assessed due to an insufficient data basis (category data deficient): *Dipoena torva*, *Theridion melanurum* (Theridiidae) and *Diaea livens* (Thomisidae).

Discussion

Recent research in the floodplain forest of Leipzig, using eclectors, flight interception traps and insecticide fogging, has revealed a diverse fauna of canopy spiders (GERHARDT 2003, STENCHLY 2005, STENCHLY et

al. 2007). In 2006 we sampled 30 trees in the 'Burgau' with insecticide fogging, extending the list of the canopy species in this forest to 96 species, adding 8 species and confirming many of the earlier records (see Appendix). By combining our new data with the data from the fogging samples of STENCHLY (2005) we found that forest spiders, canopy spiders and web-building spiders contributed a large proportion of the community's species composition, corroborating the findings of the previous studies. The compiled checklist of the canopy spiders of the floodplain forest of Leipzig (see Appendix) summarises the faunistic results of all existing data, including information on notable and threatened species as well as one first record for Saxony.

Community composition

Of the 12 recorded families, theridiid, linyphiid and philodromid spiders dominated the canopy community, complemented by a few abundant species of other families: *Anyphaena accentuata* (Anyphaenidae), *Tetragnatha montana*, *T. obtusa* (Tetragnathidae) and *Nigma flavescens* (Dictynidae). These results are consistent with other canopy studies in temperate forests (SIMON 1995, KOPONEN 1996, SCHUBERT 1998, FLOREN & OTTO 2002, OTTO & FLOREN 2007). Most variation in family composition of canopy communities is often the result of high numbers

Tab. 3: Guild structure.**Tab. 3:** Gildenstruktur.

Guild	Species		Abundance	
	n	%	n	%
Orb web	9	13	119	8
Space web	44	65	1157	74
Agile hunter	13	19	286	18
Ambusher	2	3	5	0.3
Total	68	100	1567	100

of clubionids (*Clubiona* spp.), linyphiids (*Linyphia triangularis*), philodromids (*Philodromus* spp.) and thomisids (e.g. *Diaea dorsata*, *Xysticus* spp.) (see SIMON 1995, GUTBERLET 1996, SCHUBERT 1998, FLOREN & OTTO 2002, OTTO & FLOREN 2007). The underlying causes of these variations remain to be studied.

Within the dominant families, 20 species supplied almost 90 % of all individuals and can be considered to be the core species of the community. These are widespread species and with only three exceptions species of higher strata in forest habitats (see Tab. 1 and Appendix).

The habitat preferences of the recorded spiders are similar to those known from the Białowieża Forest, an old growth, near-primary forest situated on the eastern border of Central Europe (data from OTTO 2004). The canopies of both forests are quantitatively characterised by a very high proportion of individuals of forest or forest-edge species (95 % in Białowieża vs. 97 % in Leipzig). Presumably, this correlates with well-developed forest habitats and high habitat heterogeneity in both forests, which is known to contribute to spider diversity in forests (UETZ 1991, DOCHERTY & LEATHER 1997). On the species level, the proportion of forest or forest-edge species was higher in Białowieża Forest (86 % vs. 78 %) but this difference was not significant in a tree-based comparison between Leipzig and Białowieża (medians 94.4 % vs. 94.7 %, U test, $W = 2046$, $p = 0.77$, $n_{\text{Leipzig}} = 51$, $n_{\text{Białowieża}} = 78$).

The overall proportion of canopy spiders was higher in Leipzig (65 % of all individuals vs. 43 % in Białowieża), with 63.0 % (median) canopy spiders on an average tree in Leipzig vs. 33.3 % (U test, $W = 3030$, $p < 0.001$). Whereas the overall proportion of canopy species was comparable between both forests (34 % in Leipzig vs. 32 % in Białowieża), the average proportion of canopy species was significantly higher in Leipzig 52.9 % (median) canopy species vs. 38.5 % in Białowieża (U test, $W = 3081$, $p < 0.001$). This higher average proportion of individuals and species of canopy spiders in Leipzig corresponded to a higher proportion of shrub-layer spiders in Białowieża (26 % vs. 13 % in Leipzig), whereas the proportion of shrub species was equal (19 %) in both forests. Although this has not been part of our study, the higher abundance of shrub spiders in Białowieża might have been the result of a better developed shrub layer, indicating a higher habitat structure (see SUNDBERG & GUNNARSSON 1994, HALAJ et al. 1998, 2000) but detailed informa-

tion on the habitat requirements of shrub species vs. canopy species remain to be investigated.

