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Author: Piotr Skubała, Beata Gurgul

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Importance of tree hollows for biodiversity of mites (Acari) in the forest reserve „Śrubita" (Carpathian Mountains, south Poland)

PIOTR SKUBAŁA and BEATA GURGUL

University of Silesia, Department of Ecology, 40-007 Katowice, Bankowa 9, Poland
Corresponding author: Piotr Skubała, piotr.skubala@us.edu.pl

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Abstract: Tree hollows harbour a specialized fauna, and mites usually are the most numerous arthropods in this microhabitat. Mite fauna in 3 types of tree hollows was studied in the forest reserve "Śrubita" near Żywiec, at an altitude of about 850 m. In total, 2037 individuals of Acari and 1414 of Oribatida, representing 72 species, were collected. Over 1200 individuals per 100 g dry weight of wood dust were collected from tree hollows. The total number of oribatid species in tree hollows was higher than in the forest floor. Most species (also dominants) were obligate members of communities of a certain type of tree hollows.

Keywords: mites, Oribatida, tree hollow, wood dust

INTRODUCTION

The long history of human management of forests has created the European forests that we know today: "clean" forests where it is difficult to find decaying wood. The importance of dead wood in forest ecosystems has been reiterated since the 1980s (Maser & Trappe 1984). One of the specific and important form of dead wood is wood mould in tree hollows. Today, many forest stands contain only a few trees with hollows, and these trees should be actively managed to prolong the survival of the rare saproxylic fauna (Ranius 2002). A tree hollow has a large and diverse arthropod fauna, with Acari being the most numerous (Park & Auerbach 1954). In Poland, selected groups of mites of tree hollows were studied by several authors, but mostly this microhabitat was included among others, in some complex studies (e.g. Błaszak 1974; Niedbała 1976; Błoszyk & Olszanowski 1985, 1986; Błoszyk 1990; Słojewska & Błoszyk 1992; Olszanowski & Błoszyk 1998; Gwiazdowicz 1999).

In this paper, we compared the abundance of mite groups in tree hollows and the forest floor. The oribatid fauna was analysed both quantitatively and qualitatively. The following questions were addressed:

(1) Which of the studied microhabitats (tree hollows or forest floor) is characterized by a higher abundance of mites and higher species richness?
(2) How many oribatid species are characteristic of tree hollows?
(3) Does the oribatid community composition differ strongly between tree hollows of different tree species?

MATERIALS AND METHODS

The study site was located in the 26-ha "Śrubita" nature reserve in the Beskid Żywiecki Mountains (southern Poland; 49°24'N, 19°00'E). The reserve was formally established in 1957 to preserve a natural fir-beech forest. Elevation ranges there from 780 to 960 m a.s.l. The investigation was carried out in forest plot 231. The experimental site covered 500 m^2, on a north-facing slope. The dominant plant association in the reserve is *Dentario glandulosae-Fagetum typicum* (Alexandrowicz & Denisiuk 1991). Its tree layer is dominated by European beech (*Fagus sylvatica*), European silver fir (*Abies alba*), and sycamore maple (*Acer pseudoplatanus*). The ground layer abounds with *Athyrium filix-femina*, *Dryopteris austriaca*, *Dryopteris spinulosa* and plants characteristic of this plant association: *Euphorbia amygdaloides* and *Symphytum tuberosum*.

Samples were collected from 10 tree hollows (of 4 fir-trees, 3 beech-trees, and 3 sycamore-trees) and examined for wood-inhabiting mites. Wood dust was collected by hand. Additionally, 10 soil samples were collected from the homogenous study site in the immediate vicinity of the trees. Soil samples were taken using a corer of 4.8 cm in diameter, to a depth of 10 cm. Litter, humus and other organic layers formed on average 8.5 cm of sample depth. Samples were collected on 29th September 2006. Abundance data of mites were standardized by the number of individuals per 100 g dry weight (DW).

