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Oribatid communities (Acari: Oribatida) associated with bird's nests - microhabitats in urban environment

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Abstract: The aim of this study was to determine the species composition and structure of thrush nest oribatocenoses under urban conditions in Slovakia and Germany and to further determine the influence of some environmental variables on the oribatid mite community. A total of 1,623 individuals of oribatids in different stages of their life cycles belonging to 53 species and 24 families were identified in a total of 43 nests. Of these, 24 species were recorded in Slovakia, 45 species were recorded in Germany, 20 species occurred in song thrush nests, and 49 species occurred in Eurasian blackbird nests. A total of 17 species were common to both types of nests. A total of thirty species recorded in this study were found in bird nests for the first time. There was a significant difference between the nest species compositions in different localities and between the nest oribatocenosis abundances for the two studied thrush species.

Keywords: soil mites; thrush nests; urban parks

Introduction

Bird nests are specific habitats where oribatids find suitable conditions for their life cycles and development (Ermilov *et al.* 2013). The design and structure of a nest significantly influence the microclimate conditions in that nest (Dawson *et al.* 2011). The most important microclimatic factors necessary for the development of the oribatid community in a nest include temperature and humidity (Web *et al.* 1998; Sinclair & Chown 2006). The organic matter content is another important factor influencing mite cenoses and is closely related to the humidity of the environment (Tryjanowski *et al.* 2001; Bajerlein *et al.* 2006). Nesting material is also a crucial factor affecting mite cenoses (Klekowski & Opalinski 1986; Odasz 1994). The material composition of nests is largely dependent on the nature of the habitat. Organic matter serves as a food substrate for not only oribatid mites but also various microorganisms (Coulson *et al.* 2009). With increased organic matter content, microorganisms have high growth rates and thus increase the food supply available for mites. Nest mycoflora also serves as mite feed (Schneider *et al.* 2004). The presence of keratinophilic and soil fungi in bird nests is understandable due to the main nest building materials (plant parts, feathers, fur and soil). Birds provide repeated contact between the soil and nest. Therefore, we can assume that fungal nest flora consists mainly of soil species (Otcenášek *et al.* 1967). Factors influencing the qualitative and quantitative composition of mycoflora in nests are the nesting material composition, its moisture and pH, the species of the bird and its food, repeated nesting in the nest and the habitat (Hubálek *et al.* 1973). Small arthropods enter bird nests mainly from their feathers and the material brought the birds to build the nest. Some scientific studies have shown the distribution of microarthropods by birds as a decisive factor in the occupation of new or distant habitats (Krivolutsky & Lebedeva 1999; Lebedeva & Lebedev 2008; Pilskog *et al.* 2014). Daily replenishment of green plant material and feathers by birds during the nesting period can have a significant impact on the number of oribatids in the nest (Lebedeva & Krivolutsky 2003). Oribatid mites seem to be common representatives of nidicolous fauna, which has been confirmed by several authors (Błoszyk & Olszanowski 1985; Tryjanowski *et al.* 2001; Ermilov *et al.* 2013; Meleschuk & Skilsky 2017; Melekhina *et al.* 2019). The spectrum of oribatid life forms is represented by inhabitants of the soil surface, small soil crevices, litter, and eurybiontic forms (Shahab 2006b).

The aim of this study was to determine the species composition and structure of oribatocenoses of Eurasian blackbird (*Turdus merula* Linnaeus, 1758) and song thrush (*Turdus philomelos* C.L. Brehm, 1831) nests under urban conditions of Slovakia and Germany and to further determine the influence of some environmental variables on the oribatid mite communities.

Material and Methods

This research was carried out from March to July 2011 in Bratislava -Slovakia (Garden of Janko Kral 48°08'07.6"N 17°06'35.0"E; Mirror Grove 48°06'35.5"N 17°07'01.8"E; park at the Croatian Branch - 48°06'40.1"N 17°06'32.2"E; Botanical Garden - 48°08'46.0"N 17°04'24.5"E; greenery in residential area of Petržalka - 48°06'55.9"N 17°06'30.1"E), Bernolákovo - Slovakia (greenery in the city center - 48°11'45.5"N 17°17'44.5"E) and Stupava - Slovakia (greenery in residential area of Stupava - 48°16'12.3"N 17°01'52.0"E; Borník - 48°16'28.3"N 17°02'16.9"E; Castle Park - 48°16'45.4"N 17°03'01.5"E; park by the Stupava Brook 48°16'36.6"N 17°01'25.3"E) and from May to June 2012 and from April to July 2013 in Leipizig - Germany (City park - 51°20'35.9"N 12°22'15.8"E; Nonne park 51°19'30.9"N 12°21'05.2"E; sports ground in the city center - 51°19'29.8"N 12°21'40.0"E; Clara park - 51°19'38.6"N 12°21'36.3"E). Nest materials were collected from several different city parks and urban greenery after the chicks left the nest. Microarthropods were extracted from bird nests by using modified Tullgren funnels (Tullgren 1917). Specimens were mounted on glass slides using Liquido de Swan (Swan 1936).

Identification

Species identification of oribatid mite adults and juveniles was performed using contemporary identification keys and taxonomic works (Grandjean 1958, 1963a,b, 1965; Claparède 1868; Kunst 1971; Gilyarov & Krivolutsky 1975; Seniczak 1975, 1980, 1990; Shaldybina 1986; Subías & Balogh 1989; Pérez-Íñigo 1993; Pavlitshenko 1994; Krivolutsky et al. 1995; Olszanowski 1996; Travé et al. 1996; Weigmann 2006, 2009, 2011, 2012, 2014; Seniczak & Seniczak 2007; Ermilov 2008, 2009a,b, 2010a,b, 2011a,b, 2012; Ermilov & Łochyńska 2009; Seniczak et al. 2009, 2012a,b; Pfingstl & Krisper 2011a,b,c; Ermilov et al. 2012, 2013, Ermilov & Kolesnikov 2012; Niedbała 2014).