Canopy studies in primary tropical rainforests have detected distinct arboreal spider communities (RUSSELL-SMITH & STORK 1994, 1995, SØRENSEN 2004, FLOREN & DEELEMANN-REINHOLD 2005). In contrast, our results from Leipzig's floodplain forest revealed no distinct canopy community. Only 15 % of the species and 30 % of all individuals are considered exclusive canopy spiders, while the majority of the species utilise lower strata as well. We are convinced that all individuals collected by insecticide fogging were indeed sampled from the canopy and have not entered the collection planes from lower strata. Otherwise, we would have collected a number of epigeic lycosids as well. This pattern of a low proportion of true canopy species in tree canopies is consistent with data from other temperate forests (GUTBERLET 1996, SCHUBERT 1998, SIMON 2001, OTTO & FLOREN 2007). Therefore, canopy-spider communities of temperate forests are characterised by a mixture of canopy and lower-strata species. A stratification of spider communities along the tree itself is, however, known to be well developed in temperate forests (SIMON 1995, 2001, GRUPPE et al. 2008) but again with an overall small proportion of true canopy species in each stratum (lower trunk, higher trunk, canopy).

The general pattern in familial composition seems to be similar in northern temperate forests. In tropical forests, however, a substantial number of oonopid and pholcid spiders in tree canopies as well as a higher number of Salticidae and Clubionidae is present (SILVA 1996, FLOREN & DEELEMANN-REINHOLD 2005, FANNES et al. 2008). The arboreal spider communities of forests in both climate zones are similar in harbouring high abundances of Theridiidae and Araneidae. Linyphiidae do occur neither with many species nor in large numbers in tropical lowland forests but can be abundant in canopies at higher altitudes (SØRENSEN 2004).

The distinct canopy communities in tropical forests are generally understood to be at least partially the result of their existing for several millions of years. By contrast, the flora and fauna of European temperate forests are only approx. 8000 years old, which is apparently a time period too short for the evolution of a distinct habitat-specific canopy fauna. The existing relict species in Central Europe are either relicts of previous glacial periods or thermophilic Mediterranean species, which had established populations in Central Europe during the warm Atlantic period.

None of these species seems to have evolved within their contemporary habitats (ZIMMERMANN et al. 2010). Among beetles we know a few relict species of ancient woodlands with either specific habitat requirements and/or reduced mobility (ASSMANN 1994, BENSE 1998, ASSMANN & GÜNTHER 2000, DESENDER et al. 1999, SCHMIDL & BUSSLER 2004, SROKA & FINCH 2006). The question, whether relict species of ancient woodlands exist among spiders, is still unresolved due to lacking data from such forests, but there are some candidates, e.g. *Dipoena nigroreticulata* (Theridiidae) and *Tuberta maerens* (Hahniidae) (FINCH 1999, 2001, OTTO & FLOREN 2007).

Guild structure

Approximately 78 % of all spider species (and 82 % of the individuals) belonged to web-weaving taxa. A similarly high proportion was found in previous fogging studies (FLOREN & OTTO 2002, OTTO 2004, OTTO & FLOREN 2007), by branch beating (HALAJ et al. 2000) or cutting branches (JENNINGS et al. 1990). In contrast, communities sampled by stem or branch eclectors are often dominated by hunting spiders (SIMON 1995, GUTBERLET 1996, SCHUBERT 1998, SIMON 2001).

Observed differences in guild structure may predominantly be the result of the specific capture capability of the applied sampling technique. Due to the passive foraging behaviour of web-weaving spiders (sit and wait predators) this spider guild seems to be underestimated by branch eclectors. Fogging was conducted in the morning, which might explain the lack of specifically nocturnal species such as *Larinioides patagiatus* and *Nuctenea umbratica* (Araneidae) as well as *Lepthyphantes minutus* (Linyphiidae) which have been caught in high abundances within forest canopies using branch eclectors (STENCHLY et al. 2007, SIMON 2001). It should also be kept in mind that knock-down collecting samples a community at one point during one day, whereas traps usually measure activity over several weeks and therefore reflect phenological developments during this time period.