The mites were separated from wood dust, litter, and soil by using the Tullgren method. Extracted mites were sorted into the following taxonomic groups: Oribatida, Mesostigmata, Actinedida or Acaridida. Oribatid mites were separated into adults and juveniles (nymphs plus larvae). Adults were identified to species. The classification proposed by Subias (2004) was followed. Four univariate measures were used to assess community structure: abundance, total number of species, Shannon index of diversity (H'), and equitability (J). The Mann–Whitney U test was used for differences in abundance of mite groups between pooled samples from the tree hollows and the forest floor. The differences in the abundance of mites between 4 microhabitats were tested by the Kruskal–Wallis one-way analysis of variance (ANOVA). If the Kruskal-Wallis test was positive ($P < 0.05$), then a test for pairwise comparison of subgroups was used. We used correspondence analysis (CA) to explore the compositional variation between tree hollows and the forest floor.

RESULTS

The most numerous group of mites were the Oribatida (1414) followed by Mesostigmata (333). Seventy-two oribatid species were identified from samples

(Appendix I). The average standardized abundance of Oribatida, Mesostigmata and Actinedida was significantly greater in wood dust from tree hollows (pooled) than in the forest floor (Mann-Whitney *U* test, $U = 3.05$, $p = 0.003$; $U = 2.57$, $p = 0.01$; $U = 3.62$, $p = 0.0002$, respectively). With regard to the least numerous group of mites (Acaridida), the difference between the pooled tree hollows and forest floor was not significant ($U = 0.76$, $p = 0.45$). The Kruskal–Wallis one-way ANOVA revealed significant differences in average abundance of mites between the studied microhabitats. The mean abundance of Oribatida, Mesostigmata, and Actinedida in wood dust of various tree hollows was significantly higher than their abundance in the top 10 cm of litter and soil. Only with regard to Actinedida, the abundance of mites in the tree hollows of fir and sycamore was not significantly different from that in the forest floor. Furthermore, the abundance of Acaridida in all microhabitats was low, and statistically significant differences were not observed (H=5.583, $p = 0.134$) (Table 1). The highest numbers of mites were recorded in hollows of sycamore-trees (1803.4 indiv./100 g DW), followed by those in beech-trees and fir-trees (1272 and 1209 indiv. per 100 g DW). Oribatid mites were represented by higher numbers of specimens in sycamore-tree hollows, whereas Mesostigmata and Actinedida were most abundant in the wood dust of beech-trees. The proportion of juvenile oribatids was generally slightly higher in wood dust (37.6%) than in the forest floor (28.9%). Numerous juvenile forms of oribatids were observed in beech-tree hollows (over 50%).

Estimates of species richness in the forest floor exceeded those of tree hollows (Table 1). However, the observed total number of species in the tree hollows (55 species) was greater than in the forest floor (48). The highest numbers of species were noted in fir-trees (30). Out of a total of 72 species, 41 (57 %) were common to wood dust and forest soil. However, 17 species were collected exclusively in tree hollows, and 14 others were specific to the forest floor. The species diversity (H') of oribatids was highest in the forest floor (2.921). It was slightly lower in tree hollows and did not differ significantly between the studied tree species. With regard to evenness index, it was the highest in the fir-trees, but very similar in the other trees (Table 1).

Correspondence analysis (CA) was performed in order to evaluate relationships between species abundance and microhabitat (Fig. 1). The eigenvalue was significant for axis 1 ($\lambda_1 = 0.75$) and axis 2 ($\lambda_2 = 0.56$). Over 74% of the variance was explained by the first 2 axes, and overall, microhabitats were well separated on the ordination plot. Species associated with the tree hollows of beech-trees were most separated from the other microhabitats and were scattered along the positive part of axis 1. These were species of 5 families: Oppiidae: *Oppiella (O.) besucheti* Mahunka & Mahunka-Papp, 2000; Quadroppiidae: *Quadroppia (Coronoquadroppia) monstruosa* Hammer, 1979; Chamobatidae: *Chamobates (Xiphobates) rastratus*; Carabodidae: *Carabodes (C.) femoralis* (Nicolet, 1855) and Galumnidae: *Acrogalumna longipluma* (Berlese, 1904). Axis 1 showed separation of the oribatid fauna of the other tree hollows and forest floor. They were scattered along the positive part of axis 2. Species associated with the sycamore-trees were located in the negative part of axis 1. *Moritzoppia (M.) keilbachi* (Moritz, 1969), *Rhinoppia subpectinata* (Oudemans, 1900) and *Ramusella (Rectoppia) fasciata fasciata* (Paoli, 1908) were among the most numerous species in this type of wood dust. Along the positive part of axis 1, the species characteristic of