Data analysis

Statistical analyses of the data were performed in the updated Past 4.02 program (Hammer *et al.* 2001) using generic functions and functions available in the packages vegan (Oksanen 2013) and MASS (Venables & Ripley 2002). Monitored and tested variables were host bird species (host), geographical location (country), surrounding nest habitat (nesthabitat), nest location height (height), and nesting duration (nestingdays). Abundance was expressed in the unit ex/nid (number of individuals in one nest). The number of species in the nest (S) was expressed in units of sp/nid. Species dominance (D) was expressed as the percentage of particular species individuals in relation to the total number of oribatid mites. Modified categorization into five dominance classes according to Tischler (1955) was used for dominance category identification. Species constancy (C) reflects the stability of a species in a community and thus the stability of the community species composition over time. The species were divided into four categories based on their determined constancy values (Tischler 1947). The species that showed stability equal to or above 50% (all euconstant and constant) were synecologically most important. The modified DC (DF) index according to Kiefer *et al.* (1983) was used to determine the species importance in cenosis. This index took into account both the quantitative and qualitative occurrences of oribatids (DC=D*C/100): characteristic species (> 0.90), leading species (0.10–0.90), important species (0.01–0.09), accompanying species (0.005–0.009), and accidental species (<0.005). Diversity (Shannon–Weaver's (H'), Simpson's (1-D), Margalef (M) and equitability (J) indices were used to evaluate the species richness and evenness of oribatocenoses. A t-test ($alpha_{krit}$ = 0.05) based on a matrix of dominance, abundance and constancy values of individual species was used to confirm the difference between communities of different thrush nests and nests from different sites. Nonmetric multidimensional scaling (NMDS) was used to visualize the relationship between the oribatocenoses of individual nests and sites. The advantage of this method is its robustness to outliers and usability even in the case of incomplete data. From the original data matrix based on the obtained dominance values of individual species, a matrix of Euclidean distances between nests was calculated to quantify the dissimilarity of the site communities.

Results

A total of 43 nests of two bird species were investigated. Of these, 12 nests of the Eurasian blackbird and 2 nests of the song thrush from Slovakia and 20 blackbird nests and 9 song thrush nests from Germany were collected.
A total of 1,623 individuals of oribatids in different stages of their life cycles (89.71% adults, 10.29% juveniles) belonging to 53 species and 24 families were separated. Of these, 24 species were recorded in Slovakia, 45 species were recorded in Germany, 20 species occurred in song thrush nests, and 49 species occurred in Eurasian blackbird nests. A total of 17 species were common to both types of nests (Table 1). One nest of blackbirds from Germany had no oribatids.

From the Eurasian blackbird nests collected in Germany, a total of 1,172 individuals of oribatids belonging to 41 species and 23 families were obtained. The average oribatid mite abundance was 58.3 individuals per nest. From the song thrush nests, a total of 168 individuals of oribatids belonging to 20 species and 14 families were obtained. The average oribatid mite abundance was 18.67 individuals per nest.

From the Eurasian blackbird nests collected in Slovakia, a total of 280 individuals of oribatids belonging to 22 species and 15 families were obtained. The average oribatid mite abundance was 23.42 individuals per nest. From the song thrush nests, a total of 8 oribatids belonging to 4 species and 4 families were obtained. The average oribatid mite abundance was 4.00 individuals per nest.

The oribatocenosis of the song thrush nests collected in Germany reached the highest value of the diversity and equitability indices. The highest oribatid mite abundance was recorded in Eurasian blackbird nests that also originated in Germany (Table 2).

Table 1. The list of oribatida species recorded in thrush nests.