Species diversity

A direct comparison of the species diversity of canopy spiders is often difficult due to differing sampling methods, sizes and schemes. For example, of 129 collected species in the Białowieża Forest, STERZYŃSKA & ŚLEPOWROŃSKI (1994) collected 74 spider species (43 exclusively) using Moericke yellow pan traps on

an unknown number of pine trees, whereas OTTO & FLOREN (2007) found 86 species (55 exclusively) via insecticidal knockdown on 78 oak, hornbeam and spruce trees. Species overlap between both studies was only 31 species (24 %). However, comparison of species diversity was possible between the latter study and the fogging data from the floodplain forest in Leipzig because of the same sampling method and a similar sampling scheme.

Species diversity was similar between the floodplain forest in Leipzig and the near-natural forest of Białowieża (Fig. 1). Rarefaction curves are of similar shape, indicating similar evenness. When comparing only the rarefaction curves for oaks (not figured), a similar number of species can be expected in both forests (40 in Leipzig, 39 in Białowieża at a sample size of 313 individuals). Species richness in Leipzig was highest in Linyphiidae (23) and Theridiidae (17 species); while all other families were represented by less than 6 species. This was similar to Białowieża, where Linyphiidae (37 species), Theridiidae (14) and Araneidae (11) were the families with most species (OTTO & FLOREN 2007).

In temperate forests a higher spider diversity in more natural habitats is not a general pattern. In some studies spider diversity was found to be higher in more natural forests (UETZ 1991, STERZYŃSKA & ŚLEPOWROŃSKI 1994, SCHOWALTER 1995, STAŃSKA et al. 2002, FLOREN et al. 2008). However, the opposite pattern was observed by GUTBERLET (1996) and OXBROUGH et al. (2005), whereas no significant differences between habitats were found by PETTERSSON (1996), SCHUBERT (1998, 1999), FINCH (2001), WILLETT (2001), and GUNNARSSON et al. (2004).

A higher diversity in more natural habitats is commonly thought to be the result of a number of factors (e.g. structural and micro-climatic heterogeneity, longer immigration history, higher prey abundance). Species richness is also scale dependent. Elevation range, plant species richness and certain temperature characteristics of the climate are positively correlated with spider species richness on the continental and regional scale (FINCH et al. 2008), whereas area positively correlates with spiders species richness on the regional scale.

Within a local habitat, factors such as habitat structure and heterogeneity, plant species richness, micro-climate and prey availability affect spider diversity as well (HALAJ et al. 2000, GUNNARSSON et al. 2004, FINCH et al. 2008, FINCH & LÖFFLER 2010), whereas

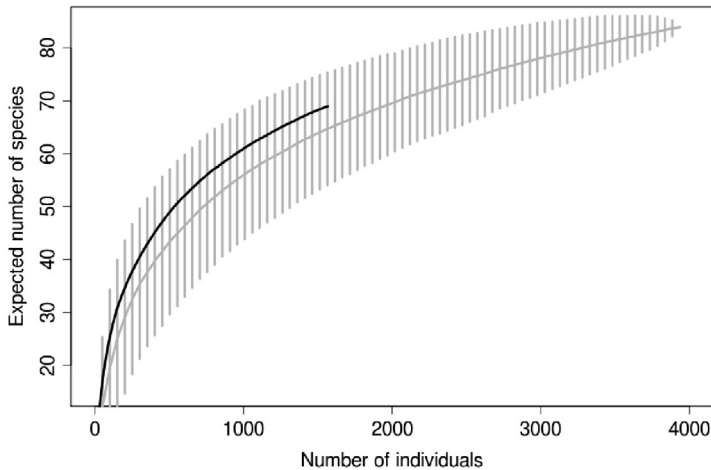


Fig. 1: Rarefaction curves for the 51 fogging samples in Leipzig ($n = 1567$, black line) and the 78 samples from Białowieża Forest ($n = 3936$, gray line with standard deviation as vertical lines, data from OTTO 2004).

