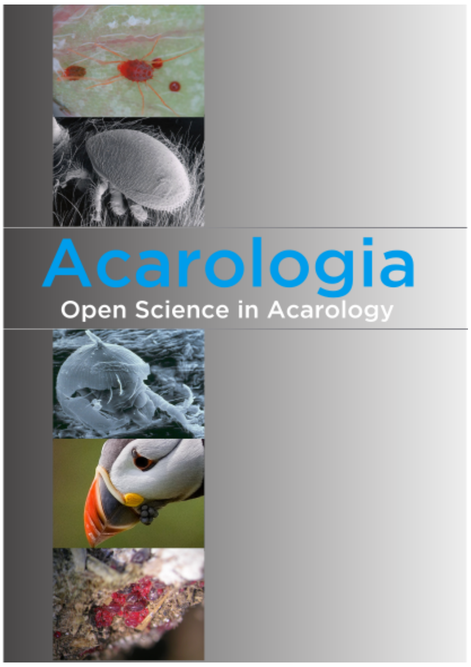

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Oribatid mite (Acari: Oribatida) communities of urban brownfields in Tallinn, Estonia, and their potential as bioindicators of wasteland successional stage

Piret Vacht[a] , Helin Niglas[a] , Annely Kuu[b] , Tiiu Koff[a,c] , Sander Kutti[b] , Jane Raamets[b]

[a] School of Natural Sciences and Health, Tallinn University, Narva Rd 25, 10120, Tallinn, Estonia.
[b] School of Engineering, Tartu College of Tallinn University of Technology, Puiestee 78, 51008, Tartu, Estonia.
[c] Institute of Ecology, Tallinn University, Uus-Sadama 5, 10120, Tallinn, Estonia.

Original article

ABSTRACT

Urban brownfields are ecologically valuable ecosystems that have been and are under various anthropogenic influences. Because brownfields are subject to rapid development in urban areas, their biological communities, including soil mesofauna, are overlooked and seldom researched, even though they could provide valuable insight into the ecological functioning of these areas. This exploratory study describes the community characteristics of oribatid mite fauna of 12 brownfields in Tallinn, Estonia, and analyzes the potential of oribatid mites as bioindicators of brownfield successional stage. This study provides the first faunistic list of oribatid mites from the brownfields of Tallinn. No significant changes in species abundance or richness depending on the successional stage were discovered. While some changes in community structure were noted, due to low overall abundance, no clear indicators of brownfield successional stage were identified. For future research on urban brownfield oribatid fauna with the intention of finding potential bioindicators of brownfield properties, increasing the sampling size and inclusion of other groups of soil mesofauna is recommended.

Keywords brownfields; wastelands; Oribatida; bioindication; technosol

Introduction

Urban brownfields, also known as wastelands (Atkinson *et al.* 2014; Mathey *et al.* 2018) are areas that have been under development in past, but have not been in formal use since (CABERNET 2006; Siebielec *et al.* 2012). The term often implies that the area is affected by contamination (CABERNET 2006; Mathey *et al.* 2018), however, this is not always the situation depending on the characteristics of previous use. Detailed information about the history of these areas is, however, not always available. This makes decision making about future developments of the urban brownfields challenging.

In Tallinn, Estonia, wastelands make up about 7% of the city area (Karro-Kalberg 2011). These areas are often considered as vacant space in cities and are therefore under rapid changes, including consturction and road development, due to the current urban processes. Wastelands are ecologically important urban green spaces that offer various ecosystem services, including habitats for miscellaneous fauna and flora (Herbst and Herbst 2006; Strauss and Biedermann 2006; Pueffel *et al.* 2018).

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Corresponding author
Piret Vacht: piret.vacht@tlu.ee

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Previous studies have shown that microarthropods are one of the first groups of soil biota to inhabit novel areas (Hågvar *et al.* 2009; Hågvar 2012). However the communities tend to be more species-rich in older soils, influenced positively by the presence of vegetation (Madej *et al.* 2011; Wissuwa *et al.* 2012). Oribatid mites (Acari: Oribatida) are known as indicators of soil properties (Steiner 1995; Behan-Pelletier 1999; Magro *et al.* 2013), but they are not often researched in harsh environments such as urban wasteland Technosols (Madej *et al.* 2011; Rumble *et al.* 2018). The former use of wastelands may also affect the soil conditions and therefore influence the soil biota, including oribatid mite communities (Zaitsev and Straalen 2001). There are few studies addressing the soil acarofauna of urban areas (Weigmann and Jung 1992; Eitminavičiūtė 2006a, b; Minor and Cianciolo 2007). In Estonia, soil oribatid mites communities have so far not been studied in urban areas, only data from some coastal areas (Eitminavičiūtė 1976), coniferous forest riparian zones (Vacht *et al.* 2014) and Estonian airfields (Vacht *et al. In Press*) have been published. Because soil biota, including microarthropods, play an important part in major soil processes and functions, their presence or absence and diversity should be monitored in order to gain knowledge about the stability and functioning of these areas. Therefore, it is important to map what kind of soil biological communities can be found in urban brownfields of Tallinn and whether these can be used as bioindicators helping to evaluate the ecological importance of these areas.