Fam	Species	DE		SK		TM		TP		SUM	
		A DC	D C	A DC	D C	A DC	D C	A DC	D C	A DC	D C
1.	*Hypochthonius rufulus* C.L.Koch, 1835	0.07 0.01	0.15 6.90	- -	- -	0.03 0.01	0.07 3.03	0.10 0.05	0.52 10.00	0.05 0.01	0.12 4.65
2.	**Steganacarus* (*Tropacarus*) *carinatus* (C.L. Koch, 1841)	- -	- -	0.07 0.03	0.35 7.14	0.03 0.01	0.07 3.03	- -	- -	0.02 0.01	0.06 2.33
	Phthiracarus sp.	1.69 1.77	3.67 48.28	0.07 0.03	0.35 7.14	0.58 0.48	1.33 36.36	3.10 6.39	15.98 40.00	1.16 0.93	3.08 30.23
3.	**Rhysotritia ardua* (C.L. Koch, 1841)	0.21 0.08	0.45 17.24	- -	- -	0.09 0.02	0.21 9.09	0.30 0.31	1.55 20.00	0.14 0.04	0.37 11.63
4.	**Malaconothrus monodactylus* (Michael, 1888)	0.41 0.03	0.90 3.45	- -	- -	0.36 0.03	0.84 3.03	- -	- -	0.28 0.02	0.74 2.33
5.	*Nothrus anauniensis* Canestrini & Fanzago, 1876	0.03 0.01	0.08 3.45	- -	- -	- -	- -	0.10 0.05	0.52 10.00	0.02 0.01	0.06 2.33
	Nothrus borussicus Sellnick, 1928	0.10 0.01	0.23 3.45	0.07 0.03	0.35 7.14	0.12 0.02	0.28 6.06	- -	- -	0.09 0.01	0.25 4.65
	Nothrus palustris C.L. Koch, 1928	0.38 0.11	0.83 13.80	- -	- -	0.18 0.03	0.42 6.06	0.50 0.52	2.58 20.00	0.26 0.06	0.68 9.30
6.	*Camisia segnis* (Hermann, 1804)	0.07 0.01	0.15 6.90	0.21 0.22	1.04 21.43	0.09 0.02	0.21 9.09	0.20 0.21	1.03 20.00	0.12 0.04	0.31 11.63
	**Heminothrus targionii* (Berlese, 1885)	0.17 0.04	0.38 10.35	- -	- -	0.06 0.01	0.14 3.03	0.30 0.31	1.55 20.00	0.12 0.04	0.31 11.63
	Platynothrus peltifer (C.L. Koch, 1839)	2.45 2.02	5.32 37.93	- -	- -	1.21 0.76	2.80 27.27	3.10 3.20	15.98 20.00	1.65 1.12	4.38 25.58
7.	*Damaeus* sp.	0.35 0.16	0.75 20.70	- -	- -	0.15 0.03	0.35 9.09	0.50 0.77	2.58 30.00	0.23 0.09	0.62 13.95
	**Kunstidamaeus tecticola* (Michael, 1888)	- -	- -	0.14 0.10	0.69 14.29	0.06 0.01	0.14 6.06	- -	- -	0.05 0.01	0.12 4.65
	Belba corynopus (Hermann, 1804)	0.10 0.02	0.23 6.90	- -	- -	0.09 0.01	0.21 6.06	- -	- -	0.07 0.01	0.19 6.98
8.	**Cepheus cepheiformis* (Nicolet, 1855)	0.03 0.01	0.08 3.45	- -	- -	- -	- -	0.10 0.05	0.52 10.00	0.02 0.01	0.06 2.33
9.	**Hafenrefferia gilvipes* (C.L. Koch, 1839)	0.35 0.10	0.75 13.80	- -	- -	0.30 0.09	0.70 12.12	- -	- -	0.23 0.06	0.62 9.30
10.	*Liacarus coracinus* (C.L. Koch, 1841)	0.03 0.01	0.08 3.45	- -	- -	0.03 0.01	0.07 3.03	- -	- -	0.02 0.01	0.06 2.33
	**Liacarus subterraneus* (C.L. Koch, 1841)	0.14 0.02	0.30 6.90	- -	- -	0.12 0.02	0.28 6.06	- -	- -	0.09 0.01	0.25 4.65
	Xenillus tegeocranus (Hermann, 1804)	0.66 0.44	1.42 31.03	0.14 0.05	0.69 7.14	0.39 0.22	0.91 24.24	0.80 0.83	4.12 20.00	0.49 0.30	1.30 23.26
11.	*Carabodes labyrinthicus* (Michael, 1879)	0.03 0.01	0.08 3.45	- -	- -	0.03 0.01	0.07 3.03	- -	- -	0.02 0.01	0.06 2.33
12.	*Tectocepheus velatus sarekensis* Trägårdth, 1910	0.28 0.062	0.60 10.35	0.57 0.59	2.77 21.43	0.49 0.20	1.12 18.18	- -	- -	0.37 0.14	0.99 13.95
13.	*Oppiella* (*Oppiella*) *nova* (Oudemans, 1902)	0.03 0.01	0.08 3.45	- -	- -	- -	- -	0.10 0.05	0.52 10.00	0.02 0.01	0.06 2.33
	Oppiella (*Moritzoppia*) *translamellata* (Willmann, 1923)	0.07 0.01	0.15 3.45	0.21 0.07	1.04 7.14	0.15 0.02	0.35 6.06	- -	- -	0.12 0.01	0.31 4.65