Abb. 1: Rarefaction-Kurven für die 51 Proben von Leipzig ($n = 1567$, schwarze Linie) und die 78 Proben aus Białowieża ($n = 3936$, graue Linie mit Standardabweichung als vertikale Linien, Daten aus OTTO 2004).

tree-species diversity has so far not been identified as a major contributing factor to forest-spider diversity (SCHULDT et al. 2008). It is therefore not surprising that we found very similar spider diversities in Leipzig and Białowieża because the forest habitats are well developed in both forests (local scale), the elevation range in both regions spans only a few meters, climate and plant-species richness are comparable and the distance between the Białowieża Forest and Leipzig hardly exceeds one degree of latitude (regional and continental scale).

Remarkable species

The 96 species in the checklist of the canopy spiders from Leipzig's floodplain forest (see appendix) include 54 species not previously reported from Leipzig or its vicinity (TOLKE & HIEBSCH 1995) as well as eight species added to the canopy checklist by the new data 2006: *Argenna subnigra* (Dictynidae), *Erigonella hiemalis*, *Porrhomma pygmaeum*, *Tenuiphantes tenebricola* (Linyphiidae), *Neon reticulatus* (Salticidae), *Micrommata virescens* (Sparassidae), *Episinus truncatus* (Theridiidae) and *Dipoena torva* – the first record of this theridiid species for Saxony. Many of the 54 first records in Leipzig represent abundant and widespread species or had long been suspected to occur in Leipzig (TOLKE & HIEBSCH 1995). Overall, approx. 265 spider species are now known to occur in Leipzig and its vicinity.

Dipoena torva (Thorell, 1875)

Material: Leipzig, Burgau nature reserve (N 51.36589°, E 12.29662°), canopy of *Quercus robur* (6 ♀♀) and *Acer pseudoplatanus* (1 ♂), pyrethrum fogging, 23rd and 24th June, 2006, leg. A. FLOREN, det. & coll. S. OTTO.

In recent years, the Palearctic species *D. torva* has repeatedly been recorded from lower parts of tree trunks (MUSTER 1998, KUBCOVÁ & SCHLAGHAMERSKÝ 2002, VON BROEN & JAKOBITZ 2004) as well as tree canopies (STERZYŃSKA & ŚLEPOWROŃSKI 1994, SIMON 1997, OTTO & FLOREN 2007) in Germany and neighbouring countries. According to these records this species prefers large pine and oak trees and has its maximum activity at heights of around 10 m (see SIMON 1997).

It can be regarded as wide-spread and common in many European regions, even within the limits of larger cities (WEBER 1999). *D. torva* can often be collected from higher parts of trees, using appropriate collecting methods (e.g. stem and branch eclectors, flight-interception traps, insecticide fogging).

The floodplain forest of Leipzig is known to harbour numerous threatened animal and plant species (GEHLHAAR & KLEPEL 1995, MÜLLER 1995, BENSE 1998, JANSEN 1999), but spiders had been neglected before the initiation of the Leipzig Canopy Crane Project. In our study, eight species (12 %) and more than 4 % of all individuals belonged to species listed in the Red List of Saxony (HIEBSCH & TOLKE 1996). Compared to the 37 % of red-listed species among all recorded species in Saxony, this number might seem comparatively low, but forests usually harbour far less threatened species than other habitats, e.g. wetland pastures, mires, xerothermic habitats (HIEBSCH & TOLKE 1996). Our findings corroborate the results from other forests (13–23 % red-list species in Lower Bavaria in SCHUBERT 1998, 6.7 % in Białowieża in OTTO & FLOREN 2007). However, increased effort in canopy research is needed for a rational assessment of the importance of the upper strata in forest ecosystems as a habitat of endangered species.

Conclusion

Our study identified the canopy layer of Leipzig's floodplain forest as an important habitat for spiders. As initially hypothesised, the studied spider community was similar in species composition and richness to that in the large old-growth forest of Białowieża in Poland. Differences in some community characteristics, such as the higher average proportion of species with a preference for the canopy stratum in Leipzig, cannot be explained by the collected data and remain to be addressed in a detailed study of the habitat characteristics of both forests.