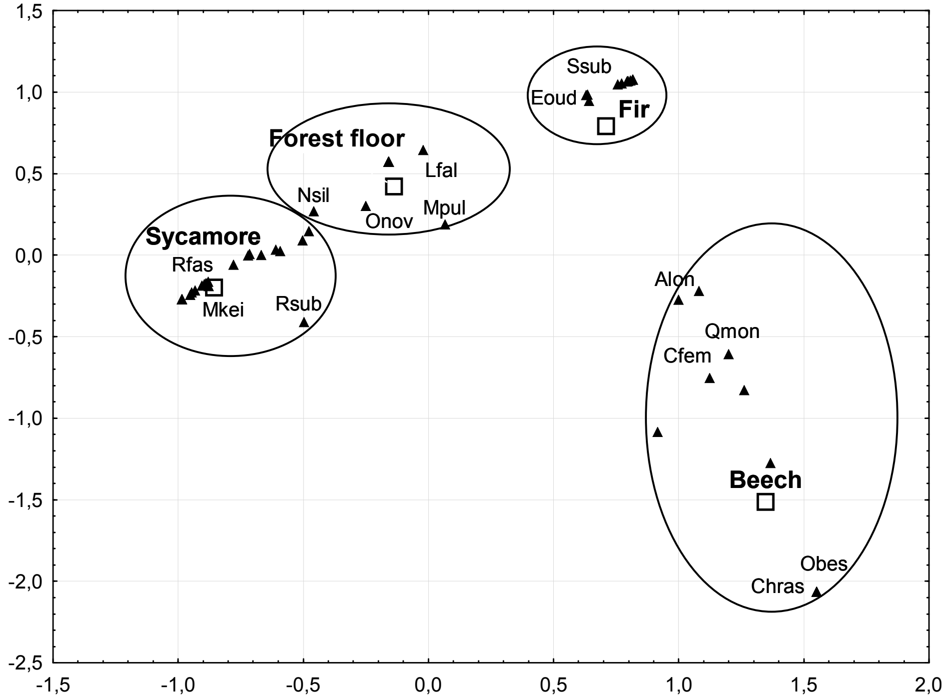

Fig. 1. Biplot of the first 2 axes of a correspondence analysis (CA) of 72 species and 4 microhabitats in the "Śrubita" reserve
Dominant species: Alon = *Acrogalumna longipluma*; Cfem = *Carabodes (C.) femoralis*; Chras = *Chamobates (Xiphobates) rastratus*; Eoud = *Eobrachychthonius oudemansi*; Lfal = *Lauroppia fallax*; Mpul = *Metabelba (M.) pulverulenta*; Mkei = *Moritzoppia (M.) keilbachi*; Nsil = *Nothrus silvestris silvestris*; Obes = *Oppiella (O.) besucheti*; Onov = *Oppiella (O.) nova*; Qmon = *Quadroppia (Coronoquadroppia) monstruosa*; Rfas = *Ramusella (Rectoppia) fasciata fasciata*; Rsub = *Rhinoppia subpectinata;* Ssub = *Suctobelbella (S.) subcornigera*

fir-trees, e.g. *Eobrachychthonius oudemansi* Hammen, 1952 and *Suctobelbella (S.) subcornigera* (Forsslund, 1941), were grouped. Between these 2 types of tree hollows, the oribatid species most abundant in the forest floor were located. *Oppiella (O.) nova* (Oudemans, 1902), *Metabelba (M.) pulverulenta* (Koch, 1839), *Nothrus silvestris silvestris* Nicolet 1855 and *Lauroppia fallax* (Paoli, 1908) appeared to be largely restricted to the forest floor.