	**Oppiella* (*Rhinoppia*) *subpectinata* (Oudemans, 1900)	0.07 0.01	0.15 3.45	- -	- -	0.06 0.01	0.14 3.03	- -	- -	0.05 0.01	0.12 2.33
	**Oppia denticulata* (R.& G. Canestrini, 1882)	0.35 0.03	0.75 3.45	0.07 0.03	0.35 7.14	0.33 0.05	0.77 6.06	- -	- -	0.26 0.03	0.68 4.65
	**Ramusella elliptica* (Berlese, 1908)	0.69 0.05	1.50 3.45	- -	- -	0.61 0.04	1.40 3.03	- -	- -	0.47 0.03	1.23 2.33
14.	**Scapheremaeus palustris* *Sellnick, 1924*	- -	- -	0.07 0.03	0.35 7.14	0.03 0.01	0.07 3.03	- -	- -	0.02 0.01	0.06 2.33
	**Micreremus brevipes* (Michael, 1888)	- -	- -	0.50 0.52	2.42 21.43	0.18 0.03	0.42 6.06	0.10 0.05	0.52 10.00	0.16 0.03	0.43 6.98
	**Micreremus gracilior* Willmann, 1931	- -	- -	0.21 0.15	1.04 14.29	0.09 0.01	0.21 6.06	- -	- -	0.07 0.01	0.19 4.65
15.	**Eupelops acromios* (Hermann, 1804)	- -	- -	1.00 2.08	4.84 42.86	0.42 0.15	0.98 15.15	- -	- -	0.33 0.10	0.86 11.63
	**Eupelops occultus* (C.L. Koch, 1835)	0.03 0.01	0.08 3.45	- -	- -	0.03 0.01	0.07 3.03	- -	- -	0.02 0.01	0.06 2.33
	**Eupelops strenzkei* (Knülle, 1954)	0.07 0.01	0.15 3.45	- -	- -	0.06 0.01	0.14 3.03	- -	- -	0.05 0.01	0.12 2.33
	Eupelops torulosus (C.L. Koch, 1839)	0.03 0.01	0.08 3.45	- -	- -	0.03 0.01	0.07 3.03	- -	- -	0.02 0.01	0.06 2.33
16.	*Achipteria coleoptrata* (Linné, 1758)	5.66 2.97	12.30 24.14	0.07 0.03	0.35 7.14	5.00 2.80	11.55 24.24	- -	- -	3.84 1.89	10.17 18.61
	**Achipteria nitens* (Nicolet, 1855)	0.10 0.01	0.23 3.45	- -	- -	- -	- -	0.30 0.16	1.55 10.00	0.07 0.01	0.19 2.33
17.	**Oribatella calcarata* (C.L. Koch, 1835)	0.03 0.01	0.08 3.45	- -	- -	0.03 0.01	0.07 3.03	- -	- -	0.02 0.01	0.06 2.33
	**Oribatella quadricornuta* Michael, 1880	0.14 0.02	0.30 6.90	- -	- -	0.09 0.01	0.21 3.03	0.10 0.05	0.52 10.00	0.09 0.01	0.25 4.65
18.	**Acrogalumna longipluma* (Berlese, 1904)	0.03 0.01	0.08 3.45	- -	- -	0.03 0.01	0.07 3.03	- -	- -	0.02 0.01	0.06 2.33
	Pegalumna nervosa (Berlese, 1914)	1.07 0.16	2.32 6.90	- -	- -	0.06 0.01	0.14 3.03	2.90 1.50	14.95 10.00	0.721 0.089	1.91 4.65
	**Pilogalumna crassiclava* (Berlese, 1914)	- -	- -	0.14 0.05	0.69 7.14	0.06 0.01	0.14 3.03	- -	- -	0.05 0.01	0.12 2.33
19.	**Ceratozetoides maximus* (Berlese, 1908)	0.10 0.01	0.23 3.45	- -	- -	0.09 0.01	0.21 3.03	- -	- -	0.07 0.01	0.19 2.33
	Trichoribates trimaculatus (C.L. Koch, 1835)	1.69 0.76	3.67 20.69	7.29 22.69	35.29 64.29	3.09 2.38	7.14 33.33	4.90 7.58	25.26 30.00	3.51 3.03	9.30 32.56
20.	**Chamobates cuspidatus* (Michael, 1884)	0.17 0.03	0.38 6.90	0.21 0.07	1.04 7.14	0.24 0.05	0.56 9.09	- -	- -	0.19 0.03	0.49 6.98
21.	**Minunthozetes semirufus* (C.L. Koch, 1841)	0.28 0.06	0.60 10.35	- -	- -	0.24 0.05	0.56 9.09	- -	- -	0.19 0.03	0.49 6.98
	Punctoribates punctum (C.L. Koch, 1839)	1.35 1.01	2.92 34.48	1.14 1.58	5.54 28.57	1.64 1.49	3.78 39.39	0.10 0.05	0.52 10.00	1.28 1.10	3.39 32.56
22.	*Euzetes globulus* (Nicolet, 1855)	0.07 0.01	0.15 3.45	- -	- -	0.06 0.01	0.14 3.03	- -	- -	0.05 0.01	0.12 2.33

23.	**Liebstadia humerata* Sellnick, 1928	0.03 0.01	0.08 3.45	0.93 0.32	4.50 7.14	0.42 0.06	0.98 6.06	- -	- -	0.33 0.01	0.86 4.65
	**Liebstadia pannonica* (Willmann, 1951)	0.03 0.01	0.08 3.45	0.14 0.10	0.69 14.29	0.06 0.01	0.14 6.06	0.10 0.05	0.52 10.00	0.07 0.01	0.19 6.98
	**Scheloribates pallidulus* (C.L. Koch, 1840)	0.07 0.01	0.15 6.90	0.86 1.48	4.15 35.71	0.42 0.21	0.98 21.21	- -	- -	0.33 0.14	0.86 16.28
24.	**Oribatula interrupta* (Willmann, 1939)	- -	- -	0.14 0.05	0.69 7.14	0.06 0.01	0.14 3.03	- -	- -	0.05 0.01	0.12 2.33
	Oribatula tibialis (Nicolet, 1855)	25.31 20.87	55.02 37.93	- -	- -	22.24 17.12	51.37 33.33	- -	- -	17.07 11.57	45.23 25.58
	Zygoribatula exilis (Nicolet, 1855)	0.48 0.22	1.05 20.69	0.29 0.10	1.38 7.14	0.36 0.10	0.84 12.12	0.60 0.93	3.09 30.00	0.42 0.18	1.11 16.28
	**Zygoribatula propinqua* (Oudemans, 1902)	0.48 0.18	1.05 17.24	6.07 12.61	29.41 42.86	2.67 1.49	6.16 24.24	1.10 1.70	5.67 30.00	2.30 1.56	6.10 25.58
		46.00		20.64		43.30		19.40		37.74	