The aim of this explorative study was (1) to characterize the oribatid mite communities (community structure, species richness, evenness and diversity) of various urban wastelands in Tallinn that differ in their properties, past usage and successional stage; (2) to find out whether oribatid mites are suitable bioindicators of wasteland successonal stage.

Methods

Sampling from 12 urban brownfields in Tallinn, Estonia, was conducted in September 2014 and September 2015. Each year four samples were collected from each study area. Table 1 shows the locations and characteristics of the sampling sites. The study areas included in this study have been out of formal use for up to 50 years, classifying into the three youngest (I, II and III) successional stages distinguished by Mathey and Rink (2010), that do not yet have high and dense vegetation cover. Samples were collected using ø 5 cm soil auger (0–10 cm of topsoil, in total 196 cm^3) from sampling sites most characteristic to the wasteland. Because this was an exploratory study, samples for soil chemical analyses were collected from each site and pooled, for general background information without aim to link them directly to the soil biological communities. Soil organic matter and carbonate content was analyzed using prepASH® 340 at Tallinn University Institute of Ecology, soil P, K, Ca and Mg content were analyzed, and pH_{KCl} measured using standard methods at the Estonian Agricultural Research Center.

Microarthropods were extracted using Berlese-Tullgren funnel until samples were fully dry (minimum of 72 hours) and stored in 90% ethanol. For clearing purposes 80% lactic acid was used on oribatid mites. Samples (N = 96) were hand sorted, oribatid mites identified (Weigmann 2006; Niedbała 2008)and counted using cavity slides on light microscope Olympus BX51 at 200–600 × magnification. The nomenclature follows Weigmann (2006). Samples have been deposited at Tallinn University Institute of Ecology. The oribatid mite species data from two years were pooled for numerical analysis.

Community parameter calculations were conducted using R programming environment (R Development Core Team 2014) using ’vegan’ package (Oksanen 2018). Due to very low abundance of oribatid mites in the samples multivariate community analysis could not be applied.

Table 1 Study area characteristics, including coordinates, site successional stage (Mathey and Rink 2010) classification (I refering sites less than 3 year old, II to sites 3 to 10 years old, III to sites 10 to 50 years old) and short description of site purpose or previous use and vegetation characteristics.