DISCUSSION

We found that the abundance of the 4 studied groups of mites in tree hollows was higher than in the same amount of soil substrate (100 g DW). The species richness and species diversity (*H*') were lower in wood dust than in forest floor. However, the

Table 1. Abundance and other characteristics of mite groups in tree hollows and in the forest floor in the “Śrubita” reserve. Mean abundance of mites (individuals per 100 g DW ± S.E.), tested by the Kruskal-Wallis test

	Tree hollows			Forest floor	Kruskal-Wallis test	
	fir	beech	sycamore		*H*	*p*
Oribatida adults	622.1 ± 244.9 [b]	240.7 ± 75.5 [ab]	877.3 ± 215.1 [b]	109.9 ± 27.9 [a]	**12.323**	**0.006**
Oribatida juveniles	196.7 ± 84.9 [ab]	257.1 ± 139.2 [ab]	521.4 ± 334.6 [b]	44.7 ± 10.9 [a]	**8.552**	**0.036**
Oribatida total	818.8 ± 315.0 [ab]	497.8 ± 156.8 [ab]	1398.8 ± 549.7 [b]	154.5 ± 36.0 [a]	**12.898**	**0.005**
Mesostigmata total	242.2 ± 85.4 [b]	382.4 ± 108.7 [b]	138.9 ± 125.3 [b]	27.6 ± 5.4 [a]	**9.695**	**0.021**
Actinedida total	113.4 ± 39.2 [ab]	316.4 ± 137.3 [b]	143.7 ± 79.4 [ab]	11.1 ± 3.5 [a]	**13.531**	**0.003**
Acaridida total	35.0 ± 35.0	76.2 ± 10.3	122.1 ± 110.7	12.7 ± 5.0	5.583	0.134
Species number	30	17	26	48		
Shannon index (*H’*)	2.452	2.429	2.316	2.921		
Evenness index (*J*)	0.866	0.714	0.711	0.755		

Bold values denote significant differences in abundance at $p < 0.05$. Different superscripts within rows denote significant differences among microhabitats based on a *post hoc* test.

total number of oribatids recorded in 10 hollows was higher than in forest litter and soil. Data on mites recorded in different forms of dead wood is scarce and ambiguous. Information on occurrence of mites in different types of tree hollows is lacking. Authors usually studied mites in other types of coarse or fine woody debris. Fager (1968), Seastedt et al. (1989) or Johnston & Crossley (1993) noted that dead wood is a poorer substrate for mites than forest floor. According to Siira-Pietikäinen et al. (2008), decaying wood and forest floor in deciduous forests harboured equal numbers of oribatid mites per volume, whereas in coniferous forests, decaying wood harboured 3-fold fewer oribatids. By contrast, Skubała & Sokołowska (2006), Skubała (2008) or Skubała & Duras (2008) usually recorded a higher abundance and species richness of mites in various forms of dead wood than in the forest floor.

Some authors have stressed that a tree hollow has its own biota (Park & Auerbach 1954, Ranius 2002). This microhabitat harbours a specialized insect fauna, mainly consisting of beetles and flies (Ranius 2002). Our results show that oribatid mites associated with wood dust of tree hollows are partly different from those in the forest floor. Oribatid communities of wood dust are over 43% distinct, with 41 species in common (complementarity = [17 + 14]/72 × 100 = 43.1%]. Seventeen oribatid species (~ ¼ of the total number) were unique to wood dust in the tree hollows. Two of them – *Chamobates (Xiphobates) rastratus* and *Oppiella* (*O.*) *besucheti* – were dominants in beech tree hollows. It is noteworthy that most of the dominant species of the tree hollows were strictly associated with a certain type of hollows, and many of them were absent in the forest floor, e.g. *Eobrachychthonius oudemansi* (fir-tree); *Chamobates (X.) rastratus*, *Oppiella (O.) besucheti* and *Acrogalumna longipluma* (beech-tree); or *Moritzoppia (M.) keilbachi* (Moritz, 1969), *Rhinoppia subpectinata* (Oudemans, 1900) and *Ramusella (R.) fasciata fasciata* (sycamore-tree). Oribatids characteristic of tree hollows represent species of various sizes and are recorded in various microhabitats. Most of oribatids are species characteristic of forests, some are known as eurytopic. Three species (*Ch. rastratus*, *O. besucheti*, *R. fasciata*) have unclear ecological preferences (Weigmann 2006). One species, which occurred in beech-tree wood dust – *Rhynchobelba inexpectata* Willmann, 1953 – is a new species for the Polish fauna.