DE - nests from Germany; SK - nests from Slovakia; TM - Eurasian blackbird nests; song thrush nests; A - abundance (ex/nid); D - dominance (%); C - constancy (%); DC - dominance-constancy index ; Fam - family: 1. Hypochthoniidae Berlese, 1910; 2. Phthiracaridae Perty, 1841; 3. Euphthiracaridae Jackot, 1930; 4. Malaconothridae Berlese, 1916; 5. Nothridae Berlese, 1896; 6. Camisiidae Oudemans, 1900; 7. Damaeidae Berlese, 1896; 8. Cepheidae Berlese, 1896; 9. Tenuialidae Jackot, 1929; 10. Liacaridae Sellnick, 1928; 11. Carabodidae C.L. Koch, 1843; 12. Tectocepheidae Oudemans, 1900; 13. Oppiidae Grandjean, 1951; 14. Cymbaeremaeidae Sellnick,1928; 15. Phenopelopidae Petrunkevich, 1955; 16. Achipteriidae Thor, 1929; 17. Oribatellidae Jackot, 1925; 18. Galumnidae Jackot, 1925; 19. Ceratozetidae Jackot, 1925; 20. Chamobatidae Grandjean,1954; 21. Mycobatidae Grandjean,1954; 22. Euzetidae Grandjean,1954; 23. Scheloribatidae Grandjean,1933; 24. Oribatulidae Thor, 1929; * oribatid mite species first found in bird nests

Table 2. Values of ecological indices of oribatid mite communities..

	DE				SK				Total			
	J	**H´**	**1-D**	**M**	**J**	**H´**	**1-D**	**M**	**J**	**H´**	**1-D**	**M**
TM	0.435	1.615	0.584	5.661	0.634	1.960	0.766	3.727	0.529	2.057	0.710	6.607
TP	0.784	2.308	0.868	3.538	0.953	1.321	0.719	1.443	0.744	2.266	0.855	3.797
Total	0.508	1.932	0.674	6.115	0.640	2.034	0.778	4.059	0.572	2.273	0.767	7.035

TM - oribatocenosis of the Eurasian blackbird nests, TP - oribatocenosis of the song thrush nests, DE - from Germany and SK - from Slovakia. Values of equitability (J) and diversity (Shannon–Weaver's (H'), Simpson's (1-D), Margalef (M)) indices

Statistical analyses

The number of species per nest, abundance and diversity were tested using generalized linear models. The number of species per nest and the Shannon-Weaver diversity index were not significantly different between the two species of birds, and none of the other environmental factors was significant (Table 3, 4).

Furthermore, we tested for differences in the abundance of mites using a negative binomial model. Of all environmental factors, only two were significant: host species and country (Table 5), with abundance averaging 47.5 ex/nid for *T. merula*, 15.4 ex/nid of *T. philomelos*, 48.6 mites per nest in Germany and 20 ex/nid in Slovakia.

Nonmetric multidimensional scaling was used to analyze the communities of oribatid mites. We tested for differences among the host species and countries using bootstrapping, using the Bray-Curtis as a measure of distance. The communities were not significantly different among the host species but were significantly different among the countries (Table 6).

Table 3. ANOVA table of generalized linear model with position distribution of residuals. No significant difference in the number of species was observed between the bird species.

	Df	Deviance	Resid. Df	Resid. Dev	Pr(>Chi)
host	1	2.25	40	104.3	0.39
country	1	3.54	39	100.8	0.28
nesthabitat	3	1.71	36	99.1	0.91
height	1	3.71	35	95.4	0.27
nestingdays	1	0.60	34	94.8	0.66

Table 4. ANOVA table showing the effect of environmental factors on Shannon-Weaver diversity index of mites in bird nests.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
host	1	0.2438	0.24382	0.6359	0.4307
country	1	0.3658	0.36582	0.9540	0.3356
nesthabitat	3	1.1214	0.37379	0.9748	0.4160
height	1	0.8479	0.84787	2.2112	0.1462
nestingdays	1	0.2806	0.28057	0.7317	0.3983
Residuals	34	13.0371	0.38344		

Table 5. ANOVA table of negative binomial model of mite abundance in nests, Theta was estimated to be 0.551.

	Df	Deviance	Resid. Df	Resid. Dev	Pr(>Chi)
host	1	4.1557	40	54.985	0.04149 *
country	1	4.5778	39	50.407	0.03239 *

Table 6. Results of the bootstrap test using Bray-Curtis distances and 999 permutations.

	Df	SumsOfSqs	MeanSqs	F.Model	R2	Pr(>F)
host	1	0.5567	0.55673	1.3973	0.03231	0.110
country	1	1.5328	1.53277	3.8471	0.08896	0.001 ***
Residuals	38	15.1399	0.39842		0.87873	
Total	40	17.2294			1.00000	

Characteristic species of thrush nests

Some euryvalent species, such as *Platynothrus peltifer* (C.L. Koch, 1839) and *Oribatula tibialis* (Nicolet, 1855), preferred forest and meadow soil substrates with species such as *Phthiracarus* sp. Perty, 1841, *Achipteria coleoptrata* (Linnaeus, 1758), *Punctoribates punctum* (Koch, 1839), often naturally inhabiting tree trunks and bark, and species such as *Trichoribates trimaculatus* (C.L. Koch, 1836) and *Zygoribatula propinqua* (Oudemans, 1902) were generally characteristic species in thrush nests. The forest soil species *Xenillus tegeocranus* (Hermann, 1804) and *Scheloribates pallidulus* (C.L. Koch, 1840), euryvalent species *Tectocepheus velatus sarekensis* Tragårdth, 1910, species found in mosses *Zygoribatula exilis* (Nicolet, 1855) (characteristic of song thrush nests) and a species tolerating drier conditions *Eupelops acromios* (Hermann, 1804) (characteristic of Eurasian blackbird nests from Slovakia), generally proved to be the primary species in thrush nests (Table 1).