			Characteristics	
Sampling site symbol	Coordinates	Successional stage	Site description	Characteristic vascular plants
L	N 59°24′55.33″ E 24°52′8.79″	I	Former urban agriculture site, near airfield	*Achillea millefolium* , *Arctium tomentosum* , *Artemisia vulgaris, Atriplex patula* , *Cirsium arvense* , *Echium vulgare* , *Scorzonera humilis* , *Trifolium medium, Tussilago farfara, Urtica dioica, Verbascum nigrum*
F	N 59°25′8.81″ E 24°45′28.3″	I	Illegal garbage dump, construction waste	*Arctium tomentosum, Artemisia vulgaris, Atriplex patula, Betula pendula, Cirsium vulgare, Epilobium angustifolium, Melilotus officinalis* , *Salix* spp, *Tanacetum vulgare*
P	N 59°27′3.49″ E 24°49′11.27″	II	Construction site, construction waste	*Acer platanoides, Achillea millefolium* , *Alchemilla vulgaris, Poaceae, Polygala vulgaris, Rosa spp, Scorzonera humilis, Taraxacum officinale* , *Tussilago farfara* , *Sorbus aucuparia*
V	N 59°25′18.32″ E 24°44′58.84″	II	Former timber mill factory site	*Acer platanoides, Anchusa officinalis, Betula pendula, Fraxinus excelsior, Poaceae, Populus tremula* , *Salix* spp
M	N 59°25′51.42″ E 24°40′58.3″	III	Snow-melting site	*Acer platanoides, Achillea millefolium* , *Melilotus albus* , *Phragmites australis* , *Plantago major, Salix spp, Solidago virgaurea* , *Taraxacum officinale* , *Tussilago farfara*
S	N 59°25′11.98″ E 24°37′23.31″	III	Semi-natural area with illegal garbage dump	*Achillea millefolium* , *Artemisia vulgaris, Alnus incana, Poaceae, Populus tremula, Ribes nigrum, Solidago virgaurea* , *Taraxacum officinale*
R	N 59°24′50.61″ E 24°39′41.89″	III	Construction waste	*Aegopodium podagraria, Angelica sylvestris, Artemisia vulgaris, Rubus idaeus, Rumex obtusifolius* , *Urtica dioica*
A	N 59°27′19.43″ E 24°41′45.21″	III	Railway side, no longer in use	*Aegopodium podagraria* , *Convolvulus arvensis* , *Equisetum pratense, Phragmites australis* , *Salix* spp, *Urtica dioica*
T	N 59°27′0.06″ E 24°43′12.38″	III	Railway side, in infrequent use	*Achillea millefolium, Aegopodium podagraria* , *Fraxinus excelsior, Medicago falcata, Poaceae* , *Rumex obtusifolius* , Salix spp, *Sedum acre*
K	N 59°26′56.23″ E 24°44′38.91″	III	Construction site, contruction waste	*Acer platanoides, Arctium tomentosum, Artemisia absinthium* , *Bunias orientalis* , *Salix* spp, *Saponaria officinalis*
U	N 59°26′26.35″ E 24°46′7.02″	III	Construction site, former harbour warehouse site	*Alnus incana, Artemisia absinthium* , *Chelidonium majus, Impatiens parviflora, Populus tremula, Salix* spp, *Taraxacum officinale*
X	N 59°26′48.93″ E 24°50′15.17″	III	Former military airfield, construction waste	*Artemisia absinthium* , *Chrysosplenium alternifolium* , *Lamium album* , *Salix* spp, *Symphoricarpos albus* , *Ulmus glabra*

Results and discussion

The studied wasteland soils can be classified as Technosols due to the high volume of anthropogenic artifacts, mostly construction waste, found in them. The amount of anthropogenic deposits in the studied soils together their low organic matter content (Table 2) refers to their low water holding capacity, which can be considered unfavorable habitat characteristics for most soil mesofauna. Urban soils in Tallinn have generally neutral to mildly alkaline pH, which was confirmed by the results. Some study areas stood out by notably higher phosphorus or potassium content. Table 2 shows the results of the soil chemical analysis. From 96 samples 300 oribatid mites were identified. The abundance of oribatid mites differed greatly between the study sites. Even after pooling the data from two years the abundance per brownfield (N=8) varied from just one individual found in K and A sites to 34 – 42 individuals at P, V and X sites. Even though the youngest successional stage had lower oribatid mite abundance than stages II and III, these older stages (II and III) also had sites with only one individual.

In total 17 species were encountered. The species list with abundance data (N=8) is shown in Table 3. Highest diversity (Shannon´s H) was encountered in the study area F (H=1.8), followed by the site P (H=1.7) and site V (H=1.4). Community evenness was highest in the study areas R, T and F (1.0, 0.9 and 0.9 respectively). Species richness did not increase with increasing successional stage.

Some changes in species composition with increasing successional stage were noted. For example, while *Platynothrus peltifer* C. L. Koch, 1839 was the species encountered only on a site belonging to the youngest successional stage (only represented by two individuals), most species that were present at stage I were also encountered at the older successional stages. The slowly reproducing *P. peltifer* is known to be more abundant in near-neutral to alkaline soil conditions (van Straalen and Verhoef 1997) and sensitive to heavy metals (Khalil *et al.* 2009). The presence of this species in urban wasteland ecosystem together with the species' known bioindicator properties is a promising combination for further studies. *Eupelops torulosus* C. L. Koch, 1939 and *Trichoribates novus* Sellnick, 1928 were only present at stages II and III. Both of these species are known to inhabit soils that already have vegetation – *E. torulosus* is often found in forest ecosystems (Siira-Pietikäinen *et al.* 2008; Vacht *et al.* 2018), *T. novus* in urban lawns (Weigmann and Kratz, 1987). Several species were indifferent to the successional stage of the wasteland (e.g *Galumna lanceata* Oudemans, 1900, *Rhysotritia ardua* C.L. Koch, 1841, *Tectocepheus velatus velatus* Knülle, 1954). All of these species are frequently encountered in urban and other human influenced ecosystems (Zaitsev and Straalen 2001; Caruso and Migliorini 2006; Eitminavičiūtė 2006b; Minor and Cianciolo 2007; Ivan and Vasiliu 2009;

Table 2 Results of soil chemical analysis to give an overview of wasteland soil conditions.