The high similarity to the arboreal communities in Białowieża provide further arguments for the protection of the floodplain forest in Leipzig. As long as the major environmental factors contributing to the community structure, the high species richness and the presence of endangered species have not been identified, forest management should minimise the effects on the natural dynamics in the forest of Leipzig. Inevitable measures of timber extraction, changes in tree composition or water regime should include a close monitoring of the effects on the spider communities, facilitating the identification of the main threats to the spider fauna and providing for the establishment of appropriate conservation strategies.

The effects of the abiotic and biotic factors on spider community structure are still poorly understood because existing data are often contradictory and based on different sampling techniques. Such questions are worth addressing in a meta-analysis of existing studies or in follow-up studies with a focus on selected factors. A future project comparing forests in the tropics, Central Europe and colchic forests in the Caucasus, for example, is planned to investigate how forest age in relation to glaciation history influences the structure and diversity of contemporary arboreal spider communities.

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Appendix

Checklist of the canopy spiders of the floodplain forest in Leipzig. Trap samples 2003-2007 from GERHARDT (2003), STENCHLY (2005), and STENCHLY et al. (2007). x – listed for Leipzig and vicinity (TOLKE & HIEBSCH 1995), (x) – collected in Leipzig from tree trunks, [x] – listed as probably occurring in Leipzig, – – listed for Saxony except Leipzig, --* – listed for Saxony in TOLKE et al. (2008), --! – first record in Saxony. **Habitat:** 1 – buildings, 2 – open habitats, 3 – shrubs and forest edges, 4 – forests, ? – data scarce (VON BROEN & JAKOBITZ 2004). **Stratum:** 1 – ground layer, 2 – field layer, 3 – shrubs and tree trunks, 4 – upper trees, 5 – tree canopies (HEIMER & NENTWIG 1991, PLATEN et al. 1999, NENTWIG et al. 2003, BLICK & GOSSNER 2006). RLG - Red List Germany according to BLICK et al. (in prep.); RLS - Red List Saxony according to (HIEBSCH & TOLKE 1996).

Species	RL	Fogging Data			Trap samples 2003-2007	Tolke & Hiebsch 1995	Habitat	Stratum
		2003	2006	Σ				
Agelenidae								
<i>Malthonica ferruginea</i> (Panzer, 1804)					(x)	x	4	1-2
<i>Malthonica silvestris</i> (L. Koch, 1872)					x	x	4	1-3
Amaurobiidae								
<i>Coelotes terrestris</i> (Wider, 1834)					x	[x]	4	1
Anyphaenidae								
<i>Anyphaena accentuata</i> (Walckenaer, 1802)		93	3	96	x	x	4	1,4
Araneidae								
<i>Araneus diadematus</i> Clerck, 1757					x	[x]	3	2-3
<i>Araneus sturmi</i> (Hahn, 1831)		4		4	x	x	3	3-4
<i>Araneus triguttatus</i> Fabricius, 1793					x	x	4	3-5
<i>Araniella cucurbitina</i> (Clerck, 1757)		21	8	29	x	[x]	3	2-4
<i>Cyclosa conica</i> (Pallas, 1772)		1	1	2	x	x	4	2-4
<i>Gibbaranea gibbosa</i> (Walckenaer, 1802)	RLS 3	5	2	7	x	-	3-4	3-4
<i>Larinioides patagiatus</i> (Clerck, 1757)					x	-	3	3
<i>Nuctenea umbratica</i> (Clerck, 1757)					x	x	3	2-3
Clubionidae								
<i>Clubiona brevipes</i> Blackwall, 1841		7	1	8	x	x	3-4	1-5
<i>Clubiona corticalis</i> (Walckenaer, 1802)		2		2	x	-	4	1-5
<i>Clubiona pallidula</i> (Clerck, 1757)		5		5	x	x	4	3-4
<i>Clubiona reclusa</i> O. P.-Cambridge, 1863					x	x	2	2
Dictynidae								
<i>Argenna subnigra</i> (O. P.-Cambridge, 1861)	RLS 4		1	1		x	2	1
<i>Dictyna arundinacea</i> (Linnaeus, 1758)					x	x	2	2
<i>Dictyna pusilla</i> Thorell, 1856		1		1	x	x	3	2-5
<i>Lathys humilis</i> (Blackwall, 1855)	RLS 3	2	1	3	x	-	3-4	2-4
<i>Nigma flavescens</i> (Walckenaer, 1830)		30	24	54	x	x	3-4	5
<i>Nigma walckenaeri</i> (Roewer, 1951)					x	x	1	1-5
Gnaphosidae								
<i>Micaria subopaca</i> Westring, 1861	RLS 3		3	3	x	x	4	3-4
Linyphiidae								
<i>Araeoncus humilis</i> (Blackwall, 1841)					x	[x]	2	2
<i>Bathypantes gracilis</i> (Blackwall, 1841)		1	2	3		[x]	2	1-2
<i>Bathypantes nigrinus</i> (Westring, 1851)					x	x	4	2
<i>Ceratinella brevis</i> (Wider, 1834)			1	1	x	[x]	3-4	1
<i>Cineteta gradata</i> (Simon, 1881)					x	--*	4	3-5
<i>Diplocephalus cristatus</i> (Blackwall, 1833)		1		1		x	2	1
<i>Diplocephalus latifrons</i> (O. P.-Cambridge, 1863)					x	[x]	4	1
<i>Diplocephalus picinus</i> (Blackwall, 1841)		2	6	8	x	[x]	3-4	1
<i>Dismodicus bifrons</i> (Blackwall, 1841)		1		1		x	3	3-5