The euryvalent species *Rhysotritia ardua* (C.L. Koch, 1841), forest species *Nothrus palustris* C.L. Koch, 1928, *Camisia segnis* (Hermann, 1804) and *Achipteria nitens* (Nicolet, 1855), and species occurring in meadow litter and moss, such as *Heminothrus targioni* (Berlese, 1885) and *Damaeus* sp.

Koch, 1835, were the leading species in song thrush nests (Table 1).

Species tied to tree bark and lichens *Liebstadia humerata* Sellnick, 1928, forest litter species also found on stumps of trees *Hafenrefferia gilvipes* (C.L. Koch, 1839) (in Germany) and forest species *Micreremus gracilior* Willmann, 1931 (in Slovakia) were characteristic species in Eurasian blackbird nests. A forest litter species also found on trees, *Micreremus brevipes* (Michael, 1888), was found in both types of nests and was the leading species in Eurasian blackbird nests collected in Slovakia (Table 1).

Most characteristic and leading species occurred in significant proportions in both types of nests in Germany and Slovakia. In addition, most of them reproduce in nests, as evidenced by the presence of females with eggs and juveniles of most of these species.

It has not been confirmed that the species composition of the oribatocenosis will be affected by the type of nest (host bird species), but there was a significant difference between the nest oribatocenosis abundances of the two studied thrush species. The thrush nest oribatocenoses had 17 common species. However, we cannot refute the composition differences in comparison with the oribatocenoses of other bird nests.

It was confirmed that there was a significant difference between the nest oribatocenoses of different localities. When visualizing the data using NMDS analysis, the difference between the nests originating from Germany and Slovakia was evident (Figure 1).

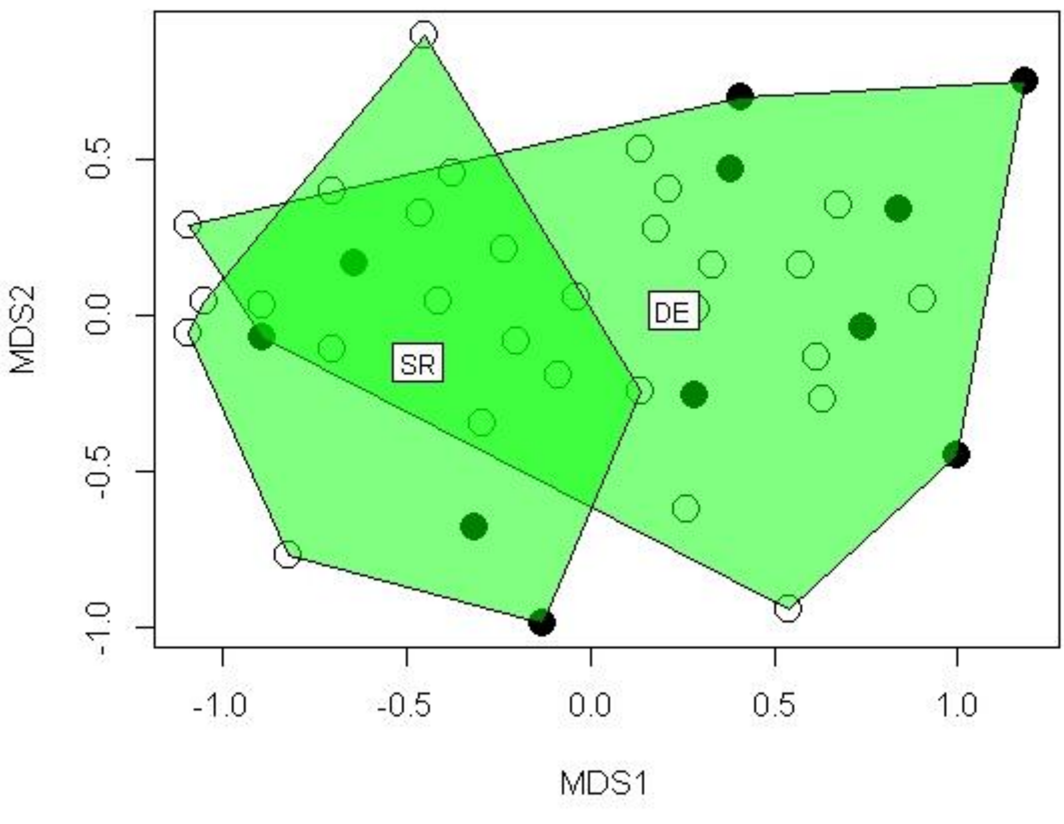

Figure 1. Visualization of the relationship between oribatocenoses of individual nests and sites. Nonmetric multidimensional scaling. DE (nests from Germany), SK (nests from Slovakia), empty point (Eurasian blackbird nest), full point (song thrush nest).