	Soil parameters						
Sampling site symbol	pH_{KCl}	P (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	Organic matter (%)	Carbonates (%)
L	7.3	48	126	7837	202	2.7	8.7
F	7.6	41	243	12800	286	4.8	16.4
P	7.6	51	143	6555	175	11.0	38.8
V	7.6	74	220	6131	219	9.7	8.6
M	7.6	31	82	8968	128	4.9	11.4
S	7.0	109	114	2761	99	4.5	0.5
R	7.4	95	140	4040	138	6.2	2.3
A	7.3	17	729	4010	129	8.0	3.1
T	7.3	78	172	5714	211	8.3	3.0
K	7.1	302	267	6312	232	10.9	16.0
U	7.2	206	213	5723	228	5.1	9.8
X	7.3	46	286	11320	197	14.8	23.2

Table 3 Species list and number of specimens collected from the study area (total N=96, each count is based on data from 8 samples of 196 cm^3 of soil).

Species	Sampling sites and successional stage											
	I		II		III							
	L	F	P	V	M	S	R	A	T	K	U	X
Rysotritia ardua (Koch, 1841)	-	2	-	1	-	-	-	-	-	-	-	1
Trhypochthonius spp (Berlese, 1904)	-	-	-	1	-	-	-	-	-	-	-	-
Platynothrus peltifer (Koch, 1839)	-	2	-	-	-	-	-	-	-	-	-	-
Hermannia convexa (Koch, 1839)	-	-	-	1	-	-	-	-	-	-	-	-
Tectocepheus velatus velatus (Michael, 1880)	-	1	-	2	-	-	2	-	-	-	-	-
Scutovertex minutus (Koch, 1835)	-	-	1	-	-	-	-	-	-	-	-	-
Eupelops torulosus (Koch, 1839)	-	-	2	1	-	1	1	-	-	-	1	4
Eupelops hygrophilus (Knülle, 1954)	-	3	4	-	-	-	1	-	2	-	-	1
Achipteria coleoptrata (Linnaeus, 1758)	-	2	3	21	4	-	-	1	3	-	-	-
Achipteria nitens (Nicolet, 1855)	-	-	1	7	-	-	-	-	-	-	-	-
Achipteria sellnicki (van der Hammen, 1952)	-	1	-	-	-	-	-	-	-	1	1	-
Scheloribates laevigatus (Koch, 1836)	1	5	16	-	-	-	-	-	-	-	-	31
Chamobates voigtsi (Oudemans, 1902)	-	-	3	2	-	-	-	-	-	-	-	-
Ceratozetes minutissimus (Willmann, 1951)	-	-	-	-	-	-	-	-	-	-	-	1
Trichoribates novus (Sellnick, 1928)	-	-	-	1	-	-	1	-	-	-	-	2
Mycobates tridactylus (Willmann, 1929)	-	-	1	-	-	-	-	-	-	-	-	-
Galumna lanceata (Oudemans, 1900)	1	-	3	-	-	-	-	-	1	-	-	2

Vacht *et al.* 2018), for example, *T. velatus velatus* is often one of the most abundant species in urban ecosystems (Eitminavičiūtė 2006b; Minor and Cianciolo 2007).

The number of individuals encountered in this study was very low compared to our previous research from areas under anthropogenic influences (Vacht *et al.* 2018; Vacht *et al. In Press*) and not sufficient for determining the full potential of oribatid mites as bioindicators of brownfield properties, including changes in community patterns in relation to successional stage, therefore this study is unable to recommend using oribatid mites alone as indicators of wasteland properties, including successonal stage. Increasing the sampling size and combining the results with other organism groups (e.g. Collembola, Mesostigmata) should be considered.

Conclusion

Due to high concentration of anthropogenic imputs and low organic matter content, urban wasteland Technosols encountered in this study, are very poor habitats for oribatid mites, resulting in low abundance and diversity. This study provided novel species data on brownfield oribatid mite communities in Tallinn, Estonia. In comparison of three successional stages no significant changes were detected in abundance or diversity of the communities, but some changes in community structure were noted. Due to the low total abundance of oribatid mites, further studies are required to test, whether oribatid mites can be used as indicators of successional stage in urban brownfields. In future studies in urban brownfields we recommend increasing the sampling size. In order to assess the ecological functioning of the areas, the bioindicative data from their oribatid mite communities should be combined with that from the other groups of soil mesofauna.

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