Species	RL	Fogging Data			Trap samples 2003-2007	Tolke & Hiebsch 1995	Habitat	Stratum
		2003	2006	Σ				
<i>Drapetisca socialis</i> (Sundevall, 1833)					(x)	[x]	?	3
<i>Entelecara acuminata</i> (Wider, 1834)		21	31	52	x	-	3-4	2-3
<i>Entelecara congenera</i> (O. P.-Cambridge, 1879)	RLS 2	23	1	24	(x)	-	3-4	2-5
<i>Entelecara erythropus</i> (Westring, 1851)					(x)	-	3	2-4
<i>Entelecara flavipes</i> (Blackwall, 1834)					x	x	2	2-3
<i>Erigone atra</i> Blackwall, 1833		7	11	18	x	[x]	2	1
<i>Erigone dentipalpis</i> (Wider, 1834)		2	1	3	x	[x]	2	1
<i>Erigonella hiemalis</i> (Blackwall, 1841)			1	1		x	3	2
<i>Gongylidiellum murcidum</i> Simon, 1884	RLS 3	2	1	3		x	3-4	1
<i>Lepthyphantes minutus</i> (Blackwall, 1833)					x	-	4	3-5
<i>Linyphia hortensis</i> Sundevall, 1830		4		4		[x]	3	2
<i>Linyphia triangularis</i> (Clerck, 1757)					x	[x]	3	1-2
<i>Maso sundevalli</i> (Westring, 1851)					(x)	x	3-4	1-2
<i>Meioneta innotabilis</i> (O. P.-Cambridge, 1863)		1	2	3	x	-	4	3-4
<i>Meioneta rurestris</i> (C.L. Koch, 1836)		1		1	x	[x]	2	1
<i>Moebelia penicillata</i> (Westring, 1851)		50	56	106	x	-	4	3-4
<i>Neriere emphana</i> (Walckenaer, 1841)			1	1	x	-	2	1-3
<i>Neriere montana</i> (Clerck, 1757)		3	1	4	x	[x]	1-4	0-4
<i>Neriere peltata</i> (Wider, 1834)	RLS 4	19	3	22	x	-	3-4	2
<i>Oedothorax apicatus</i> (Blackwall, 1850)		1	1	2	x	[x]	2	1
<i>Porrhomma microphthalmum</i> (O. P.-Cambridge, 1871)					x	x	2	2
<i>Porrhomma pygmaeum</i> (Blackwall, 1834)			1	1		x	3-4	0-1
<i>Tenuiphantes flavipes</i> (Blackwall, 1854)		1	11	12		[x]	4	1-5
<i>Tenuiphantes tenebricola</i> (Wider, 1834)			1	1		[x]	4	1
<i>Tenuiphantes tenuis</i> (Blackwall, 1852)		2	1	3	x	[x]	2	1-2
<i>Trematocephalus cristatus</i> (Wider, 1834)					x	x	3-4	2-4
Mimetidae								
<i>Ero furcata</i> (Villers, 1789)					x	x	3-4	2-4
Philodromidae								
<i>Philodromus albidus</i> Kulczynski, 1911		120	11	131	x	--*	3-4	3-5
<i>Philodromus aureolus</i> (Clerck, 1757)		2	10	12	x	x	3	3-5
<i>Philodromus buxi</i> Simon, 1884		5		5	x	x	3	3-5
<i>Philodromus praedatus</i> O. P.-Cambridge, 1871		17		17	x	--*	3-4	3-5
<i>Philodromus rufus</i> Walckenaer, 1826					x	x	3	2-3
Salticidae								
<i>Ballus chalybeius</i> (Walckenaer, 1802)		2		2	x	x	3	1-3
<i>Neon reticulatus</i> (Blackwall, 1853)			1	1		x	3-4	2-3
<i>Salticus zebraneus</i> (C.L. Koch, 1837)		2	1	3	x	x	4	3-4
Sparassidae								
<i>Micrommata virescens</i> (Clerck, 1757)			1	1		x	3	2
Tetragnathidae								
<i>Metellina mengei</i> (Blackwall, 1870)		8		8		-	3	2,4
<i>Metellina segmentata</i> (Clerck, 1757)		16		16	x	[x]	3	2,4
<i>Pachygnatha degeeri</i> Sundevall, 1830		1		1		[x]	2	1-2
<i>Tetragnatba montana</i> Simon, 1874		23	10	33	x	-	3-4	3
<i>Tetragnatba nigrata</i> Lendl, 1886					x	-	2	5
<i>Tetragnatba obtusa</i> C.L. Koch, 1837		15	4	19	x	-	3	2,5