Discussion

Oribatid mite occurrence in the bird nests

Oribatid mites are typical inhabitants of the soil and its upper layers. Research in this area is extensive and includes both studies on different types of natural soils and disturbed soils. Work related to nests as a natural habitat for mites is focused on parasitic groups, but research on nests as a natural habitat for oribatids is modest. The regular occurrence of oribatid mites in the nests of various bird species has been confirmed by several authors. Available and relevant data were obtained from Europe (Błoszyk & Olszanowski 1985; Fain *et al.* 1993; Tryjanowski *et al.* 2001; Lebedeva & Shahab 2005; Shahab 2006a,b; Coulson *et al.* 2009; Kaľavský *et al.* 2009; Kolb *et al.* 2015; Meleschuk & Skilsky 2017) and Asia (Gupta & Paul 1985; Shahab 2006a,b; Ardeshir 2010; Ermilov *et al.* 2013; Melekhina *et al.* 2019). To date, no study has been conducted directly on thrush nest oribatocenoses. Our study demonstrated that oribatid mites were typical representatives of thrush nest fauna. Only a single nest examined in our study had no oribatid mites. From positive nests, 53 oribatid mite species were identified. Similarly, a high proportion of positive nests (750 of the 859 examined) of twenty-eight bird species collected in the Ukrainian Carpathians was reported by Meleschuk & Skilsky (2017). Kaľavský and coauthors (2009) noted that up to 70% of the oribatid mite-positive nests for common kestrels were collected in residential and rural areas of Bratislava (Slovakia). However, the numbers of oribatid species in the nests are very different not only within a bird family but also within one bird species. Fewer than ten oribatid mite species were reported from the bird nests of the families Alaudidae, Anatidae, Columbidae, Laridae, Muscicapidae, Passeridae, Strigidae, Sturnidae, Sylviidae and Turdidae (Błoszyk & Olszanowski 1985; Gupta & Paul 1985; Fain *et al.* 1993; Coulson *et al.* 2008; Ardeshir 2010). More than twenty oribatid mite species were recorded in the bird nests of the families Calcariidae, Muscicapidae and Pittidae (Tryjanowski *et al.* 2001; Ermilov *et al.* 2013; Melekhina *et al.* 2019). Shahab (2006 a,b) noted more than one hundred oribatid mite species from bird nests. These birds belonged to different taxonomic and ecological groups.

In our case, the bird host species and geographical location had an impact on oribatid mite abundance. Both host bird species are ground-foraging birds, and their breeding biology is similar (Chaplygina *et al.* 2019). Both species construct similarly sized, cup-shaped open nests, but the difference is a coating of mud on the nest space of the song thrush (Khwaja & Lloyd-Jones 2015). A mud layer prevents the free movement of the mites in the nest and may result in lower abundance.

Despite the fact that nests were obtained from similar urban park habitats under temperate conditions with similar altitudes, geographical location had an impact on not only abundance but also the structure of the oribatid mite communities. Further study on the basis of geographical distribution is needed to analyze this result.

Oribatid mite species common in bird nests

Almost 40% of the oribatid mite species found in the thrush nests in this study have also been recorded in the nests of other bird species in the past. The following species were present in the nests of both thrushes in our study. *Hypochthonius rufulus* C.L.Koch, 1835 was recorded in house sparrow and common linnet nests in previous studies (Lebedeva & Shahab 2005; Shahab 2006a). *N. palustris* C.L. Koch, 1928 was recorded in starling and sand martin nests (Błoszyk & Olszanowski 1985; Lebedeva & Shahab 2005). *C. segnis* was confirmed in the nests of the Eurasian blackbird by Błoszyk & Olszanowski (1985). *P. peltifer* was found in starling and red-backed shrike nests (Błoszyk and Olszanowski 1985, Tryjanowski *et al.* 2001). This species occurred in high proportions in both thrush nests in our study. *X. tegeocranus* was recorded by

Lebedeva & Shahab (2005) in the nests of small passerine birds (the Eurasian tree sparrow and the great tit). *Pergalumna nervosa* (Berlese, 1914) was observed in both thrush nests with significantly higher abundance in the song thrush nests than in the Eurasian blackbird nests. This species has also been recorded in red-backed shrike and gray heron nests (Tryjanowski *et al.* 2001, Lebedeva & Shahab 2005; Shahab 2006b). *T. trimaculatus* is another species that can be considered a common representative of nest fauna. It was recorded in high abundances in both thrush nests in our study and has occurred in the nests of eight other bird species: in house sparrow, Eurasian tree sparrow, Eurasian blackbird, white wegtail and rook nests (Lebedeva & Shahab 2005; Shahab 2006a), in the eagle owl and the common eider nests (Fain *et al.* 1993; Coulson *et al*. 2009). High abundance of *T. trimaculatus* was reported by Lebedeva and Shahab (2005) in the nests of the hooded crow and the Eurasian magpie. *P. punctum* was recorded with higher abundance in the nests of the blackbird compared to in the nests of the song thrush in our study. This species was also reported by Lebedeva and Shahab (2005) as occurring in rook nests. *Z. exilis* was another common species in bird nests. It has been recorded in the nests of another 12 bird species. It was present with high abundance in red-backed shrike, rook, Eurasian magpie and chaffinch nests (Tryjanowski *et al.* 2001; Lebedeva & Shahab 2005; Shahab 2006a). It was also recorded with lower abundance in house sparrow, Eurasian tree sparrow and Eurasian blue tit nests, as well as in white wagtail, mallard and hooded crow nests (Lebedeva & Shahab 2005; Shahab 2006a). Melekhina *et al.* (2019) reported *Z. exilis* in Lapland bunting nests, and it was also recorded by Lebedeva *et al.* (2014) as occurring in snow bunting nests.