In previous studies of mite fauna in dead wood and forest floors, Johnston & Crossley (1993) observed that only some species of mites use coarse wood debris (CWD) exclusively and they suggested that fallen logs in the forest floor are refuges for mite species that normally occur in forest soil. Similarly, Seastedt et al. (1989) found that only a few species were restricted to decaying wood. Furthermore, Marra & Edmonds (2005) reported on the overlap in community composition between CWD and the forest floor. They suggested that it may be a function of the advanced state of decay (4th) of the logs they sampled. Our results are consistent those of studies by Skubała & Sokołowska (2006), Siira-Pietikäinen et al. (2008) or Skubała & Duras (2008), who found a high dissimilarity between the number of oribatid species associated with dead wood and those of the forest floor. Siira-Pietikäinen et al. (2008) concluded that the oribatid mites of decaying wood represent distinct and diverse sub-communities of mites. However, none of the above authors sampled tree hollows separately.

CONCLUSIONS

Wood dust of tree hollows appears to be a relatively rich substrate for mites. Abundance of mites exceeded 1200 individuals per 100 g DW, and 55 oribatid species were recorded in the 10 studied tree hollows.

Partly distinct communities of oribatid mites inhabit tree hollows of different trees. Most species appeared to be largely restricted to a certain type of tree hollows or forest floor.

Oribatid fauna of tree hollows contributes to forest biodiversity. The lack of tree hollows in a forest might mean decreasing the number of oribatid species by ¼. Thus the presence of tree hollows is desired, both in managed and natural forests, to increase or preserve their biodiversity.

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Appendix I. Species list of adult oribatid mites and abundance of juvenile oribatids and of other major mite groups recorded in tree hollows and in the forest floor in the "Śrubita" reserve. Numbers indicate the absolute number of individuals found at each microhabitat

Species	Tree hollows			Forest floor
	fir	beech	sycamore	
Eobrachychthonius oudemansi Hammen, 1952	66	-	6	-
Liochthonius (*L.*) *tuxeni* (Forsslund, 1957)	-	-	-	3
Mesoplophora (*Parplophora*) *pulchra* Sellnick, 1928	-	-	-	6
Euphthiracarus (*E.*) *reticulatus reticulatus* (Berlese, 1913)	1	-	-	-
Atropacarus striculus striculus (Koch, 1835)	1	-	2	23
Phthiracarus (*Archiphthiracarus*) *anonymus* Grandjean, 1933	-	-	1	26
Nothrus silvestris silvestris Nicolet, 1855	-	-	1	45
Heminothrus (*Platynothrus*) *peltifer* (Koch, 1839)	-	-	-	1
Belba (*B.*) *corynopus* (Hermann, 1804)	-	-	1	3
Damaeus (*Epidamaeus*) *bituberculatus* (Kulczynski, 1902)	-	1	-	-
Damaeus (*Kunstidamaeus*) *tecticola* Michael, 1888	-	2	-	-
Dameobelba minutissima (Sellnick, 1929)	-	1	-	15
Metabelba (*M.*) *pulverulenta* (Koch, 1839)	4	1	3	43
Metabelba (*Parametabelba*) *italica* (Sellnick, 1931)	-	-	-	3
Cultroribula juncta (Michael, 1885)	-	-	3	-
Ceratoppia quadridentata (Haller, 1882)	-	-	-	3
Adoristes ovatus (Koch, 1839)	-	-	-	2
Eremaeus hepaticus Koch, 1835	-	-	-	1
Eueremaeus oblongus (Koch, 1835)	6	-	-	1
Caleremaeus monilipes (Michael, 1882)	1	-	2	-
Pantelozetes paolii (Oudemans, 1913)	-	-	5	-
Conchogneta willmanni willmanni (Dyrdowska, 1929)	-	-	1	16
Banksinoma lanceolata lanceolata (Michael, 1885)	-	1	-	-
Ramusella (*Insculptoppia*) *furcata* (Willmann, 1928)	5	-	-	-
Ramusella (*Rectoppia*) *fasciata fasciata* (Paoli, 1908)	2	-	14	1
Rhinoppia subpectinata (Oudemans, 1900)	2	3	11	-
Berniniella (*B.*) *bicarinata* (Paoli, 1908)	-	-	-	1
Berniniella (*B.*) *conjuncta* (Strenzke, 1951)	-	-	-	8
Berniniella (*B.*) *sigma* (Strenzke, 1951)	1	-	-	5
Dissorhina ornata (Oudemans, 1900)	5	-	-	10
Lauroppia beskidyensis (Niemi & Skubala, 1993)	-	2	-	-
Lauroppia falcata falcata (Paoli, 1908)	-	-	-	2
Lauroppia fallax (Paoli, 1908)	1	-	-	142
Lauroppia maritima (Willmann, 1928)	3	-	-	-
Moritzoppia (*M.*) *keilbachi* (Moritz, 1969)	2	-	72	-
Moritzoppia (*M.*) *unicarinata* (Paoli, 1908)	-	-	-	6