Species	RL	Fogging Data			Trap samples 2003-2007	Tolke & Hiebsch 1995	Habitat	Stratum	
		2003	2006	Σ					
Theridiidae									
<i>Anelosimus vittatus</i> (C.L. Koch, 1836)	RLG D	6	2	8	x	-	3	3-4	
<i>Dipoena melanogaster</i> (C.L. Koch, 1837)		59	21	80	x	-	3	5	
<i>Dipoena torva</i> (Thorell, 1875)			7	7		--!	4	5	
<i>Enoplognatha ovata</i> (Clerck, 1757)			1	76	77	x	[x]	3	2-4
<i>Episinus truncatus</i> Latreille, 1809		RLS 4		1	1		x	3	2
<i>Neottiura bimaculata</i> (Linnaeus, 1767)			4		4	x	[x]	2	2
<i>Paidiscura pallens</i> (Blackwall, 1834)			193	87	280	x	-	3-4	3-4
<i>Parasteatoda lunata</i> (Clerck, 1757)			29	5	34	x	-	3	3-4
<i>Parasteatoda simulans</i> (Thorell, 1875)				21	21	x	x	3-4	2
<i>Parasteatoda tepidariorum</i> (C.L. Koch, 1841)			2		2	x	x	1	1,5
<i>Platnickina tincta</i> (Walckenaer, 1802)	RLG V	75	20	95	x	-	3	3-5	
<i>Rugathodes instabilis</i> (O. P.-Cambridge, 1871)		1		1		--*	2	2	
<i>Sardinidion blackwalli</i> (O. P.-Cambridge, 1871)		1	6	7	x	--*	3	3	
<i>Theridion melanurum</i> Hahn, 1831	RLG D	1		1	x	x	1	1	
<i>Theridion mystaceum</i> L. Koch, 1870		45	19	64	x	-	3-4	3-5	
<i>Theridion pictum</i> (Walckenaer, 1802)					x	x	2	2-5	
<i>Theridion pinastri</i> L. Koch, 1872		62	8	70	x	-	3	2-5	
<i>Theridion varians</i> Hahn, 1833		57	14	71	x	-	3	2-3	
Thomisidae									
<i>Diaea dorsata</i> (Fabricius, 1777)	RLG D	3		3	x	x	3-4	2-4	
<i>Diaea livens</i> Simon, 1876					x	--*	4	3-4	
<i>Xysticus cristatus</i> (Clerck, 1757)					(x)	x	?	2	
<i>Xysticus lanio</i> C.L. Koch, 1835			2		2	x	x	3	1-3
Total		1065	502	1567					
Species		56	48	68	73 + (6)				