Some oribatid mite species, which have been reported from several bird species nests in previous studies, were present only in the Eurasian blackbird nests in our study. For example, *Nothrus borrussicus* Sellnick, 1928 was reported in common eider nests, *Belba corynopus* (Hermann, 1804) and *Liacarus coracinus* (C.L. Koch, 1841) were reported in swallow nests in the past (Shahab 2006b). *L. coracinus* also occurred in red-backed shrike nests (Tryjanowski *et al.* 2001). In addition to our records, *Carabodes labyrinthicus* (Michael, 1879) had already been recorded in the nests of four bird nesting species - red-backed shrike, rook, common eider and European herring gull (Tryjanowski *et al.* 2001; Lebedeva & Shahab 2005; Shahab 2006b). This species was found only in Eurasian blackbird nests with low abundance in our study. *T.v. sarekensis*, in addition to our study, was found in the nests of the eagle owl (Fain *et al.* 1993). *Oppiella* (*Moritzoppia*) *translamellata* (Willmann, 1923) occurrence in bird nests has been reported by several authors. It occurred with low abundance in Eurasian reed warbler and barnacle goose nests (Lebedeva & Shahab 2005; Pilskog *et al.* 2014). It was also recorded in snow bunting and black-legged Kittiwake nests (Lebedeva *et al.* 2014; Pilskog *et al.* 2014). *Eupelops torulosus* (C.L. Koch, 1839) occurred at a higher abundance in the nests of red-backed shrike (Tryjanowski *et al.* 2001) than in the Eurasian blackbird nests in our study. *A. coleoptrata* was another common species for these two bird nesters. While it was not numerous in the red-backed shrink nests (Tryjanowski *et al.* 2001), it reached a high abundance in the blackbird nests. *Euzetes globulus* (Nicolet, 1855), which occurred at a low abundance in the blackbird nests, was also recorded in white wagtail nests in the past (Shahab 2006a). *O. tibialis* seems to be another species common of bird nests. It occurred in the black thrush nests with high abundance. It has been recorded in the nests of several bird species in the past: hooded crow and small passerine nests (house sparrow, the great tit and the Eurasian blue tit) as well as in water and seabird nests (mallard, barnacle goose, European herring gull, black legged Kittiwake, common eider and glaucous gull) (Lebedeva &

Shahab 2005; Shahab 2006b; Coulson *et al.* 2009; Lebedeva *et al.* 2012; Pilskog *et al*. 2014).

Two oribatid mite species, which have been reported in bird nests in previous studies, were present only in the song thrush nests in our study: *Nothrus anauniensis* (Canestrini & Fanzago, 1876), which was recorded only in the Eurasian blackbird nests by Błoszyk & Olszanowski (1985), and *Oppiella (Oppiella) nova* (Oudemans, 1902), which appears to be a species commonly found in nests. *O.* (*O.*) *nova* has been recorded in nests of several bird species in the past: in house sparrow, black-winged stilt and blue-rumped pitta nests (Lebedeva & Shahab 2005; Shahab 2006a, b; Ermilov *et al.* 2013). Its presence was confirmed in the snow bunting nests (Lebedeva *et al.* 2014), and its high abundance was recorded in the Lapland bunting nests (Melekhina *et al.* 2019).

It is possible to identify some oribatid mite species that occur repeatedly in nests often with high abundances, both adults and juveniles, in nests of different bird species. Of those recorded in this study, we identified two eurybiontic species with worldwide distribution: *O. (O.) nova* found in different habitats and *P. peltifer* with a preference for meadow and forest soils. Several species with a Holarctic distribution can also be included in this category. For example, species preferring forest or meadow soils such as *A. coleoptrata* and *O. tibialis* - eurybiontic species also found in mosses and lichens; *C. labyrinthicus*, *T. trimaculatus* and *Z. exilis* also found in mosses and on tree bark; *O. (M.) translamellata* (occurring with a lower abundance, however regularly) with unclear ecology also found in mosses; and *P. nervosa* species of acid forest soils and peat bogs. *Z. propinqua* can also be included here. It was not documented in the nests of other bird species, but in our material, it occurred steadily in both types of nests. Unlike the previous species, it is a Palearctic species. It is often found on tree trunks and in soils.

A total of thirty species recorded in this study were found in bird nests for the first time (Table 1). Many of them are commonly found in the surrounding habitats, so their occurrence in nests can be expected. However, that the occurrence of these species had not yet been recorded in the surrounding habitats was very interesting. These included several species found in nests in Bratislava.

Colonization of bird nests

Oribatids can actively enter nests. This applies in particular to species that move along tree bark or are tied to mosses and lichens on trees. This can be assumed for the *T. trimaculatus*, *C. labyrinthycus* or *Z. propinqua* in our case. However, oribatids can also enter nests passively when they are brought by birds in nesting material. Another way to enter the nest is transfer on birds. Some oribatids occur constantly in bird feathers. These mites do not feed on bird skin but on the fungi that grow on bird skin and feathers (Krivolutsky *et al.* 2001a,b, Krivolutsky & Lebedeva 2003). It has been confirmed that birds play an important role in oribatid mite distribution (Lebedeva & Lebedev 2008; Pilskog *et al.* 2014). Several species found in thrush nests have been recorded in bird feathers in the past, for example: *N. palustris*, *P. peltifer* in mute swan feathers, and *B. corynopus*, *Chamobates cuspidatus* (Michael, 1884) and *M. brevipes* in common eider feathers. Other species in bird feathers were *C. labyrinthicus* in swan goose, *A. coleoptrata* in mallard and *O. tibialis* in ferruginous duck (Lebedeva 2005). Some oribatid species like *P. punctum*, *O. (O.) nova*, *O. tibialis*, and *Z. exilis* were found in feathers of several different bird species (Krivolutsky *et al.* 2003; Lebedeva 2005).

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