Moritzoppia (*Moritzoppiella*) *neerlandica* (Oudemans, 1900)	1	-	-	1
Oppiella (*O.*) *besucheti* Mahunka & Mahunka-Papp, 2000	-	4	-	-
Oppiella (*O.*) *nova* (Oudemans, 1902)	5	-	7	40
Subiasella (*Lalmoppia*) *quadrimaculata* (Evans, 1952)	1	-	-	1
Quadroppia (*Coronoquadroppia*) *monstruosa* Hammer, 1979	15	13	-	10
Quadroppia (*Q.*) *quadricarinata* (Michael, 1885)	-	1	-	-
Allosuctobelba grandis (Paoli, 1908)	2	1	-	4
Rhynchobelba inexpectata Willmann, 1953	-	1	-	-
Suctobelba atomaria Moritz, 1970	-	-	-	1
Suctobelba regia Moritz, 1970	-	-	-	1
Suctobelba reticulata Moritz, 1970	3	-	-	3
Suctobelba trigona (Michael, 1888)	1	-	3	22
Suctobelbata prelli (Märkel & Meyer, 1958)	3	-	-	-
Suctobelbella (*S.*) *acutidens acutidens* (Forsslund, 1941)	-	-	1	3
Suctobelbella (*S.*) *acutidens sarekensis* (Forsslund, 1941)	-	-	2	11
Suctobelbella (*S.*) *longicuspis longicuspis* Jacot, 1937	-	-	1	-
Suctobelbella (*S.*) *subcornigera* (Forsslund, 1941)	5	-	-	35
Suctobelbella (*Flagrosuctobelba*) *forsslundi* (Strenzke, 1950)	-	-	1	7
Suctobelbella (*Flagrosuctobelba*) *nasalis* (Forsslund, 1941)	-	-	-	4
Carabodes (*C.*) *areolatus* Berlese, 1916	1	2	-	-
Carabodes (*C.*) *femoralis* (Nicolet, 1855)	2	3	-	21
Carabodes (*C.*) *labyrinthicus* (Michael, 1879)	-	-	-	1
Tectocepheus alatus Berlese, 1913	-	-	-	1
Tectocepheus minor Berlese, 1903	-	-	-	5
Tectocepheus velatus velatus (Michael, 1880)	-	-	-	1
Licneremaeus licnophorus (Michael, 1882)	1	-	2	1
Ophidiotrichus vindobonensis Piffl, 1961	-	-	1	-
Oribatella (*O.*) *calcarata* (Koch, 1835)	1	-	-	1
Melanozetes mollicomus (Koch, 1839)	-	-	1	12
Chamobates (*C.*) *birulai* (Kulczynski, 1902)	-	-	1	-
Chamobates (*C.*) *pusillus* (Berlese, 1895)	1	-	3	23
Chamobates (*Xiphobates*) *rastratus* (Hull, 1914)	-	5	-	-
Chamobates (*Xiphobates*) *voigtsi* (Oudemans, 1902)	-	-	5	30
Hemileius (*H.*) *initialis* (Berlese, 1908)	-	-	-	7
Topobates circumcarinatus (Weigmann & Miko, 1998)	1	1	-	-
Acrogalumna longipluma (Berlese, 1904)	10	6	1	-
Oribatida juveniles	46	50	101	253
Mesostigmata	62	75	19	177
Actinedida	28	62	27	62
Acaridida	7	15	16	73
Total	296	250	314	1177